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KINESIOLOGY & COACHING

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Analysis of Muscle Damage and Strength in Training and Competition simulation in Brazilian Jiu Jitsu Athletes

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Key words: muscle damage, jiu jitsu, strength, competition

Abstract
Background. It is important to evaluate the specificity of the training and its relationship with the competition variables in Jiu Jitsu athletes.
Problem and aim. The objective was to analyze muscle damage, strength, and their correlation under two distinct conditions, a specific training session and a competition simulation session.
Methods. The study sample included nine subjects (22.50±2.84 years) that were submitted to the following two interventions: 1. simulation of training and 2. simulation of competition.
Results: It can be observed that there were no significant differences in the Counter Movement Jump (CMJ) test; however, 48 h after training, higher values than those in the week of the competition were observed. Regarding Creatine Quinase (CK) levels, there were significant differences after competition in relation to the other time points and the intervention (p=0.004), with a high effect. The Lactate Dehydrogenase (LDH) levels, there were significant differences in post-competition and pre-competition in relation to pre- and post-training (p=0.019), with a high effect. It was observed that the power in the upper limbs (PUL) results showed a median correlation 24 (0.554) and 48h (0.473) after the intervention. The Squat Jump (SJ) test results showed a high correlation (0.716), and the other test results showed a very high correlation (>0.8). All variables presented a very high correlation at both time points of the study. Only the variable LDH level, 48 h later, presented a high correlation. Conclusion. It was concluded that a good correlation exists between training simulation and competition simulation, where the model adopted as training can meet the needs imposed in the competition.

Introduction

In combat sports competitions, the number of fights to which athletes are submitted and their respective durations and intervals are random; these factors may influence performance, in addition to the factors related to the physiological, technical, and tactical part of each sporting modality [Andreato *et al.* 2013; Andreato *et al.* 2014].

On the other hand, training in all sports tends to maintain the athletic performance during the competitive period, where the plasticity of skeletal muscle tissue aims to adapt to various functional demands of each sporting modality [Palmer *et al.* 2015; Lesinski, Prieske, Granacher 2016], and where the training aims to increase the tolerance to the exercise, triggering adaptive processes of mechanical, metabolic, and electrophysiological characteristics according to the requirements of each modality [Lafay *et al.* 2009; Raciais *et al.* 2015].

Thus, to maintain the pace of training for a high-performance athlete, it is necessary to exert a great physical effort during physical preparation [Detanico *et al.* 2015]. This effort generates a series of biochemical and cellular changes that result in deterioration of the muscular structure, which could generate a deficit in the maintenance of these activities, leading to a specific adaptation to competitive conditions [Byrne, Eston 2002; Torre *et al.* 2012].

To understand these effects, it is necessary to study the muscle damage generated during physical activity [Torres *et al.* 2012]. Among the most investigated muscle damage markers are creatine Quinase (CK), Lactate Dehydrogenase (LDH) [Clarkson, Hubal 2002], Aspartate Aminotransferase (AST), and Alanine Aminotransferase (ALT) [Chishaki *et al.* 2012]. An increase in CK caused by the practice of exercises is directly related to the onset of late muscle pain, as well as to the greater expression of cartilage injury markers [Fonseca *et al.* 2016].

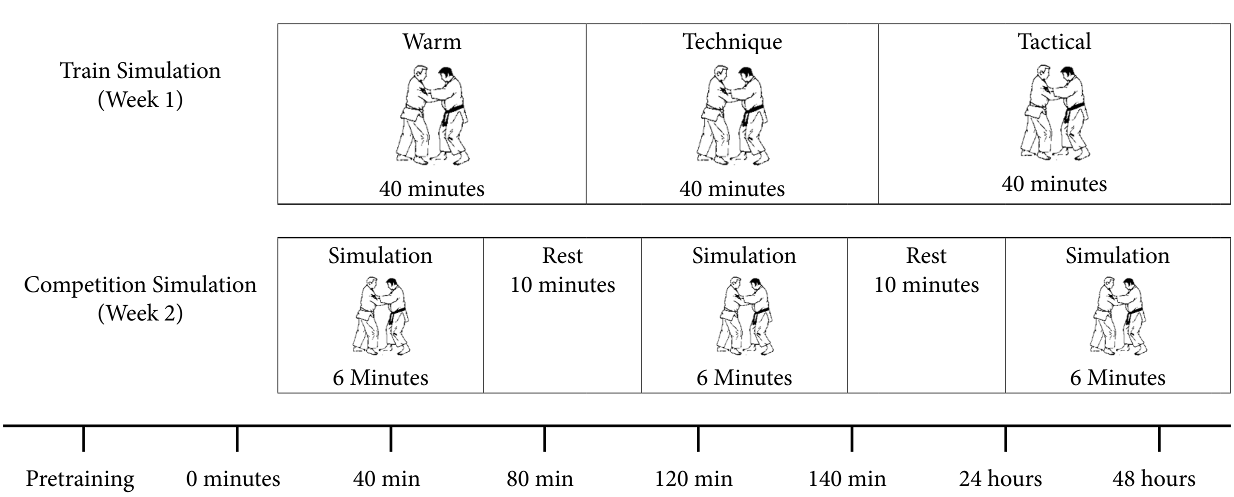
Although some studies have evaluated Jiu-Jitsu, and addressed questions related to training and competition by studying physiological variables, few studies that have evaluated training specificity and its relationship with competition variables have reported highly contradictory results [Andreato *et al.* 2017]. In this context, the objective of our study was to analyze muscle damage, strength and their correlation under two distinct conditions, a specific training session, and a competition simulation session. This study hypothesized that muscle damage markers as well as strength will be greater when evaluated in the simulation of competition than in relation to training.

Materials and Methods

A crossover model was used for the study, where two training sessions were separated by 1-week intervals. The procedures of data collection are described in Figure 1. The training protocol included a typical session characterized by progressive and exhaustive effort. Each training session comprised the following structure: 40 min each of the following modules: generalized exercises (calisthenics), technical training, and combat simulation, amounting to 120 min of training. Widespread exercises included warm-up exercises involving aerobic activities such as races and speed and counter resistance exercises using body weight. Technical training focused on specific movements of Jiu-Jitsu such as guard passes, projections, scraping, immobilizations, and submission. The combat

Figure 1. Design of the procedures performed in the study

Anthropometry (Before Intervention)	Muscle Test Blood Collection (Before Intervention)	Tests (Before Intervention)	Muscle Test Blood Collection (After Intervention)	Muscle Test Blood Collection (24 h After Intervention)	Muscle Test Blood Collection (48 h After Intervention)



simulations occurred with 6-min fights, totaling three fights for each individual with a 10-min interval between fights. This training model was adapted in other studies on Jiu-Jitsu [Fonseca *et al.* 2016; Diaz-Lara *et al.* 2016; Andreato *et al.* 2015]. The volunteers were familiar with the training regimen.

Sample

The study sample included nine subjects, all males with at least 12 months of Jiu-Jitsu experience, who participated in official competitions in the last 6 months at regional and national levels. These subjects were 22.50 ± 2.84 years old, with a height of 1.77 ± 0.05 m, body mass of 75.45 ± 6.86 kg, and body fat of 14.45 ± 3.36 %. All participants were submitted to the following two interventions: 1. simulation of training and 2. simulation of competition. Each subject performed the two exercise conditions in a random order.

The inclusion criterion was not using any type of stimulants or involving in any rapid weight loss process before the intervention, because this practice could negatively affect the physical performance [Fonseca *et al.* 2016], and these facts were confirmed by an interview with the subjects. In addition, athletes should be at least blue belts and compete at the national or state level. Participation in the study was subject to medical authorization, and only clinically healthy subjects were included.

All subjects were submitted to two familiarization sessions and two familiarizations for the tests with a minimum rest interval of 72 h between sessions. All subjects were informed about the study, and all of them signed the authorization (free, informed and consent) in accordance with resolution 466/2012 of the National Commission of Ethics in Research - CONEP, National Health Council, according to the ethical principles of the Declaration of Helsinki (1964, reworded in 1975, 1983, 1989, 1996, 2000, 2008, and 2013) of the World Medical Association.

The study was approved by the Research Ethics Committee of the Federal University of Sergipe (protocol 01723312.2.0000.0058), according to the Council on experiences with humans.

Instruments

Body mass, height, and body fat

A digital platform scale (Fillizola 2002, Filizola, Brazil) calibrated from 0 to 150 kg, with an accuracy of 0.1 kg, was used to measure the weight in kilograms (kg).
The height measurements were done in triplicate for the calculation of the mean value, using a tape type ES2040 (Sanny, Brazil) compact stadiometer, fixed to the wall, with a capacity of 2.0 m and an accuracy of 0.1 cm.
Body density was measured using a scientific adipometer of the Sanny® brand (Sanny, Brazil) and was obtained by the quadratic equations of three skinfolds of Jackson and Pollock [1978] for men, to estimate the percentage of body fat.

Muscle damage

The markers of muscle damage, i.e., serum creatine kinase (CK), lactate dehydrogenase (LDH), aspartate transaminase (AST), and alanine transaminase (ALT) concentrations, were measured. Blood samples were collected during the pre- and post-training periods, post-intervention, and 24 and 48 h after intervention. A total of 8 mL of blood was collected from the antecubital vein and stored in tubes containing coagulant gel (Vacuette; Greiner Bio-One, Campinas, São Paulo, Brazil). Blood was kept for 30 min at room temperature for coagulation and then centrifuged at 4,000 rpm for 8 min to separate the serum. Biochemical measurements were performed on an automated analyzer (Vitros model 5600; Ortho Clinical Diagnostics, Raritan, NJ, USA).
Biochemical measurements were performed using the Vitros® 5600 film system (Ortho-Clinical Diagnostics, Johnson & Johnson Company, USA). LDH, AST, and ALT levels were measured using the multipoint kinetic technique. The CK level was measured by the multipoint rate technique.

Serum levels of LDH (coefficient of variation for the same sample of 1.2%, precision of 1.909 IU/L), serum AST (coefficient of variation for the same sample of 1.8%, precision of 1.781 IU/L), and serum ALT (coefficient of variation for the same sample of 1.9%, precision of 1.909 IU/L) levels were measured using the multipoint kinetic technique. Serum CK level was measured using the multipoint rate technique (coefficient of variation for the same sample of 1.5%, accuracy of 8.456 IU/L).

Squat jump (SJ) and countermovement jump (CMJ)

For the evaluation of the squat jump (SJ) and countermovement jump (CMJ) tests, a 50 × 60 cm conductive surface contact mat (Probotics Inc., USA) was used that was connected to a display (Probotics Inc., USA). The height of the vertical jump resulting from the time interval between the loss of contact of the feet with the carpet and the subsequent contact after the fall was measured.

Muscle power test

All athletes performed a muscle power test using a suppressed footprint bar and an encoder attached to their Muscle lab Encoder belts (Model PFMA 3010e Muscle Lab System; Ergotest, Langesund, Norway).

Procedures

Body density was estimated indirectly (Lange Skinfold Caliper; Beta Technology, Santa Cruz, CA) using the equation of Thorland *et al.* [1991] for college wrestlers as follows:

D (g/mL) = 1.1030 – [0.000815(SD)] + [0.00000084(SD)];
Where D is the body density and SD is the sum of subscapular and abdominal skinfold thicknesses. Body fat percentage (BF%) was estimated using the equation of Brozek *et al.* [1963] as follows:

$$BF\% = 457/D - 414.2$$

Power in upper limbs (PUL)
During pre-training, post-recovery, and 24 h and 48 h after recovery, all athletes performed muscle power test using a bar with the footprint in the supinated position where three repetitions were performed, and the best result was selected for analysis. The reliability calculation was performed from baseline and intraclass coefficient (ICC) of 0.96 and a standard error (SE, 95%) of 16.4 W (2.1%). The initial and final positions of the upper limbs during the power test were performed according to the methodology described by Fonseca *et al.* [2016].

SJ and CMJ
During pre-training, post-recovery, 24 h, and 48 h after recovery post-collection, all participants performed a potency test of the lower limbs. For the evaluation of both jumps, the athlete stood on the mat, the weight being evenly distributed on both feet and the hands placed on the hips, and must remain throughout the test. To execute the SJ upon hearing the "ready" command, he crouched down by flexing his knees at a 90° angle, and after the "Go" command, he made the vertical jump as high as possible, keeping his knees in extension. For the CMJ, the jump movement was performed after a single "Go" command starting from a standing position, followed by a squat to push in the execution of the vertical jump. The SJ and CMJ were evaluated before and after the intervention.

For the jumps, the subjects made two attempts and the best result was used for analysis. For the lower limbs, we calculated the reliability of the baseline replicates and found ICCs (0.96 and 0.95, respectively) and SEs (95% for both) of 1.23 and 1.39 cm, respectively (1.9% and 2.4%, respectively).

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS), version 22.0. The central tendency measures, mean ± standard deviation, were used. To verify the normality of the variables, the Shapiro–Wilk test was used, considering the sample size. To verify the possible differences between the groups divided by the age group, the two-way ANOVA (type of intervention and time point) was used. The post hoc Bonferroni test was used for assessing the indicators

Table 1. Squat Jump Rate (SJ), Counter Movement Jump (CMJ) and Power in Upper Limbs (PUL) (mean ± standard deviation) in training and combat simulation.

	SJ (Cm)		CMJ (Cm)		PUL (N)	
	Training Simulation	Combat simulation	Training Simulation	Combat simulation	Training Simulation	Combat simulation
Before	41,71±3,33	41,71±3,33	44,53±5,56	44,53±5,56	559,41±136,88	558,00±163,32
After	44,48±6,22	45,32±6,11	46,93±5,98	46,93±5,98a	534,34±118,75	533,15±144,61
After 24 h	44,96±4,74	44,70±6,11	46,54±6,06	46,54±6,06b	540,81±150,07	613,02±84,29
After 48 h	45,35±5,33	45,27±6,04	47,55±7,88	47,55±7,88c	579,90±156,89	634,96±85,55
P	NS		NS		NS	

SJ: Squat Jump, CMJ: Counter Movement Jump, PUL: Power in Upper Limbs, NS: Non Significance

Table 2. Squat Jump Rate (SJ), Counter Movement Jump (CMJ) and Power in Upper Limbs (PUL) (mean ± standard deviation) in Training and Competition situations.

	CK (U/L)		LDH (U/L)		AST (U/L)		ALT (U/L)	
	Training Simulation	Combat simulation	Training Simulation	Combat simulation	Training Simulation	Combat simulation	Training Simulation	Combat simulation
Before	451,11±133,36	512,78±209,85	129,00±12,98	129,22±21,92a	9,89±2,80	9,67±2,29	10,22±3,67	10,00±2,85
After	473,22±133,67	559,89±203,21[a]	131,67±13,95	130,33±22,39[b]	9,78±2,17	9,33±2,40	10,11±2,93	10,00±2,30
24 h	466,67±143,36	526,67±176,85[b]	125,89±27,86	124,89±13,69	9,89±2,71	9,89±2,32	10,78±2,52	10,11±1,52
48 h	449,00±128,41	515,44±156,05[a]	128,67±17,59	128,00±11,91	9,78±1,72	9,89±1,62	10,11±2,48	9,89±1,55
p	"a" p=0,001; "b"p=0,008		"a" p=0,019, "b" p=0,001		NS		NS	

SJ: Squat Jump, CMJ: Counter Movement Jump, PUL: Power in Upper Limbs, NS: Non-Significance,

Table 3. Correlation between training and competition simulation in squat jump, counter movement jump, power in upper limbs, and muscle damage (mean ± standard deviation)

Moment	Training simulation	Combat simulation	*r*	R^2	*P*	Equation
SJ (Cm)	41,73±3,28	45,31±6,10	0,716*	0,512	0,030	5,534±0,259 T
SJ (Cm) 24h	44,99±4,75	44,70±6,10	0,748*	0,560	0,020	0,541±0,964 T
SJ (Cm) 48h	45,36±5,33	45,26±6,05	0,874#	0,764	0,002	0,136±0,991 T
CMJ (Cm)	44,43±5,11	46,38±6,93	0,801#	0,642	0,009	1,096±0,929 T
CMJ (Cm) 24h	46,53±6,07	46,03±5,74	0,934#	0,873	<0,001	1,913±0,885 T
CMJ (Cm) 48h	47,55±7,87	45,70±5,41	0,861#	0,741	0,003	6,927±0,591 T
PUL (W)	558,13±44,89	533,15±96,37	0,922#	0,849	<0,001	66,223±1,122 T
PUL (W) 24h	540,81±159,18	613,02±89,40	0,554	---	0,122	---
PUL (W) 48h	579,90±166,41	634,96±90,74	0,473	---	0,199	----

* High correlation, # Very high correlation

SJ: Squat Jump; CMJ: Counter Movement Jump; PUL: Power in Upper Limb; h: Hour; T: Training Simulation

Table 4. Correlation between training and competition simulation in the CK, LDH, AST and ALT tests (mean ± standard deviation)

	Training simulation	Combat simulation	*r*	R^2	*P*	Equation
CK (UI/L)	473,33±22,36	560,00±55,23	0,982#	0,964	<0,001	-0,588+2,425 T
CK (UI/L) 24h	466,67±26,46	526,67±50,00	0,917#	0,840	<0,001	-0,282+1,732 T
CK (UI/L) 48h	448,89±32,19	515,56±75,68	0,988#	0,976	<0,001	-0,527+2,323 T
LDH (UI/L)	129,11±1,96	124,89±2,15	0,922#	0,849	<0,001	-0,052+1,007 T
LDH (UI/L) 24h	131,44±3,36	128,56±4,22	0,969#	0,939	<0,001	-0,314+1,217 T
LDH (UI/L) 48h	130,33±2,96	128,00±2,60	0,748*	0,560	0,020	0,424+0,657 T
AST (UI/L)	9,61±0,33	9,47±0,30	0,988#	0,977	<0,001	0,060+0,923 T
AST (UI/L) 24h	9,87±0,42	9,71±0,42	0,992#	0,984	<0,001	0,011+0,995 T
AST (UI/L) 48h	9,82±0,39	9,73±041	0,989#	0,979	<0,001	-0,031+1,022 T
ALT (UI/L)	10,02±0,31	9,98±0,32	0,986#	0,972	<0,001	-0,016+1,012 T
ALT (UI/L) 24h	10,24±0,27	10,17±0,38	0,088	---	0,821	---
ALT (UI/L) 48h	10,16±0,68	10,07±0,69	0,996#	0,992	<0,001	-0,013+1,004 T

* High correlation, # Very high correlation

CK: Creatina Kinase; LDH: Lactatato Desidrogenase; AST: Aspatato Aminotransferase; ALT: Alamina Aminotrasnferase; h: Hour; T: Training Simulation

of strength and muscle damage. Pearson's correlation coefficient "*r*" was used to correlate the post-training and post-competition results and the training regression equation to predict the competition values. To verify the effect size, the Cohen f^2 test was used, in addition to the cut points from 0.02 to 0.15, with a small effect from 0.15 to 0.35 as the median and greater than 0 [Grissom, Kim 2005]. Statistical significance was considered at $p<0.05$.

Results

Tables 1 and 2 show the results of the results of the SJ and CMJ tests as well as the PUL, and muscle damage, i.e., the levels of CK, LDH, AST, and ALT, test at pre- and post-test and 24 and 48 h after intervention through training simulation and competition, along with their kinetics.

Table 1 shows no significant differences in SJ, CMJ and PUL test ($p > 0.990$). Table 2, regarding CK levels, there were significant differences after competition in relation to the other time points and intervention, with a strong effect. Regarding LDH levels, there were significant differences in post-competition and pre-competition in relation to pre- and post-training ($p = 0.019$), with a high effect. The other variables did not present significant differences both at the different time points and between the training intervention and the competition. The AST and ALT levels showed no significant differences and presented a very similar kinetics, and the values were also similar.

Table 3 describes the correlation at the different time points between training and the combat simulation.

It was observed that the PUL results showed a median correlation 24 h (0.554) and 48 h (0.473) after the intervention. The SJ test results showed a high correlation (0.716), and the other test results showed a very high correlation (>0.8).

Table 4 describes the correlation at the different time points between the training simulation and the combat simulation (CK, LDH, AST, and ALT levels).

All variables presented a very high correlation at both time points of the study. Only the variable LDH level, 48 h later, presented a high correlation. ALT did not present a good correlation to make an equation.

Discussion

The present study aimed to analyze the muscle damage, strength and their correlation that could exist in the Jiu-Jitsu modality at two different time points.

It was verified that in relation to the strength measured by the SJ, after training (41.73±3.28 cm) and post-competition (45.31 ± 6.10 cm), the correlation was $r = 0.716$, and after 24 ($r = 0.748$) and 48 h ($r = 0.874$), the correlation was still higher. Regarding CMJ, the correlation at all time points was higher than 0.800, demonstrating that there is a correlation between training and competition for the various types of strength manifestations. However, regarding the PUL, there was a correlation after training (558.13 ± 44.89 W) and after the competition simulation (533.15 ± 96.37 W).

However, after 24 h, the recovery did not occur with the same kinetics, with different values in training (540.81 ± 159.18 W) and competition (613.02 ± 89.40 W) with an intermediate correlation ($r = 0.554$), and after 48 h, the correlation was lower ($r = 0.473$). These results demonstrate that competitive efforts tend to be higher in relation to upper limbs, and the requirements in competition tend to be more stressful in this follow-up than those in training.

The fatigue effects in the lower limbs can be attributed to intense isometric, concentric, and eccentric actions performed during matches [Diaz-Lara *et al.* 2016; Diaz-Lara *et al.* 2014], such as guard passes, sweeps, and leg submissions. It has been documented that the actions performed at high intensity and with short rest periods, primarily in the eccentric mode, produce immense overload and mechanical stress on muscular structures [Byrne, Eston 2002; Twistm Eston 2005]. During a simulated judo contest, Detanico *et al.* [2015] found a decrease in vertical jump performance after three matches, and this was explained by the powerful eccentric actions performed by the legs during that combat, which caused impairments in muscle function.

On the other hand, another study demonstrated that, through training procedures with recovery in ice water, the PUL showed significant differences 24 h after training, and the values presented were superior to the present study values, with recovery in cold water (757.9 ± 125.1 W) and in the control group (695.9 ± 56.1 W) [Fonseca *et al.* 2016].

Regarding muscle damage, a high correlation was observed in all indicators of CK damage ($r > 0.9$) at all time points after training simulation or combat simulation. In the same context, it was verified that in CK levels, significant differences were found at the time point after all the time points in the competition in relation to the training (post-training 560.00±55,23 to 473.33±22,36, 24 h 526.67±50,00 to 466.67±26,46, and 48 h after 515.56±75,68 to 448.89±32,19), respectively. The results of the present study corroborate with those of other studies that found an increase in serum concentrations of post-exercise CK, which was inversely proportional to the capacity of the muscle to generate strength [Pinho Júnior *et al.* 2014]. On the other hand, another study that evaluated muscle damage after training also identified CK levels to be more altered [Fonseca *et al.* 2016].

Regarding LDH levels, a high correlation between training and combat was observed ($r > 0.9$ in the post-training and after 24 h, and $r = 0.748$ after 48 h). On the other hand, LDH is present in large quantities in the skeletal muscle, as this enzyme is responsible for the anaerobic conversion of pyruvate to lactate. The association of LDH with muscle damage is closely linked to increased CK concentration [Hausswirth *et al.* 2011], which would explain the results of our study.

Regarding AST and ALT levels, the correlation between training and combat was high ($r > 0.888$ at all time points after). AST and ALT are important liver enzymes for amino acid catabolism, and although not concentrated in the muscle, increased activity of these enzymes occurs during intense exercise [Nazari, Azarbayjani, Azizbeigi 2016] or intermittent exercise [Samadi *et al.* 2012], since intense exercise tends to increase protein catabolism. However, no major changes in AST and ALT levels were found in our study. In addition, regarding CK and LDH levels, a study using other grappling methods found an increase of 15%–42% in the serum concentration of these enzymes after 2.5 h of training [Yamamoto 2006].

Future perspectives are that the findings of the present research contribute to the direction of sports training. It is important to emphasize that this study represents an important conceptual advance in the demonstration of how combat simulation during the training phase is important and brings beneficial results which can improve the results during the championships.

Conclusions

It was possible to conclude that there was a good correlation between training and competition simulation, where the model adopted as training can meet the needs imposed in the competition and may undergo changes to better approach the true conditions found in a competition.

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Analiza uszkodzeń i siły mięśni w symulacji treningu i zawodów u brazylijskich sportowców Jiu Jitsu

Słowa kluczowe: uszkodzenie mięśni, jiu-jitsu, siła, rywalizacja

Streszczenie

Tło. Ważne jest, aby ocenić specyfikę treningu i jego związek ze zmiennymi zawodów u sportowców Jiu Jitsu.

Problem i cel. Celem pracy była analiza uszkodzeń mięśni, siły i ich korelacji w dwóch różnych warunkach, określonej sesji treningowej i sesji symulacji zawodów.

Metody. Próba badawcza obejmowała dziewięć osób (22,50±2,84 lat), które zostały poddane dwóm interwencjom: 1. symulacja treningu i 2. symulacja rywalizacji.

Wyniki: Można zaobserwować, że nie było istotnych różnic w teście skoku z kontrruchem (CMJ); jednak 48h po treningu zaobserwowano wartości wyższe niż w tygodniu zawodów. Jeśli chodzi o poziomy kinazy kreatynowej (CK), po zawodach wystąpiły istotne różnice w stosunku do innych punktów czasowych i interwencji (p=0,004), z wysokim rezultatem. Stężenia dehydrogenazy mleczanowej (LDH) były istotne po zawodach i przed zawodami w stosunku do stanu przed i po treningu (p=0,019), z wysokim rezultatem. Zaobserwowano, że wyniki mocy w kończynach górnych (PUL) wykazały medianę korelacji 24 (0,554) i 48h (0,473) po zabiegu. Wyniki testu skoku z przysiadu (SJ) wykazały wysoką korelację (0,716), a wyniki pozostałych testów wykazały bardzo wysoką korelację (>0,8). Wszystkie zmienne charakteryzowały się bardzo wysoką korelacją w obu punktach czasowych badania. Jedynie zmienny poziom LDH 48 h później wykazywał wysoką korelację.

Wniosek. Stwierdzono, że istnieje dobra korelacja pomiędzy symulacją treningu a symulacją zawodów, gdzie model przyjęty jako trening może zaspokoić potrzeby narzucone podczas zawodów.