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Dynamics of cortisol and testosterone in acute response to a simulated Brazilian jiu-jitsu competition practiced by athletes with disabilities: multiple case study

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Abstract
Objective. This study aimed to investigate the acute effects of a simulated Brazilian jiu-jitsu match, practiced by athletes with disabilities, on the serum levels of hormonal and lactate markers.
Methods. Five male athletes were included (mean and SD: age 38.5 ± 4.2 years; height 1.68 ± 0.05 cm; body mass 89.4 ± 5.8 kg; BMI 31.6 ± 3.7 kg.m^2); participants I and II were professional athletes with world titles. The results were individually analyzed, which constitutes a multiple case study under the Ethics Committee registration no. 2.997.241. Blood samples were collected before and immediately after the simulated match session. The data analyzed were: lactate, cortisol, testosterone, and body temperature.
Results. Regarding testosterone values, an increase was observed in all participants after the match (mean and SD: 36.4 ± 6.8 pre-match and 45.9 ± 8.1 post-match), with a significance of p = 0.006 between moments. For cortisol, the gross values of all participants decreased after the match (mean and SD: 157.6 ± 15.4 pre-match and 121.8 ± 14.7 post-match), with a significant difference between moments (p=0.02). The lactate values also increased in all participants (mean and SD: 2.52 ± 0.05 pre-match and 11.6 ± 0.8 post-match), with a significant difference between moments (p=0.0004). In addition, no correlations were found between hormonal concentrations and age (Testosterone x Age, p-value=0.7600; Cortisol x Age, p-value=0.600).
Conclusions. Different alterations in hormonal and metabolic parameters represent responses to acute physical exercise. From these data, it is possible to evaluate the training load implemented and suggest periodization and recovery techniques according to the individual responses.

Introduction

Brazilian jiu-jitsu, as well as other sports, practiced by individuals with disabilities, are responsible for generating stress to the body [Lopes *et al*. 2019; Lopes *et al.* 2019b]. However, different types of effort induce different metabolic responses. Thus, knowledge about physiological mechanisms triggered by a simulated match, in a real scenario, constitutes essential information to optimize the training prescription dynamics based on specific needs for rest or overload. In addition, the competitive environment includes aspects that comprise different feelings such as anxiety, fear, ego, novelty, and happiness that associated with the stress produced by exercise, induce and anticipate the hypothalamic-pituitary-adrenal (HPA) axis, responsible for stimulating and secreting cortisol [Anderson *et al.* 2016]. On the other hand, in cases of reproduction of stress in the laboratory, feelings can be suppressed, differing from the real situation experienced during competitions, making it important to implement studies in a real condition [Haneishi *et al.* 2007].

In this scenario, cortisol exerts effects that contribute to the mobilization of energetic substrates, which are essential during the effort [Moreira *et al.* 2012] but high serum levels can negatively affect the recovery process. Testosterone, in turn, is an anabolic-androgenic steroid, secreted mainly by Leydig cells in the testicles cortisol [Anderson *et al.* 2016], which influences anabolic effects in the body. Both described hormones are widely studied in sports settings, due to their relationship with the regulation of the breakdown and synthesis of proteins [Fragala *et al.* 2018], related to the control of the generated stress or recovery parameter, necessary for the healthy maintenance of the athlete. In their study, Leicht *et al*. [2016], demonstrated that the aforementioned hormones, cortisol and testosterone, characterize markers indicating stress and recovery from exercise. Thus, after acute exercise, the serum levels of both hormones change proportionally to the volume and intensity of the interdependent variables. These parameters assist in diagnostics, making it possible to identify the presence of overtraining, for example.

In addition, lactate has also been used in sports science as a metabolic marker capable of indicating the intensity of the load implemented during effort. Specific responses in lactate concentrations are also observed after each type of exercise. This parameter, like others, is used to diagnose training conditions and prescribe periodization protocols according to verified biological individuality [Rissanen *et al*. 2020].

Regarding the above, studies show [Andreato *et al.* 2017; Andreato *et al.* 2015] that the biomechanics implemented during the techniques of jiu-jitsu raise stress levels when compared to other sports that use the aerobic oxidative path predominantly. For example, the study by Andreato *et al.* [2013] investigated hormonal outcomes and lactate in response to simulated jiu-jitsu combat. In conclusion, this study found that successive combats, with short recovery periods, should be avoided, as this dynamic triggers overloading of organism, which can compromise the performance and increase the chances of injuries. However, to date, with regard to jiu-jitsu practiced by athletes with disabilities, the authors are unaware of the existence of information available in the literature on hormonal and lactate responses to combat.

Thus, although it is well understood that physical exercise modifies serum levels of testosterone and cortisol, some studies in the literature show different behavior, sometimes even with contrary responses, due to the specific characteristic of the sports analyzed. These differences make it necessary to evaluate unexplored modalities, as is the case of para-sport jiu-jitsu.

It is hypothesized that, as in other sports, in Brazilian para-sport jiu-jitsu the same response occurs to a match; stimulation of the neuroendocrine system, triggering alterations in serum levels of cortisol, testosterone, and lactate. Thus, we are interested in understanding and exploring the magnitude of these alterations, which will allow us to initiate a discussion on the subject. Therefore, the objective of the present study was to investigate acute hormonal and metabolic responses after a simulated match of Brazilian jiu-jitsu, practiced by athletes with disabilities.

Methods

Subjects

Five athletes with disabilities, practitioners of Brazilian jiu-jitsu participated in this study (mean and SD: age 38.5±4.2 years; height 1.68±0.05 cm; body mass 89.4±5.8 kg; BMI 31.6±3.7kg.m^2). All athletes were male; participants I and II were elite athletes, with recent world titles, while athletes III, IV, and V were of amateur level. The included participants who trained on average 5 times a week, with a mean duration of 90 minutes each training session. All participants, regardless of competitive level (amateur or elite), were involved in routine competitions.

To be included, participants were required to have practiced Brazilian para-sport jiu-jitsu for more than 6 months. The sample size was characterized by a convenience scenario, attributed to the logistical difficulty in grouping a large number of participants with the inclusion characteristics adopted in the study. Participants who did not complete all stages of the study would have been excluded; however, no cases of exclusion were necessary.

All participants attended the same training center, where they were used to training and competing periodically, to ensure a real collection environment. No musculoskeletal injuries were reported during the procedures and the anonymity of the participants was ensured.

Masking of the participants, investigator, and evaluator was carried out in relation to the results, hypotheses, and outcomes analyzed.

In addition, to be included, participants were required to report the absence of anemia, inflammation, diabetes, cardiovascular disease, and musculoskeletal injuries in the six months prior to data collection. Furthermore, they were advised to refrain from taking anti-inflammatory drugs, analgesics, alcoholic beverages, and tobacco and not to perform any exercise not proposed by the study.

All subjects followed a similar diet and received no special supplements. Control of the participants' diet was performed subjectively through verbal guidance.

Regarding the functional classifications and types of injuries, the participants included presented Physical Disability (66.4%) and Visual Impairment (33.6%), represented by the functional classifications S6 (Leg amputations) and S12 (Partial visual impairment), respectively.

The anthropometric characteristics of the participants are shown in Table 1.

Ethics statement and clinical trial registry

The participants were informed about the procedures and objectives of the study and, after agreeing, signed a consent form. The consent obtained from the participants was both informed and written. The Ethics Committee in Research of the Federal University of Mato Grosso previously approved all procedures (Araguaia campus, number: 2.997.241).

Experimental Approach to the Problem

This is an observational study. Data collection was carried out in January 2020 at the usual training center of the participants (Grace Barra Academy) located in the municipality of Barra do Garças - MT, Brazil, and data analyzes were conducted at the Federal University of Mato Grosso, Araguaia Campus. All procedures were performed under standard conditions (temperature: 28 ± 1°C, relative humidity: 84%).

The procedures took place in the morning. First, anthropometric measurements were collected, characterized by measuring weight and height. Next, a simulated match was carried out with hormonal (cortisol and testosterone) and lactate evaluations at the pre and post-match moments. An overview of the study is presented in Fig. 1.

No significant differences were observed in the participants' body mass between the pre and post-match moments, which indicates that no dehydration occurred during this study.

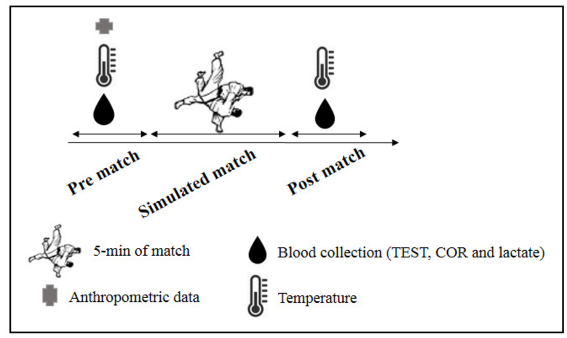

Fig 1. Study design. TEST= Testosterone; COR= Cortisol

Procedures

Simulated Match Protocol

All procedures of the match protocol used in the current study were in line with the design suggested in the study by Lopes *et al.* [2019]. Thus, a warm-up was performed with Brazilian jiu-jitsu movements of low intensity, characterized by low heart rate and low force requirement, for five minutes. The Simulated Match Protocol occurred in accordance with the rules of the Brazilian Jiu-Jitsu Sports Confederation, lasting for six minutes, excluding any type of finalization. In these cases, the athletes were separated and directed to return to the match immediately. Thus, the maximum effort was advocated. In addition, after 3 minutes of matching, the opponent was replaced by a rested opponent, to maintain the intensity as high as possible, and to implement the greatest possible metabolic stress. The parathlete fought with a non-disabled athlete.

The match protocol started with the athletes kneeling, to minimize the chances of injury due to a fall. Both subjects were instructed to maintain high mobility and to prevent the clash from ending ahead of schedule.

Height and Body Mass Measurements

All participants were submitted to an anthropometric evaluation (Table 1) using a scale (Tanita BC554, Iron

Table 1. Anthropometric characteristics of the participants (n=5)

	Age (years)	Stature (m)	Body mass (kg)	Training time (years)	Training time per week (hours)	Competitive level
Participant I	44	1.63	96.5	22	18	Professional
Participant II	36	1.70	82.3	7	9	Professional
Participant III	41	1.65	90.0	1	7	Amateur
Participant IV	34	1.76	89.0	1.2	6	Amateur
Participant V	40	1.63	84.0	0.7	6	Amateur

Legend: Parathletes I and II are world champions in their respective categories.

Man/Inner Scaner, Tanita, Illinois, USA) and a stadiometer (Sanny, American Medical do Brasil, São Paulo, Brazil). Body mass index (BMI) values were calculated from the height and weight collected data.

Blood Sampling and Analysis

Participants refrained from consuming caffeinated foods and products for at least 2 hours before the collection. The athletes provided blood samples collected five minutes before and immediately after the simulated competition. Plasma was used for subsequent analysis of serum concentrations of cortisol and testosterone levels now mentioned.

Cortisol and testosterone activity was verified by blood collection from the antecubital vein, collected using a syringe (62 μL) by a qualified professional. The ELISA method and an Advia 1650 analyzer (Siemens Healthcare Diagnostics, Deerfield, IL, USA) in a specialized laboratory analyzed the blood sample, evaluated in serum.

Blood lactate measurements

The blood was centrifuged for 10 minutes to separate and obtain plasma. The material was frozen at -10°C until analyzed. Plasma samples were obtained and placed in tubes with fluoride-containing anticoagulants to stabilize lactate. Thus, lactate was measured in plasma by the colorimetric enzymatic method.

Body temperature measurements

An ear thermometer (Infrared thermometer model IT-903) was used to measure body temperature. The mean value verified after two consecutive measurements was used. The values were recorded with a precision of 0.1°C and all measurements were taken in the subject's left ear, while they were sitting in silence on a bench. The described protocol was performed as suggested in a previous study [Fragala *et al.* 2018].

Statistical Analysis

Due to the sample size, we chose to present the individual raw data and delta (final value 2 initial value) for each investigated variable. In addition, mean and standard deviation (SD) values were also calculated. A comparison across the different time points was performed by conducting a one-way analysis of variance for repeated measures followed by Bonferroni post hoc analysis.

The data obtained were presented in the form of normalized (relative) graphs made using the program Instat (San Diego, Califórnia, EUA). Comparisons of

Table 2. Variation (Δ) of the physiological and biochemical responses of athletes during the simulated competition (n = 5)*

	Pre-simulated match	Post-simulated match	*Chang (Δ %)*	*p-value*
TESTOTERONE (ng/ml)				
Participant I	44.5	60.0	34.8	
Participant II	59.0	69.0	17.0	*0.006#*
Participant III	26.8	33.1	23.4	
Participant IV	31.2	41.9	34.3	
Participant V	20.5	25.6	24.8	
CORTISOL (ng/ml)				
Participant I	103	67	-35.0	
Participant II	165	157	-4.9	
Participant III	183	129	-29.5	0.024#
Participant IV	189	127	-32.8	
Participant V	148	129	-12.9	
LACTATE (mmol / l)				
Participant I	1.7	11.3	564	
Participant II	2.2	14.0	536	*0.0004#*
Participant III	4.7	12.8	172.3	
Participant IV	2.1	11.2	433.3	
Participant V	1.9	8.8	363.1	
TEMPERATURE (°C)				
Participant I	35.2	36.3	3.1	
Participant II	35.5	36.0	1.4	
Participant III	35.3	37.1	5.0	0.080
Participant IV	36.1	36.3	0.5	
Participant V	36.8	36.9	0.3	

Legend: Δ%: Change from baseline; * The raw data from each participant are presented for each variable investigated. #Statistically significant difference (P<0.05) from baseline the variables analyzed between the baseline and post-match protocol moments were calculated by averaging the percentage differences. Correlation analyzes between age and hormonal concentration were performed using the CorReg program, Version: 1.0. The effect size (ES) was calculated for post match. Cohen (d) (1998) reports the following intervals for ES: 0.1 to 0.3: small effect; 0.3 to 0.5: moderate effect.

Results

The anthropometric characteristics of the participants are presented in Table 1. Table 2 presents the relative values of all the markers evaluated at the moments described, together with the Chang value, which represents the change values, in percentages, from baseline.

Regarding testosterone values, an individual increase was observed in all participants after the match. The mean and standard deviation (SD) values found were: 36.4 ± 6.8 (pre match) and 45.9 ± 8.1 (post match), with significance of p = 0.006 between moments.

Regarding cortisol, it was observed that the gross values of all participants decreased immediately after the match. The mean and standard deviation (SD) values found were: 157.6 ± 15.4 (pre-match) and 121.8 ± 14.7 (post-match), with a statistically significant difference between moments (p=0.02).

The lactate values also increased in all participants, with mean and SD values corresponding to 2.52 ± 0.05 for the pre-match moment and 11.6 ± 0.8 for the post-match moment. There was a statistically significant difference between moments (p=0.0004).

Finally, with regard to the outcome of body temperature, a slight increase was found in all participants immediately after the match. The mean and SD values recorded were 35.7 ± 0.2 at the pre-match moment and 36.5 ± 0.2 at the post-match moment. No statistically significant differences were observed (p=0.080). Analysis of correlations between age and hormonal concentration demonstrated an absence of any type of associations between these variables (Testosterone x Age, p-value = 0.7600; Cortisol x Age, p-value = 0.600).

Table 3 shows the results of effect size for each variable on post match. There was a small effect for testosterone and a strong effect for the other variables (cortisol, lactate, and temperature).

Table 3. Effect size for each variable before and then the match

	before vs. then
Testosterone (ng/ml)	0.1 (-0.10 to 0.5)
Cortisol (ng/ml)	0.7 (-0.9 to 1.2)
Lactate (mmol / l)	-2.8 (-2.9 to 4.3)
Temperature (°C)	-1.00 (-1.2 to 1.9)

* Statistically significant difference (p<0.05)

Discussion

As expected, the outcomes demonstrated significant acute alterations in serum levels of cortisol, testosterone, and lactate in response to the practice of simulated jiu-jitsu combat practiced by athletes with disabilities. For body temperature, there was a tendency to increase but the data were not statistically different.

Regarding testosterone, there was an increase in serum levels in all evaluated participants. The study by Popovic *et al.* [2019], points out that the level of this hormone is directly related to the type, intensity and duration of the exercise performed, and in aerobic resistance athletes the increase rates are lower, whereas higher elevations are verified in cases of sports with explosion and anaerobic resistance, which is the case in the current study. This information partly aids in understanding the observed outcomes.

In addition, studies [Smith *et al.* 2017; Ronay *et al.* 2017] show that high testosterone levels are related to feelings of power, self-confidence, and eventual aggression. Coincidentally, there were higher concentrations of this hormone in athletes I and II, who are elite level, and have recently won world titles. Thus, we believe that the higher testosterone values in these participants are also related to the athletic status described.

Another factor related to testosterone levels is age [Resnick *et al.* 2017]. Although there was no evidence of a correlation between these variables in the present study, individual values of the participants demonstrate particular behavior, which deserves to be explored and discussed. Thus, it can be observed that athlete I is 44 years old with 22 years of training at a professional level, which probably influences body composition, with a higher percentage of lean mass. In addition, although he is the oldest participant, he presented the highest concentration of testosterone and lowest cortisol, which suggests a level of effort implemented below the maximum capacity of the subject, with the absence of indications of a stressful scenario in the body, which can collaborate and influence the frequently acquired titles and medals. Athlete II, despite being younger and with less training time than athlete I, presented a similar testosterone concentration and higher cortisol, which in this case possibly indicates an evident stressor scenario, which could be attributed not only to the effort performed but also to external factors related to physical fitness and psychological aspects.

Regarding serum cortisol levels, the outcomes demonstrated a reduction in all participants after the simulated match. In this regard, some studies on cortisol [Anderson *et al.* 2016; Ahmadi *et al.* 2018], found a similar reduction in cortisol after the effort to that observed in the current study. In contrast, other studies [Adebero *et al.* 2019; Moreira *et al.* 2018] demonstrated an increase in this marker after exposure to stress, justified by the release of adrenocorticotropic hormone by the anterior pituitary, which binds to receptors in the adrenal cortex and increases cortisol secretion. The divergence between these findings could be explained in three ways: 1) intensity and volume of effort not enough to generate stress; 2) physiological adaptation; and 3) familiarization with stressful events or situations. In addition, the fact that the match was held in the early morning may also have influenced the verified data associated with the level of advanced conditioning of some athletes analyzed, which may also indicate a possible adaptation.

Still, concerrning the cortisol data, the observed outcome indicates that adaptive responses were triggered, which perhaps demonstrates the need for overload in view of the fact that adequate levels of cortisol are important to control the availability of energy substrates (glucose and fatty acids), in addition to stimulating proteolysis, necessary for the release of amino acids used in tissue repair. In addition, a circumstance that justifies the decreases in cortisol is related to the fact that the simulated matching environment created to carry out this study did not actually elicit the real effects and feelings experienced on competition days. Another hypothesis refers to the athlete's nutritional condition, which, based on the adopted eating routine, can influence the use of different energy substrates, according to the available reserve.

Regarding the lactate marker, there was a mean increase of 550% after the match, when compared to baseline. These data agree with previous studies, which report an increase in this metabolite after effort, making it a commonly used predictor for measuring the intensity of effort [Moreira *et al.* 2018]. Lactate is an intermediary in the metabolism of carbohydrates under anaerobic conditions, since the O2 supply does not increase instantly and proportionally to the initial energy demand of the exercise. Thus, the bioenergetic pathways for ATP production during high-intensity exercise are muscle glycogenolysis and anaerobic glycolysis, culminating in an increase in lactate production, which is consistent with the result observed after the match [Hoff *et al.* 2016].

The outcomes presented have inherent potential regarding the magnitude of the training load implemented, allowing adjustments aimed at protecting the organism and optimizing levels of conditioning [Lopes *et al.* 2019]. It would be interesting for future studies to implement new efforts to reproduce the real competition scenario, perhaps collecting data in real competitions, in order to control this variable by verifying factual and common physiological responses in the routine of this para-sport modality.

We believe that the sample number does not characterize a limitation, in view of the logistical difficulties inherent in the process of recruiting participants who meet the proposed inclusion criteria. In this context, studies that describe multiple cases, with unprecedented characteristics, are important to measure and discover important parameters, which have intrinsic potential in the management of future interventions. In this regard, the study by Halperin [2018] found that studies of this type have little-recognized benefits with regard to the possibility of using data as an important tool by coaches in practical settings, and can serve as a strategy of agreement between scientists and trainers, creating future opportunities for research collaborations.

One limitation of the current study refers to the fact that a long-term follow-up was not carried out, requiring future studies to use this design to characterize the long-term effects and physiological adaptations triggered in the investigated markers in response to combat. The data presented should not be extrapolated to different population profiles.

The simulated Brazilian para-sport jiu-jitsu match was responsible for triggering alterations in the body's homeostasis, in hormonal and metabolic parameters, which, however, did not seem to indicate strenuous effort, capable of causing stress and impairment in recovery levels. In conclusion, the results presented are responses to acute physical exercise.

Practical Applications

In exhaustive exercises, it is common for cortisol and testosterone to demonstrate inverse responses; cortisol levels increase and testosterone levels decrease. However, the opposite scenario was found in the present study, which demonstrates that the practice of simulated matching, in this case, did not trigger significant levels of stress and did not affect the recovery of the body systems. It should be noted that this study only found an immediate response, and it is important that future studies adopt a longitudinal design to verify long term responses in this population profile.

In addition, these findings may support the routine of coaches, since the parameters presented are able to predict possible needs for changes in the training load according to the individual responses verified, in addition to providing indicators of the adequacy of recovery protocols. From this, coaches and athletes will benefit from a better understanding of the physiological demands of para-sport jiu-jitsu, which will also help to monitor adaptation and sports performance, from periodized training plans.

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Dynamika kortyzolu i testosteronu w ostrej reakcji na symulowane zawody brazylijskiego jiu-jitsu uprawiane przez sportowców niepełnosprawnych: studium wielu przypadków

Słowa kluczowe: sztuki walki, medycyna sportowa, specjalność fizykoterapia, stan zapalny, zjawiska fizjologiczne w układzie mięśniowo-szkieletowym, mleczan

Streszczenie

Cel. Celem pracy było zbadanie ostrego wpływu symulowanej walki brazylijskiego jiu-jitsu, uprawianego przez sportowców niepełnosprawnych, na stężenie w surowicy krwi markerów hormonalnych i mleczanowych.

Metody. W badaniu brało udział pięciu mężczyzn (średnia i SD: wiek 38,5 ± 4,2 lat; wzrost 1,68 ± 0,05 cm; masa ciała 89,4 ± 5,8 kg; BMI 31,6 ± 3,7 kg.m2), przy czym uczestnicy I i II byli zawodowymi sportowcami z tytułami mistrzów świata. Wyniki analizowano indywidualnie, co stanowi studium wielu przypadków. Próbki krwi pobierano przed i bezpośrednio po symulowanej sesji walki. Analizowane dane to: mleczan, kortyzol, testosteron i temperatura ciała.

Wyniki. Jeśli chodzi o wartości testosteronu, zaobserwowano wzrost u wszystkich uczestników po walce (średnia i SD: 36,4 ± 6,8 przed walką i 45,9 ± 8,1 po walce), z istotnością statystyczną p = 0,006. W przypadku kortyzolu, wartości brutto wszystkich uczestników zmniejszyły się po walce (średnia i SD: 157,6 ± 15,4 przed walką i 121,8 ± 14,7 po walce), z istotną różnicą pomiędzy momentami (p=0,02). Wartości mleczanu również wzrosły u wszystkich uczestników (średnia i SD: 2,52 ± 0,05 przed walką i 11,6 ± 0,8 po walce), z istotną różnicą pomiędzy momentami (p=0,0004). Ponadto nie stwierdzono korelacji pomiędzy stężeniami hormonów a wiekiem (Testosteron x Wiek, p-value=0,7600; Kortyzol x Wiek, p-value=0,600).

Wnioski. Różne zmiany w parametrach hormonalnych i metabolicznych są odpowiedzią na ostry wysiłek fizyczny. Na podstawie tych danych można ocenić obciążenie treningowe oraz zaproponować techniki periodyzacji i regeneracji w zależności od indywidualnych reakcji.