© *Idōkan Poland Association*
"IDO MOVEMENT FOR CULTURE. Journal of Martial Arts Anthropology",
Vol. 23, no. 2 (2023), pp. 50–57
DOI: 10.14589/ido.23.2.7

PHYSIOLOGY & COACHING

Raquel S. Mendes-Netto(ABCDEF)[1,3*], Renata C. Matos(ABCDE)[1], Dayanne da C. Maynard(ABC)[1], Luana Edla de Lima(ABC)[3], Charles Nardelli(DEF)[1], Ciro J. Brito(DEF)[2], Marzo E. da S. Grigolleto(ABC)[1]

[1] Master's Science Program in Physical Education, University Federal of Sergipe (Brazil)
[2] Physical Education Graduate Program, Federal University of Juiz de Fora (Brazil)
[3]Master's Science Program in Nutrition Sciences, University Federal of Sergipe (Brazil)
Corresponding Author*: Raquel Simoes Mendes-Netto, Marechal Rondon Av, Sao Cristovao (SE), Brazil. 49100-000. Phone:+55(79)31946662.
e-mail: raquel@academico.ufs.br

Acute carbohydrate restriction induces a higher weight loss and preserves the athletic performance of Brazilian jiu-jitsu athletes

Submission: 2.03.2020; acceptance: 29.07.2021

Key words: combat sports, carbohydrate, specific athletic performance, weight loss, metabolism

Abstract
Background and objective. Brazilian Jiu-jitsu (BJJ) is a combat sport with intense physical contact, emphasizing takedowns, and with a time limit of 10 minutes per fight, which requires strength, flexibility, motor coordination, and good aerobic endurance. Carbohydrate restriction is a widely used strategy for weight loss, yet its application to Brazilian Jiu-Jitsu athletes remains debatable, especially regarding the effects on energy metabolism and performance.
Material and Methods. This study assessed the acute effect of carbohydrate restriction on metabolic variables, weight loss and physical fitness tests. A randomized clinical trial was composed of 16 BJJ male athletes. Participants were randomized into 2 groups according to dietary strategy: R-CHO (2-3 $g/kg.d^{-1}$), n=10, and A-CHO (5-7 $g/kg.d^{-1}$), n=6. Four physical fitness tests and blood markers of energy metabolism and muscle damage at baseline and follow-up were assessed.
Results. The main results indicated that both diet strategies promoted weight loss and did not affect performance. Regarding energy metabolism markers, carbohydrate restriction for 28 days lead to an increase in blood lactate and creatinine after an intense exercise bout. In spite of increased uric acid in the R-CHO group, both interventions caused reductions in its levels. Blood glucose increased in both groups at baseline.
Conclusions. In conclusion, R-CHO promoted a higher weight loss and increased the mobilization of fast energy reserves, however these metabolic changes did not affect performance.

Introduction

Brazilian Jiu-jitsu (BJJ) is a combat sport with intense physical contact, emphasizing submissions, chokes and armlocks, and with a time limit of 10 minutes per fight which requires strength, stretching, motor coordination, and adequate aerobic endurance [Agricola *et al*. 2016]. The athletes need to perform at maximal effort during the combats, which makes a higher cardiorespiratory capacity necessary in order to dispute the next combats, as occurs in championship tournaments. BJJ involves lactic anaerobic effort for recovery and the athlete needs good aerobic capacity to release lactate from muscles [Del Vecchio *et al*. 2007; Podrigalo *et al*. 2019].

Many athletes engage in rapid weight loss strategies before competitions in order to compete in a lighter weight division [Marquet *et al*. 2013; Artioli *et al*., 2010]. These strategies can be harmful, affect their performance and change the blood glucose, urea, creatine kinase and creatinine levels [Tipmann *et al*. 2008; Yang *et al*. 2014]. According to the official rules of Jiu-jitsu, weighing is done immediately before the competition, as this strategy aims to prevent the athlete from using rapid weight loss strategies; however, previous studies have shown that the prevalence of rapid weight loss in this combat sport varies between 56.8 [Brito *et al.* 2012] and 88% [Barley *et* *al.* 2018]. In addition, 27.1% of athletes reported losing more than 5% of body mass in the pre-competition week [Brito *et al.* 2012]. Carbohydrate-restriction is a strategy used for gradual weight loss which has been extensively applied recently. Specifically, in relation to jiu-jitsu, 33% of the athletes evaluated by Barley *et al.* [2018] stated that they maintain fasting before the competition; in addition, 40.9% of those who lost weight avoid carbohydrates intake [Brito *et al.* 2012]. However, the application of this method to athletes is still controversial [Paoli *et al.* 2012] due to the importance of adequate carbohydrate intake and maintenance of muscle glycogen reserves in high-intensity short-duration sports [Lima-Silva *et al.* 2011]. Glycolysis is largely activated in combat sports, and therefore athletes need dietary plans which comprise sufficient amounts of carbohydrate [Andreato *et al.* 2015; Sa *et al.* 2015; Santos *et al.* 2011].

Baseline values of blood markers may not be affected by gradual weight loss [Yang *et al.* 2014], which demonstrates the need to study the changes in these energy metabolism markers after athletes have undergone physical stress and to evaluate which are the best weight loss strategies without implicating performance. Therefore, the aims of this study were to evaluate the acute effects of two weight loss strategies involving energy restriction, with and without carbohydrate restriction, on the performance and metabolic variables in Brazilian jiu-jitsu athletes. We hypothesized that carbohydrate restriction affects the biochemical and athletic performance.

Materials and methods

Participants

This protocol was previously approved by the ethics committee on research at the university where it was carried out (protocol no.855,069). For the present study, we enrolled 16 Brazilian Jiu-jitsu athletes at state, regional and national competition levels. This study followed the ethical recommendations of the Helsinki Declaration and from the Brazilian National Health Council no. 510/2016. The participants were informed about the study procedures and were asked to sign an informed consent form which was conditional to their participation in the study. The inclusion criteria were: a) males; b) ≥18 years; c) not participating in competitions during the study period (4 weeks); d) ≥5 years practicing Brazilian Jiu-jitsu (2-5 training sessions/wk. 1.5-2 hours/session), e) ≥blue belt; and f) weight above the maximum limits expected for the weight division in which they compete. The following participants were excluded: a) those who did not complete all of the protocol; and b) those who did not follow the prescribed diet. The participants were randomized into two diet intervention groups: R-CHO (n=10) carbohydrate-restricted dietary plans during 28 days; and A-CHO (n=6) adequate carbohydrate intake.

Nutritional protocol

The restriction protocol was planned to promote a 5% bodyweight loss after 28 days (4 weeks). This percentage was set according to bodyweight losses usually practiced by combat sports athletes[4]. Therefore, the caloric restriction was calculated knowing that 1g of mixed energy reserve provides 7 kcal [Garthe *et al.* 2011]. Thus, dietary plans were elaborated to comprise the calculated energy restriction with different amounts of carbohydrates: the carbohydrate intake in group R-CHO was 2 to 3 $g/(kg.d^{-1})$ and an intake of 5-7 $g/(kg.d^{-1})$ was established for group A-CHO [Burke *et al.* 2011]. Both dietary plans also comprised 1.2-2.0 $g/(kg.d^{-1})$ of protein and > 20% of the energy coming from fat, a nutrient with high energy density, in order to provide satiety and variety. We planned 4 dietary plans for each athlete with 6 meals each, including snacks. None of the plans comprised less than 2000 kcal/d. A researcher visited the participants every week in order to clear any possible doubts about the proposed dietary plans and to assess their adherence to it by a dietary adherence questionnaire into which the participant would indicate how many days of the week the diet had been followed. The data regarding the results achieved with the weight loss protocol is presented in an article previously published by our research group [Maynard *et al.* 2018].

Anthropometry

We performed the anthropometric measurements at baseline and follow-up according to standards proposed by Lohman [1988]. Bodyweight was assessed with a digital electronic platform scale with 100-g precision (LIDER®, SP, Brazil); height was measured with a stadiometer with the scale in millimeters (ALTUREXATA®, SP, Brazil). Skinfold thickness was measured with a caliper (LANGE®, MA, USA) with 0.1 mm of precision, and we subsequently calculated body fat percentage from the measured values using the 7-skinfold equation for males provided by Jackson and Pollock [1978].

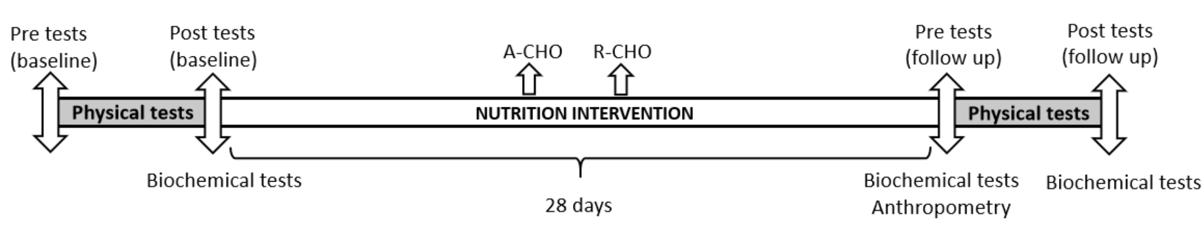

Figure 1. Experimental design. The study consisted of two assessments at Baseline and follow-up with a 28-day period dietary intervention. A-CHO – Experimental group consuming adequate amounts of carbohydrates. R-CHO – Experimental group consuming restricted amounts of carbohydrates.

Blood sample analysis

The study protocol consisted of biochemical tests before and after physical fitness tests, which occurred during baseline and after 28 days of following the dietary plans (i.e. the follow-up) (Figure 1).

Laboratory tests were performed four times during the study: twice at baseline and twice at follow-up. An accredited professional performed all blood collections. First, 10 mL of blood was drawn from the antecubital veins and samples were immediately sent to the Laboratory of Clinical Analyses at University Hospital for analysis of plasma urea and creatinine, uric acid, liver enzymes – Alanine and Aspartate transaminase (ALT and AST), blood glucose, creatine kinase (CK), lactate dehydrogenase (LDH) and lactate. Biochemical measurements were performed in an automated analyzer (model Vitros 5600; Ortho Clinical Diagnostics, NJ, USA). Serum LDH, AST and ALT (variation coefficient was 1.2%, 1.8%, 1.9% for LDH, AST, ALT respectively) were measured using the multipoint kinetic technique. Serum CK (1.5% of accuracy) was measured by the multipoint rate technique.

Physical fitness tests

Participants were familiarized with the physical fitness tests one week before the study started. Tests were performed progressively according to the intensity of each one in order to minimize the effect of the order in the last tests:

Upper body power

For the upper body power assessment, we used a pull-up exercise test in a fixed bar with a coder (Encoder, Muscle Lab System®, Model PFMA 3010e, Ergotest, Langesund, Norway) placed in the belt the participant was wearing. After warming up, participants would place their hands on the bar in a prone position, elbows completely extended and feet suspended. From this position, the participant had to try to elevate their body until touching their clavicle into the bar, and then start a new repetition. Each participant performed three repetitions and only the best result out of the three was saved for analysis. These procedures were performed according to Fonseca *et al.* [2016].

Lower body power

Counter movement jump test (CMJ) on a contact mat (Globus®, Rome, Italy) was used for the estimation of lower body power [Bosco *et al.* 1983]. For CMJ, the participant departs from an erect position and performs a preparatory movement of flexing their knees before a vertical jump. We instructed the participants to keep their arms next to their waist in order to avoid the effect of the arm movement in performing the test. The participants were instructed to jump as high as they could in each try. After the familiarization phase, the participant repeated the jumps three times, and only the best result out of the three was saved for the analyses.

Fatigue Index

The Repeated Sprint Ability test (RSA) was used for the fatigue index calculation. It consists of 20m sprints (approximately 10 seconds) interspersed with 60 seconds of recovery [Girard *et al.* 2011]. It involved a change of direction in order to make the test closer to the physiological demands of the modality. The participants started at the starting line, sprinted to the finish line, changed their direction and came back to the starting point. After the sprint, the participants had to come walking to the starting line and waited until the next sprint. Two pairs of photocells were placed in the starting and finishing lines to measure the sprint duration. The two shortest and largest times were used to calculate RSA value. The ratio between them is an indicative of a loss of performance. The procedures of these tests were performed according to Maynard *et al.* [2018].

Aerobic endurance test

We used the Yo-Yo test for assessing aerobic endurance [Bangsbo 1996]. It consisted of shuttle runs in a 40-meter path (20m + 20m), with an initial speed of 11.5 km/h and progressive increases in speed which were controlled by sound buzzers. Recovery time was progressively reduced throughout the test. At the end of each run, the participant had to perform a common movement in the modality called “jumping guard” at someone standing at the finish line, and stay in the position for 10 seconds. After this 10-second period, a buzzer sounded and participants had to go through the running path another time. This process was repeated until the participant would have failed twice at either arriving at the finish line in time or running at the stipulated speed. The participants were warned if they were not able to adequately perform the jumping guard movement. These tests were performed according to Maynard *et al.* [2018].

Statistical analysis

Data is expressed as means and standard deviations. All statistical analyses were performed in the SPSS version 20.0 software program. Data normality was tested by the Shapiro-Wilk test. The variables were compared by two-way ANOVA with repeated measures in which we compared results between groups and within groups at baseline and follow-up. We also calculated variation values (Δ), in order to assess how markers changed after dietary intervention. We considered $p \leq 0.05$ as significant.

Results

The results regarding the 16 participants who went through all of the study phases are as follows: 10 participants in R-CHO and 6 in A-CHO. The physical characteristics and estimated energy requirement are displayed in Table 1, where we show that groups did not differ at baseline (p>0.05). Reduction in bodyweight BMI and body fat percentage after the 4 weeks was significant (p<0.001) (data not shown). However, it is noticeable that R-CHO reached weight loss rates closer to the 5% originally planned, as shown in Figure 2.

Table 1. Physical characteristics of jiu-jitsu athletes.

	Age (years) X±SD	Height (cm) X±SD	Body mass (kg) X±SD	EER (Kcal) X±SD
R-CHO (n=10)	24.5± 4.8	173.7±7.0	82.9±12.9	4596.0±484.1
A-CHO (n=6)	28.8±8.6	177.3±6.6	85.2±6.9	4184.0±371.5

X = mean, SD = Standard deviation. A-CHO – Experimental group consuming adequate amounts of carbohydrate. R-CHO – Experimental group consuming restricted amounts of carbohydrates. EER – Estimated Energy Requirement.

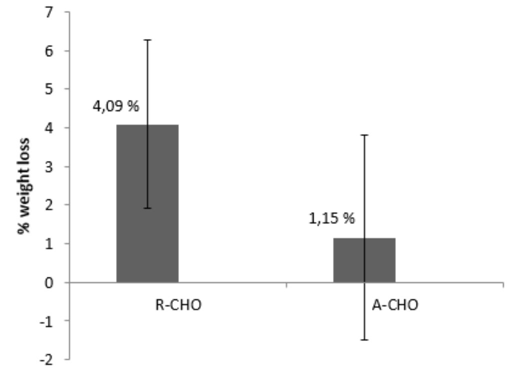

Figure 2. Percentage of weight loss for each group after dietary intervention. A-CHO – Experimental group consuming adequate amounts of carbohydrate.

In Table 2 we present results referring to blood glucose, energy metabolism and muscular damage markers during physical fitness tests at baseline and follow-up.

Table 2. Biochemical markers before and after the execution of the performance tests and in the pre- and post-dietary intervention moments.

	Baseline			**Follow up**		
	Pre testes X±SD (n=10)	**Post tests X±SD (n=6)**	**p-value**	**Pre tests X±SD (n=10)**	**Post tests X±SD (n=6)**	**p-value**
Metabolic Markers						
Glucose mg/Dl						
R-CHO	88.1±6.7	97.2±19.9	G = 0.427	83.5±7.5	88.0±21.9	G = 0.313
A-CHO	98.8±37.2	108.2±42.8	T = 0.035	95.3±23.5	90.5±13.2	T = 0.978
			GxT = 0.493			GxT = 0.805
Lactate mg/dL						
R-CHO	10.8±3.1	112.0 ±28.0*	G = 0.151	12.4±7.1	79.1±35.3*#	G = 0.85
A-CHO	12.2±5.2	88.4±29.4*	T <0.001	11.5±3.7	77.6±11.5*	T <0,001
			GxT = 0.672			GxT = 0.265
Creatinine mg/dL						
R-CHO	1.1±0.2	1.4±0.3*	G = 0.726	1.3±0.2	1.7±0.3*#	G = 0.174
A-CHO	1.1±0.2	1,5±0.2*	T < 0.001	1.1±0.2	1.4±0.2*	T < 0.001
			GxT = 0.107			GxT = 0.283
Uric acid mg/dL						
R-CHO	5.1±1.4	7.0±1.6*	G = 0.641	5.5±1.4	6.7±1.6*	G = 0.404
A-CHO	5.1±0.9	6.4±0.7*	T < 0.001	5.2±0.8	5.9±0.9*	T < 0.001
			GxT = 0.374			GxT = 0.243
Urea mg/dL						
R-CHO	29.3±10.4	32.7±10.5*	G = 0.245	33.7±9.2	37.6±8.6*	G = 0.672
A-CHO	26.7±14.0	40.2±14.2*	T < 0.001	32.5±6.8	35.2±6.8*	T < 0.001
			GxT = 0.245			GxT = 0.565
Muscle injury markers						
LDH mg/dL						
R-CHO	398.0±74.5	479.0±119.2*	G = 0.925	421.4±85.8	479.4±95.3*	G = 0.369
A-CHO	404.0±77.1	464.0±92.7*	T <0.001	376.5±69.0	443.8±88.1*	T <0.001
			GxT = 0.796			GxT = 0.470
CK U/L						
R-CHO	208.4±86.2	269.4±71.8*	G = 0.330	332.0±86.1	368.2±93.2*	G = 0.863
A-CHO	303.3±189.1	368.5±198.0*	T = 0.005	317.3±109.1	358.0±134.9*	T = 0.005
			GxT = 0.328			GxT = 0.897
AST U/L						
R-CHO	30.0±16.5	29.6±17.0	G = 0.619	35.5±25.2	36.9±30.0	G = 0.437
A-CHO	26.0±9.8	25.8±11.0	T = 0.708	26.8±7.7	26.8±0.1	T = 0.560
			GxT = 0.638			GxT = 0.443
ALT U/L						
R-CHO	38.4±44.6	38.3±44.5	G = 0.726	31.9±31.6	32.1±33.94	G = 0.949
A-CHO	31.2±9.2	32.2±11.0	T = 0.394	32.7±11.0	33.2±11.6	T = 0.582
			GxT = 0.748			GxT = 0.942

X= mean, SD = Standard deviation, G= group, T= time, GxT = group and moment of measurement interaction. *Significant difference over time (Pre vs. Post), R-CHO: reduced carbohydrate; A-CHO: adequate carbohydrate.

No differences were found between groups for blood glucose ($F=0.518$; $p=0.607$; $\eta^2=0.074$), ALT ($F=0.192$; $p=0.827$; $\eta^2=0.039$) or AST ($F=0.301$; $p=0.745$; $\eta^2=0.044$) at neither at baseline nor follow-up ($p>0.05$). Nonetheless, blood glucose increased significantly for both groups during baseline. We observed an isolated effect of the measurement moment for creatinine, CK ($F=5.81$; $p=0.005$; $\eta^2=0.293$), lactate ($F=74.527$; $p\leq0.001$; $\eta^2=0.92$), LDH ($F=42.982$; $p\leq0.001$; $\eta^2=0.869$) and uric acid ($F=52.179$; $p\leq0.001$; $\eta^2=0.889$), where we found an increase in the concentrations after the physical fitness tests. It is worth noticing that creatinine and lactate were found to be elevated in the R-CHO group at follow-up after the physical fitness tests relative to the A-CHO group at the same moment.

The results of physical fitness tests are shown in Table 3. No differences between baseline and follow-up were found for upper body power ($F=0.434$; $p=0.523$; $\eta^2=0.035$), lower body power ($F=2.763$; $p=0.119$; $\eta^2=0.165$), fatigue index ($F=2.902$; $p=0.111$; $\eta^2=0.172$) or aerobic endurance ($F=1.642$; $p=0.221$; $\eta^2=0.105$) between the R-CHO and A-CHO groups.

Table 3. Physical tests applied to Jiu-Jitsu practitioners before and after a four-week nutritional intervention.

	R-CHO X±SD (n=10)	A-CHO X±SP (n=8)	p-value
Upper Body Power (W)			
Baseline	463.7±116.1	579.2±183.3	G=0.209
Follow up	499.1±141.2	579.1±172.1	T=0.674
Δ (Δ%)	44.4±10.6	-25.1±-3.9	GxT=0.417
Lower body power (W)			
Baseline	0.339±0.03	0.361±0.1	G=0.246
Follow up	0.369±0.04	0.398±0.1	T=0.134
Δ (Δ%)	0.03±9.2	0.03±13.1	GxT=0.351
Fatigue index (w/s)			
Baseline	1.5±1.4	1.7±0.7	G=0.696
Follow up	1.1±0.4	1,37 (0,85)	T=0.258
Δ (Δ%)	-0.4±24.8	-0.3±-8.1	GxT=0.482
Aerobic endurance (m)			
Baseline	404.0±76.5	400.0±80.0	G=0.913
Follow up	404.0±76.5	400.0±101.2	T=1.0
Δ (Δ%)	0.0±1.7	0.0±1.1	GxT=0.93

Two-way ANOVA $p\leq0.05$. X = mean, SE = Standard error, G= group, T= time, GxT= group and moment of measurement interaction. R-CHO: reduced carbohydrate; A-CHO: adequate carbohydrate.

Discussion

Our study evaluated the acute effects of restricted energy and carbohydrate dietary intake on energy metabolism and muscle damage markers in Brazilian Jiu-jitsu athletes. The main results indicated that participants lost weight, independently of the group into which they were assigned, without affecting performance. Regarding energy metabolism measures, carbohydrate restriction increases the blood lactate and creatinine after an intense exercise bout. In spite of increased uric acid in R-CHO group, both interventions caused reductions in its levels. There is moderate activation of the glycolytic pathway during jiu-jitsu bouts [Andreato *et al.* 2014]. In our study, blood glucose increased during baseline after the physical fitness tests. These results may suggest that muscle glycogen reserves were depleted to provide energy to support intense muscle activity, as observed in other studies with combat sports athletes [Andreato *et al.* 2014; Barbas *et al.* 2011]. The increased blood lactate concentrations also support this hypothesis.

After the intervention, blood glucose did not change, which has already been observed in jiu-jitsu and other combat sports athletes [Tipmann *et al.* 2008; Andreato *et al.* 2015], and the extension of increase in blood lactate was smaller. This may indicate that dietary energy restriction resulted in decreased availability of energy reserves [Burke *et al.* 2021]. Despite the changes in blood glucose and lactate at follow-up relative to baseline, no implications in performance were observed in either group. This indicates that neither energy nor carbohydrate restrictions were sufficiently severe to compromise performance. Our results are in line with those observed in other populations of athletes, whether these activities are predominantly aerobic [Che *et al.* 2021], mixed [Durkalec-Michalski *et al.* 2021] or strength [Paoli *et al.* 2021].

Creatinine is the final product of muscle creatine degradation. During high-intensity bouts of exercise, phosphocreatine (PCr), which has a high potential for phosphate transfer, is hydrolyzed to provide an inorganic phosphate group to resynthesize ATP from ADP. The more extensive the phosphate transfer is, the more creatine is generated, and because muscle cells at this state are low in total energy, re-phosphorylation of creatine into phosphocreatine becomes difficult. Hence, creatine is transformed into creatinine by non-enzymatic dehydration, which is in turn transferred into blood for excretion [Hellsten *et al.* 1999]. Creatinine was significantly increased in both groups at baseline and follow-up. In addition, creatinine values at follow-up were increased in the R-CHO group after physical fitness tests, which may evidence a greater use of ATP-PCr energy system.

In this fast energy-delivering system (ATP-PCr), two ADP molecules, products of ATP used during exercise, are converted into ATP and AMP [Hellsten *et al.* 1999]. AMP goes through deamination by adenylate deaminase, which generates ammonia and inosine monophosphate (IMP). Because IMP does not easily diffuse to the blood, it is accumulated in muscle cells, where it is de-phosphorylated to generate hypoxanthine, which in turn is converted into xanthine and posteriorly into uric acid, by xanthine oxidase [Vina *et al.* 2000; Cordeiro *et al.* 2007; Gerber *et al.* 2014]. These biochemical reactions explain the significant increases in uric acid concentrations in athletes after physical effort. Other studies with Brazilian Jiu-jitsu athletes also observed increases in uric acid after fights [Andreato *et al.* 2015; Brandao *et al.* 2014]. Uric acid was higher in the R-CHO group compared to A-CHO, probably due to lesser activation of the glycolytic pathway, which compensates a greater use of ATP-PCr energy delivering system, with consequent increased ADP formation, conversion of AMP to IMP and resulting increase uric acid concentrations. Urea is synthesized in the liver from carbon dioxide and ammonia, two end products of protein catabolism [Degoutte *et al.* 2003]. In accordance with what has been observed before for jiu-jitsu athletes [Brandao *et al.* 2014], blood urea significantly increased after physical fitness tests, yet no significant differences were found between groups. Ammonia generated as an AMP byproduct may have contributed to urea generation, together with protein catabolism during physical efforts [Brandao *et al.* 2014; Zhao *et al.* 2000].

Regarding cellular damage markers, LDH, CK, ALT and AST were significantly elevated at all times after physical fitness tests, regardless of diet composition. This effect has been already reported in jiu-jitsu fights [Coswig *et al.* 2013]. CK is an indirect marker for muscle cell damage since the generation of lactic acid affects membrane permeability and some enzymes, such as CK, diffuses into the blood [Miles *et al.* 2008]. Despite ALT and AST being sensitive indicators of liver health, they are also present in skeletal muscle, and therefore they can be used in association with other muscle damage markers in order to accurately reflect the damage generated by physical effort during a fight [Pettersson *et al.* 2008]. In order to avoid erroneous conclusions, these markers should be evaluated in conjunction with athletes' clinical context and performance [Siqueira *et al.* 2009]. Our study presents an original methodological proposal regarding the acute changes in biochemical variables related to glycemic control, energy metabolism, muscle damage and protein status after following two dietary strategies for weight loss.

One of the limitations of our study was the use of physical fitness tests instead of a real jiu-jitsu fight. However, we tried to use tests that would require similar energy expenditures of participants to the ones measured in jiu-jitsu fights. For this purpose, we used adapted evaluations. In conclusion, carbohydrate restriction during 28 days favored weight losses closer to the originally planned 5%, and despite implicating decreased and faster depletion of muscle energy reserves, these metabolic adaptations did not compromise performance.

Abbreviations

A-CHO – Adequate carbohydrate
ALT – Alanine transaminase
AST – Aspartate transaminase
BJJ – Brazilian Jiu-Jitsu
BMI – Body mass index
CMJ – Counter-movement jump test
CK – Creatine kinase
IMP – Inosine monophosphate
LDH – Lactate dehydrogenase
R-CHO – Reduced carbohydrate
RSA – Repeated Sprint Ability test

Financial Support: PIBIC-CNPq and HERMES/UFS
The authors report no conflicts of interest.

References

1. agricola N.P.A., Souza J.B.A., Bonilha M.R., Guillo L.A. (2016), *Chronic Haematological Profile Study in Brazilian Jiu Jitsu Athletes*, "American Journal of Sports Medicine", vol. 4, pp. 13-19; doi: 10.12691/ajssm-4-1-3.
2. Andreato L.V., Franzo'i-de-Moraes S.M., Esteves J.V.D.C., Miranda M.L., Pastorio J.J., Pastorio E.J., Branco B.H.M., Franchini E. (2014), *Psychological, physiological, performance and perceptive responses to Brazilian jiu-jitsu combats*, "Kinesiology", vol. 46, pp. 44–52; doi: 10.13140/2.1.2975.5522.
3. Andreato L.V., Julio U.F., Panissa V.L.G., Esteves J.V.D.C., Hardt F., Moraes S.M.F., de Souza C.O., Franchini E. (2015), *Brazilian jiu-jitsu simulated competition part i: metabolic, hormonal, cellular damage, and heart rate responses*, "The Journal of Strength and Conditioning Research", vol. 29, pp. 2538-2549; doi: 10.1519/JSC.0000000000000918.
4. Artioli G.G., Gualano B., Franchini E., Scagliusi F.B., Takesian M., Fuchs M., Lancha A.H. (2010), *Prevalence, magnitude, and methods of rapid weight loss among judo competitors*, "Medicine & Science in Sports & Exercise", vol. 42, pp. 436-442. doi: 10.1249/MSS.0b013e3181ba8055.
5. Bangsbo J. (1996), *Yo-Yo Test*, "HO+Storm", Copenhagen, Denmark and Tocano Music A/S, Smorum, Denmark.
6. Barbas I., Fatouros I.G., Douroudos I., Chatzinikolaou A., Michailidis Y., Draganidis D., Jamurtas A.Z., Nikolaidis M.G., Parotsidis C., Theodorou A.A., Katrabasas I., Margonis K., Papassotiriou I., Taxildaris K. (2011), *Physiological and performance adaptations of elite Greco-Roman wrestlers during a one-day tournament*, "European Journal of Applied Physiology", vol. 111, pp. 1421-1436; doi: 10.1007/s00421-010-1761-7.
7. Barley O., Chapman D., Abbiss C. (2018), *Weight Loss Strategies in Combat Sports and Concerning Habits in Mixed Martial Arts*, "International Journal of Sports Physiology and Performance", vol. 13, pp. 933-939; doi: 10.1123/ijspp.2017-0715.
8. Bosco C., Luhtanen P., Komi P.V. (1983), *A simple method for measurement of mechanical power in jumping*, "European Journal of Applied Physiology and Occupational", vol. 50, pp. 273–282.
9. Brandao F., Fernandes H.M., Alves J.V., Fonseca S., Reis V.M. (2014), *Hematological and biochemical markers after a Brazilian Jiu-Jitsu tournament in world-class athletes*,

"Revista Brasileira de Cineantropometria & Desempenho humano", vol. 16, pp. 144-151; doi: 10.5007/1980-0037.2014v16n2p144 .

10. Brito C.J., Roas A.F.C.M., Brito I.S.S., Marins J.C.B., Cordova C., Franchini E. (2012), *Methods of Body-Mass Reduction by Combat Sport Athletes*, "International Journal of Sport Nutrition and Exercise Metabolism", vol. 22, pp. 89-97; doi: 10.1123/ijsnem.22.2.89
11. Burke L.M., Hawley J.A., Wong S.H., Jeukendrup A.E. (2011), *Carbohydrates for training and competition*, "Journal of Sports Sciences", vol. 29, pp. 17–27; doi: 10.1080/02640414.2011.585473.
12. Burke L.M., Whitfield J., Heikura I.A., Ross M.L., Tee N., Forbes S.F., Hall R., McKay A.K.A., Wallett A.M., Sharma A.P. (2021), *Adaptation to a low carbohydrate high fat diet is rapid but impairs endurance exercise metabolism and performance despite enhanced glycogen availability*, "The Journal of Physiology", vol. 599, no. 3, pp. 771-790; doi: 10.1113/JP280221. Epub 2020 Aug 19.
13. Che K., Qiu J., Yi L., Zou M., Li Z., Carr A., Snipe R.M.J., Benardot D. (2021), *Effects of a Short-Term "Fat Adaptation with Carbohydrate Restoration Diet on Metabolic Responses and Exercise Performance in Well-Trained Runners*. "Nutrients", vol. 13, no. 3, pp. 1033; doi: 10.3390/nu13031033.
14. Cordeiro E.M., Gomes A.L.M., Guimaraes M., Silva S.G., Dantas E.H.M. (2007), *Alteracoes hematológicas e bioquimicas oriundas do treinamento de combate em atletas de Kung fu Olímpico*, "Fitness & Performance", vol. 6, pp. 255-261; doi: 10.3900/fpj.6.4.255.p [in Portuguese].
15. Coswig V.S., Neves A.H.S., Del Vecchio F.B. (2013), *Respostas bioquimicas, hormonais e hematologicas a lutas de jiu-jitsu brasileiro*, "Revista Brasileira de Ciencia e Movimento", vol. 21, pp. 19-30; doi: 10.18511/0103-1716 [in Portuguese].
16. Degoutte F., Jouanel P., Filaire E. (2003), *Energy demands during a judo match and recovery*, "British Journal of Sports Medicine", vol. 37, pp. 245–249; doi: 10.1136/bjsm.37.3.245.
17. Del Vecchio F.B., Bianchi S., Hirata S.M., Chacon-Mikahil M.P.T. (2007), *Analise Morfo-funcional de praticantes de Brazilian Jiu Jitsu e estudo da temporalidade e da quantificacao das acoes motoras na modalidade*, "Movimento e Percepcao", vol. 7, pp. 263-281 [in Portuguese].
18. Durkalec-Michalski K., Nowaczyk P.M., Glowka N., Ziobrowska A, Podgorski T. (2021), *Is a Four-Week Ketogenic Diet an Effective Nutritional Strategy in CrossFit-Trained Female and Male Athletes?*, "Nutrients", vol. 13, no. 3, pp. 864; doi: 10.3390/nu13030864.
19. Fonseca L.B, Brito C.J., Silva R.J.S, Silva-Grigoletto M.E., Junior W.M.S., Franchini E. (2016), *Use of Cold-Water Immersion to Reduce Muscle Damage and Delayed-Onset Muscle Soreness and Preserve Muscle Power in Jiu-Jitsu Athletes*, "Journal of Athletic Training", vol. 51, pp. 540-549; doi: 10.4085/1062-6050-51.9.01.
20. Durkalec-Michalski K., Nowaczyk P.M., Glowka N., Ziobrowska A, Podgorski T. (2021), *Is a Four-Week Ketogenic Diet an Effective Nutritional Strategy in CrossFit-Trained Female and Male Athletes?*, "Nutrients", vol. 13, no. 3, pp. 864; doi: 10.3390/nu13030864.
21. Fonseca L.B, Brito C.J., Silva R.J.S, Silva-Grigoletto M.E., Junior W.M.S., Franchini E. (2016), *Use of Cold-Water Immersion to Reduce Muscle Damage and Delayed-Onset Muscle Soreness and Preserve Muscle Power in Jiu-Jitsu Athletes*, "Journal of Athletic Training", vol. 51, pp. 540-549; doi: 10.4085/1062-6050-51.9.01.
22. Durkalec-Michalski K., Nowaczyk P.M., Glowka N., Ziobrowska A, Podgorski T. (2021), *Is a Four-Week Ketogenic Diet an Effective Nutritional Strategy in CrossFit-Trained Female and Male Athletes?*, "Nutrients", vol. 13, no. 3, pp. 864; doi: 10.3390/nu13030864.
23. Fonseca L.B, Brito C.J., Silva R.J.S, Silva-Grigoletto M.E., Junior W.M.S., Franchini E. (2016), *Use of Cold-Water Immersion to Reduce Muscle Damage and Delayed-Onset Muscle Soreness and Preserve Muscle Power in Jiu-Jitsu Athletes*, "Journal of Athletic Training", vol. 51, pp. 540-549; doi: 10.4085/1062-6050-51.9.01.
24. Garthe I., Raastad T., Sundgot-Borgen J. (2011), *Long-term effect of nutrition counseling on desired gain in body mass and lead body mass in elite athletes*, "Applied Physiology, Nutrition, and Metabolism", vol. 36, pp. 547-554; doi: 10.1139/h11-051.
25. Gerber T., Borg M.L., Hayes A., Stathis C.G. (2014), *High-intensity intermittent cycling increases purine loss compared with workload-matched continuous moderate intensity cycling*, "European Journal of Applied Physiology", vol. 114, pp. 1513–20; doi: 10.1007/s00421-014-2878-x.
26. Girard O., Mendez-Villanueva A., Bishop D. (2011), *Repeated-sprint Ability – part 1: factors contributing to fatigue*, "Sports Medicine", vol. 41, pp. 673-94; doi: 10.2165/11590550-000000000-00000.
27. Hellsten Y., Richter E.A., Kiens B., Bangsbo J. (1999), *AMP deamination and purine exchange in human skeletal muscle during and after intense exercise*, "The Journal of Physiology", vol. 520, pp. 909-920; doi: 10.1111/j.1469-7793.1999.00909.x.
28. Jackson A.S., Pollock M.L. (1978), *Generalized equations for predicting body density of men*, "British Journal of Nutrition", vol. 40, pp. 497-504.
29. Lima-Silva A.E., Pires F.O., Bertuzzi R.C., Lira F.S., Casarini D., Kiss M.A. (2011), *Low carbohydrate diet affects the oxygen uptake on-kinetics and rating of perceived exertion in high intensity exercise*, "Psychophysiology", vol. 48, pp. 277-84; doi: 10.1111/j.1469-8986.2010.01059.x.
30. Lohman T.G., Roche A.F., Martorell R. (1988), *Anthropometric standardization reference manual*, "Human Kinetics Books", Champaign, Illinois.
31. Marquet L.A., Brown M., Tafflet M., Nassif H., Mouraby R., Bourhaleb S., Toussaint J.F., Desgorces F.D. (2013), *No effect of weight cycling on the post-career BMI of weight class elite athletes*, "BMC Public Health", vol. 13, no. 510; doi 10.1186/1471-2458-13-510.
32. Miles M.P., Andring J.M., Pearson S.D., Gordon L.K., Kasper C., Depner C.M., Kidd J.R. (2008), *Diurnal var-*

iation, response to eccentric exercise, and association of inflammatory mediators with muscle damage variables, "Journal of Applied Physiology", vol. 104, pp. 451-458.
33. Paoli A., Grimaldi K., D'Agostino D., Cenci L., Moro T., Bianco A., Palma A. (2012), *Ketogenic diet does not affect strength performance in elite artistic gymnasts*, "Journal of the International Society of Sports Nutrition", vol. 9, no. 34; doi: 10.1186/1550-2783-9-34.
34. Paoli A., Cenci L., Pompei P., Sahin N., Bianco A., Neri M., Caprio M., Moro T. (2021), *Effects of Two Months of Very Low Carbohydrate Ketogenic Diet on Body Composition, Muscle Strength, Muscle Area, and Blood Parameters in Competitive Natural Body Builders*, "Nutrients", vol. 13, no. 2, pp. 374; doi: 10.3390/nu13020374
35. Pettersson J., Hindorf U., Persson P. (2008), *Muscular exercise can cause highly pathological liver function tests in healthy men*, "British Journal of Clinical Pharmacology", vol. 65, pp. 254-259.
36. Podrigalo L, Cynarski W.J., Rownaya O., Volodchenko O., Halashko O., Volodchenko J. (2019), *Studying of physical development features of elite athletes of combat sports by means of special indexes*, "Ido Movement for Culture. Journal of Martial Arts Anthropology", vol. 19, no. 1, pp. 51-57; doi: 10.14589/ido.19.1.5.
37. Rankin J.W., Ocel J.V., Craft L.L. (1966), *Effect of weight loss and refeeding diet composition on anaerobic performance in wrestlers*, "Medicine & Science in Sports & Exercise", vol. 28, pp. 1292-1299.
38. Sa C.A.G., Bennemann G.D., da Silva C.C., Ferreira A.J.C. (2015), *Consumo Alimentar, Ingestão Hídrica e uso de Suplementos Proteicos por Atletas de jiu-jitsu*, "Revista Brasileira de Nutricao Esportiva", vol. 9, pp. 411-418.
39. Santos F.R.S., Navarro F., Donatto F.F., Ide B.N. (2011), *Avaliacao do Perfil Nutricional de Atletas de jiu-jitsu*, "Revista Brasileira de Nutricao Esportiva", vol. 5, pp. 198-207 [in Portuguese].
40. Siqueira L.O., Muccini T., Agnol I.D., Filla L., Tibbola P., Luvison A., Costa L., Moreira J.C.F. (2009), *Analise de parametros bioquimicos sericos e urinarios em atletas de meia maratona*, "Arquivos Brasileiros de Endocrinologia & Metabologia", vol. 53, pp. 844-852; doi: 10.1590/S0004-27302009000700008 [in Portuguese].
41. Tipmann S. Oopik V., Paasuke M., Medijainen L, Ereline J. (2008), *Acute effects of self-selected regimen of rapid body mass loss in combat sports athletes*, "Journal of Sports Science and Medicine", vol. 7, pp. 210-217.
42. Vina J., Gimeno A., Sastre J., Desco C., Asensi M., Pallardo F.V., Cuesta A., Ferrero J.A., Terada L.S., Repine J.E. (2000), *Mechanism of free radical production in exhaustive exercise in humans and rats; role of xanthine oxidase and protection by allopurinol*, "IUBMB Life", vol. 49, pp. 539-544.
43. Yang W.H., Grau M., Kim P., Schmitz A., Heine O., Bloch W., Mester J. (2014), *Physiological and psychological performance of taekwondo athletes is more affected by rapid than by gradual weight reduction*, "Archives of Budo", vol. 10, pp. 169-177.
44. Zhao S., Snow R.J., Stathis C.G., Febbraio M.A., Carey M.F. (2000), *Muscle adenine nucleotide metabolism during and in recovery from maximal exercise in humans*, "Journal of Applied Physiology", vol. 88, pp. 1513-1519.

Ostra restrykcja węglowodanów indukuje większą utratę masy ciała i zachowuje sprawność sportową zawodników brazylijskiego *jiu-jitsu*

Słowa kluczowe: sporty walki, węglowodany, specyficzna sprawność sportowa, utrata masy ciała, metabolizm

Streszczenie
Tło i cel. Brazylijskie *Jiu-jitsu* (BJJ) jest sportem walki z intensywnym kontaktem fizycznym, kładącym nacisk na obalenia (*takedown*) i z limitem czasowym 10 minut na walkę, co wymaga siły, elastyczności, koordynacji ruchowej i dobrej wytrzymałości tlenowej. Ograniczenie węglowodanów jest szeroko stosowaną strategią utraty wagi, jednak jej zastosowanie u zawodników brazylijskiego *Jiu-Jitsu* pozostaje dyskusyjne, zwłaszcza w odniesieniu do wpływu na metabolizm energetyczny i wydajność.
Materiał i metody. W badaniu oceniano ostry wpływ ograniczenia węglowodanów na zmienne metaboliczne, utratę masy ciała i testy sprawności fizycznej. W randomizowanym badaniu klinicznym brało udział 16 zawodników BJJ płci męskiej. Uczestnicy zostali losowo przydzieleni do 2 grup według strategii żywieniowej: R-CHO (2-3 g/kg.d-1), n=10, oraz A-CHO (5-7 g/kg.d-1), n=6. Oceniono cztery testy sprawności fizycznej oraz markery krwi metabolizmu energetycznego i uszkodzenia mięśni na poziomie wyjściowym i w trakcie obserwacji.
Wyniki. Główne wyniki wskazały, że obie strategie żywieniowe promowały utratę masy ciała i nie miały wpływu na wydajność. W odniesieniu do markerów metabolizmu energetycznego, ograniczenie węglowodanów przez 28 dni prowadziło do wzrostu stężenia mleczanu i kreatyniny we krwi po intensywnym wysiłku fizycznym. Pomimo zwiększenia stężenia kwasu moczowego w grupie R-CHO, obie interwencje spowodowały redukcję jego poziomu. Glukoza we krwi wzrosła w obu grupach wyjściowych.
Wnioski. Podsumowując, R-CHO promowało większy spadek masy ciała i zwiększało mobilizację szybkich rezerw energetycznych, jednak te zmiany metaboliczne nie miały wpływu na wydajność.