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Original Article

Characterization of Brazilian Jiu-Jitsu training effects on the physical Fitness of men and women

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Abstract
Brazilian Jiu-Jitsu (BJJ) has gained substantial attention over the past decades, but still facesgreat absence of scientific production about its characteristics. To substantiate the approach to BJJ instruction, it is essential to understand the physical changes associated to its practice. The purpose of this investigation was to evaluate the changes in physical fitness parametersin response to BJJ training, in men (M) and women (W) non-practitioners. Sixteen volunteers (8 M and 8 W) were evaluated before and after 6 weeks of BJJ training, performed twice a week, one hour a day. Body mass, body composition, aerobic power, anaerobic power, 1-RM, hand grip strength, and flexibility data were collected. Data were treated separately for M and W and compared using*Student´st-test*. Matches were classified aspredominantly vigorous. No changes were observed in body mass and body composition. Significant increases were observed in VO_{2max} (M and W), time to exhaustion (M and W), HR_{max} (M), absolute and relative maximum anaerobic power (M and W) and absolute and relative average anaerobic power (M) values. 1-RM test values for lower limbs were increased in both groups. Non-dominant hand grip strength was elevated for W and the flexibility was increased for M. When comparing the improvements between groups, the delta was greater for M flexibility only. We conclude that a BJJ matchis a vigorous activity, and structured BJJ training can promote positive changes in several physical fitness parameters, including aerobic power, anaerobic power, strength and flexibility. Despite the ACSM (2010) exercise recommendations, it is possible to improve physical fitness parameters with as few as 2 hours of BJJ training per week.
Keywords: Martial Arts, BJJ, JuJitsu, Grappling, Wrestling, Judo.

Introduction

Combat sports have been present in Brazil since the twentieth century,affecting the society with associated values and cultural traits. Combat sports cover all modalitiesthat involvetwo athletesbattlingfor thevictory, which isdetermined by points, loss of consciousness, submission, or disqualification (Lorenço-Lima et al., 2010). BJJ isone of the most practiced combat sportsin Brazil. However,scientific studies analyzing the physical fitness changes as result ofBJJ training are still incipient when compared to other martial arts.

The word "Jiu-Jitsu"comes from the synonymous *jujutsu*, described by two Japanese characters:*ju*that means "gentleness" and*jutsu*meaning"art". Thus, the term Jiu-Jitsu can be translated as the "gentle art"(IBJJF, 2010). BrazilianJiu-Jitsu began in *Belém*in 1917 when the Japanese master Mitsuyo Maeda, whothen presented the principles of Japanese Jiu-Jitsu (Kano Jiu-Jitsu)to the Gracie family (Almeida Junior et al., 2019). Later on, Carlos and*Hélio* Gracie started practicing Japanese Jiu-Jitsu and evolvedthe art into what is currently known as BJJ. They popularized BJJin Brazilby challenging other martial arts to timeless combats (IBJJF 2010).

The purpose of BJJis toforce the opponent to submit duringamatch through techniques such as takedowns, holds, chokes, and joint locks. A matchcan last from 2 to 10 min, depending mainly on the participants'belt rank, gender,and age. If there is no submission during the match, a specific scoring system is used to determine the winner.

BJJmatches arecharacterized as acyclic due to the different movement sequences employed, requiring a large amount of strength, speed, power, anaerobic endurance,and flexibility(Oliveira et al., 2009).A low-/high-intensity ratio of 8:1 is demonstrated during matches, with high-intensity actions lasting in average 3 seconds (Andreato et al., 2015b). Due to theseacyclic and high-intensitycharacteristics, there is a reduction in the intramuscular phosphocreatine and glycogen concentrations(Andreato et al., 2015b; Balson et al., 1999;

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Hargreaves et al., 1997; Oliveira et al., 2009). However, in comparison with striking-based combat sports, grappling-based arts, such as BJJ, can be performed at higher intensity with lowerrisk of major injuries (Øvretveit et al., 2019).

BJJ is a prominent sport in Brazil and has been gaining substantial interest worldwide over the last few decades (Andreato et al., 2017). Considering the popularity of BJJ, the absence of scientific information about this modality emphasizes an existing gap in grappling sportsscience, and therefore leading toinsufficient understanding about the specificity of BJJ making the training prescriptions limited as well (Andreato, et al., 2015a; Coswig et al., 2018). Most instructors and trainers are unaware of the physiological and biomechanical characteristics that may take place during and after matches, which may lead to the adoption of empirical training methods (Del Vecchio et al., 2007). Therefore, the aim of this study was to determine whether the practice of BJJ for 2 hours a week, can improve strength, aerobic power, anaerobic power, and flexibility in male (M) and female (W) non-practitioners.

Methods

Sixteen non-experiencedvolunteers (8 men and 8 women) participated in this study. Volunteerswere all physical education students and signed a consent form approved by the*Cruzeiro do Sul* University Ethics Committee. Exclusion criteria were: history of severe muscle injury, disorder of the endocrine system, use of any hormonal or nutritional supplement, and previous practice of any grappling sport.

The experimental protocol was divided in three phases. Phase one consisted of 5days. In the morning of the first day, the volunteersbody mass, height, body composition, maximum handgrip strength, and flexibility data were collected. In the afternoon, one repetition maximum (1-RM) was collected for squat and bench press. On the third day (48 hours after the 1-RM tests), anaerobic power was evaluated, and onthe fifth day (after an additional 48 hours), the aerobic powerwas collected. Phasetwo consisted of BJJ No-Gi training (no uniform), performedone hour per day, twice a week, for 6 weeks. All subjectshad 100% participation. Training sessions were composed ofwarm up (10 min),technical drilling (15 min),live rounds (30 min), and cooldown (5 min).Matches during live roundswere periodized, allowing volunteers to increaseand sustain motivation. In the first two weeks three 5-minmatches were performed, with one 5-mininterval between each one. Inthe third and fourth weeks,two 5-minmatches were performed, followed by one5-min rest and two more 5-min matches. In the last two weeks,five 5-minmatches were performed with no rest interval amongmatches. During the training period, volunteers learned and practiced 16 BJJ techniques: three chokes, six joint locks,three sweeps, two guard passes and two escapes.Phase threewas performed in the same fashion as phase one for optimal comparative analyses.

Toclassifythe intensity of the matches,heart rate (HR) was collected through anHR monitor(Polar RS800CX)during the last two weeksof phase two. HR was recorded at rest,in addition toaverage HR and maximum HR during the five combatsusing the software Polar ProTrainer 5. HR was used to determine the intensity due to its viability, considering the huge body contact during matches. Intensity was calculated according to the formula(Karvonen et al., 1957):Intensity (%HRR) = ($HR_{average}$ - HR_{rest}) / ($HR_{maximum}$ - HR_{rest}). Average intensity was classified using the ACSM position stand (ACSM, 2011).

Height was measuredutilizing a professional stadiometer (Sanny® ES2020). Body composition was assessed by bioelectrical impedance analyzer (Biodynamics 310E), according to the manufacturer's instructions. Body mass was determinedby a digital scale (Welmy® W200).VO_{2max}, HR_{max}, and time to exhaustion were performed on a treadmill (Gesanmodel RY3500) according to the protocol suggested by Davis et al. (1982). During the test,agas analyzer with telemetry system (K4b2, Rome, Italy) was used. The highest value recorded on theHR monitor until fatigue was considered as HR_{max}. The test was interrupted when the volunteers were not able to sustain the effort (time to exhaustion).

The anaerobic power was determined by the 30-s Wingate test showing theabsolute (W_{max}) and relative ($W_{max/kg}$) maximum anaerobic power, absolute (W_{ave}) and relative ($W_{ave/kg}$) average anaerobic power, and fatigue index (FI) forthe lower limbs. Test load applied was 83 $g \cdot kg^{-1}$ of body weight and 75 $g \cdot kg^{-1}$ of body weightfor M and W, respectively(Dotan & Bar-Or, 1983). A cycleergometer CEFISEBiotec 1800 with the software Ergometric6.0 was employed for data collection.

After a brief warm up, 1-RM was determined after four consecutive attempts with 180 seconds rest, on bench press and squat. The highest value collected was consideredfor analysis(ACSM, 2010).Upper limb strength was also determined using the handgrip dynamometer (Electronic Handgrip Dynamometer, Day Home EH101). Testing wasperformed with bothdominant and non-dominant hands. During the test,volunteersremained sat down in a chair, and maintained the arm resting on a table with the hand in a supinateposition. Three non-consecutive attempts of maximum effort, alternatingbetween dominant and non-dominant hand,were performed, pausing for 60 seconds between efforts(Sale et al., 1990). The highest value was considered for analysis.

To access the trunk and lower limbs flexibility, the sit and reach test was applied(Wells & Dillon, 1952). AWells Box (Sanny Instant Flex ® BW2002) was employed for data collection.Results are expressed as mean and (±) standard deviation and were analyzed by *Student´s t-test* for paired samples using IBM SPSS Statistic 25software.

Results

Average age and height for M was 22.13 ± 5.08 years and 175.25 ± 3.01 cm and for W was 20.75 ± 3.54 years and 159.75 ± 7.17 cm, respectively. There was no difference inbody mass(M Pre: 78.86 ± 7.92 kg, M Post: 79.16 ± 8.07 kg; W Pre: 56.25 ± 9.96 kg, W Post: 56.51 ± 8.87 kg),body fat percentage (M Pre: 19.36 ± 5.16 %, M Post: 18.21 ± 5.16 %; W Pre: 24.16 ± 3.60 %, W Post: 23.71 ± 4.38 %), body fat weight (M Pre: 15.48 ± 5.18 kg, M Post: 14.68 ± 5.26 kg; W Pre: 13.78 ± 4.43 kg, W Post: 13.51 ± 3.95 kg), lean weight(M Pre: 63.37 ± 4.91 kg, M Post: 64.47 ± 4.45 kg; W Pre: 42.42 ± 6.14 kg, W Post: 42.8 ± 6.68 kg), body water (M Pre: 43.91 ± 3.96 L, M Post: 45.07 ± 3.53 L; W Pre: 29.52 ± 3.51 L, W Post: 30.07 ± 3.32 L), body water percentage (M Pre: 56.05 ± 3.86 %, M Post: 57.15 ± 3.78 %; W Pre: 52.93 ± 3.59 %, W Post: 53.57 ± 3.50 %) and body water of lean weight (M Pre: 69.32 ± 1.23 %, M Post: 69.86 ± 1.33 %; W Pre: 69.76 ± 2.06 %, W Post: 70.17 ± 2.12 %) for both groups between pre and post-training. Average matches intensity was 77.38 ± 6.80 % and 70.36 ± 18.79 % for M and W, respectively, both being classified as vigorous activity (Table 1). HR_{rest} was statistically different between groups (H: 72.87 ± 5.64 bpm; M: 65.63 ± 10.50 bpm).

Table 1. Heart rate (HR) and matches intensity (%).

	Rest	Average during matches	Maximum during matches	Intensity (%)
Men	72.87 ± 5.64[a]	159.75 ± 6.56	190.62 ± 6.56	77,38 ± 6,80
Women	65.63 ± 10.50	149.13 ± 25.15	182.63 ± 21.10	70,36 ± 18,79

[a]$p < 0.05$ between groups

Squat's 1-RM was higher after training, for M (Pre: 91.25 ± 26.95 kg; Post: 108.75 ± 31.36 kg) and W (Pre: 61.25 ± 22.95 kg, Post: 78.75 ± 6.40 kg). Bench press 1-RM did not show any difference for both groups (M Pre: 82 ± 22.37 kg, M Post: 81.5 ± 20.38 kg; W Pre: 33.5 ± 4.1 kg, W Post: 35.75 ± 4.06 kg). Flexibility increased for M (Pre: 25.5 ± 8.83 cm; Post: 28.87 ± 8.0 cm) but not for W (Pre: 32.62 ± 11.53 cm, Post: 33.12 ± 11.20 cm).

Handgrip strength increased for W non-dominant hand (Pre: 24.35 ± 3.58 kg; Post: 26.98 ± 4.02 kg). No differences were found for the dominant handfor W (Pre: 27.53 ± 4.52 kg, Post: 29.15 ±4.38kg) and dominant (Pre: 49.27 ± 10.14 kg, Post: 49.87 ± 9.26 kg) or non-dominant (Pre: 48.41 ± 9.89 kg, Post: 49.12 ± 7.68 kg) hand forM.An increase in both, absolute and relative maximum anaerobic power (M and W) was observed, as well as in absolute and relative average anaerobic power (M). Despite the increase, fatigue index did not change (Table 2).

Table 2. Anaerobic power pre and post BJJ training.

	M Pre	M Post	W Pre	W Post
Max. power (W)	325.82 ± 37.17	363.42 ±30.63[a]	184.75 ± 28.75	201.83 ± 19.64[a]
Max. power (W/kg)	4.22 ± 0.53	4.63 ± 0.53[a]	3.30 ± 0.44	3.61 ± 0.33[a]
Ave. power (W)	202.02 ± 31	208.88 ± 30.52[a]	115.26 ± 19.64	118.93 ± 13.91
Ave. power (W/kg)	2.57 ± 0.39	2.65 ± 0.37[a]	1.87 ± 0.35	1.98 ± 0.28
FI (%)	62.07 ± 17.15	65.26 ± 15.09	59.02 ± 5.68	63.15 ± 4.86

[a] $p<0.05$ vs pre; M Pre, men pre; M Post, men post; W Pre, women pre; W Post, women post.

Improved aerobic powerwas observed due to BJJ training for both groups, as demonstrated by the increase in VO_{2max} relative forMand W.
This increase can also be notedin the absolute VO_{2max} for M and W. Time to exhaustion was increased for M and W. $HR_{max}$was higher for M only (Pre: 185.75 ± 9.76 bpm; Post: 192.00 ± 12.02 bpm) (Table 3).

Table 3. Aerobic capacity pre and post BJJ training.

	M Pre	M Post	W Pre	W Post
VO_{2max} (mL/kg/min)	46.28 ± 4.30	50.57 ± 5.29[a]	38.34 ± 4.85	43.73 ± 7.91[a]
VO_{2max} (L/min)	3.63 ± 0.29	3.98 ± 0.32[a]	2.13 ± 0.33	2.44 ± 0.41[a]
FC_{max} (bpm)	185.75 ± 9.76	192.00 ± 12.02[a]	183.70 ± 9.99	190 ± 10.28
Time to exhaustion (min)	11.34 ± 0.92	12.42 ± 1.23[a]	9.08 ± 1.69	10.07 ± 1.94[a]

[a] $p < 0.05$ vs pre; M Pre, men pre; M Post, men post; W Pre, women pre; W Post, women post.

Delta (post minus pre) was calculated for the gain comparison between groups. M gain was greater than Wfor flexibility only, whereas the gain for M was 3.37 ± 3.02 cm and the gain for W was 0.5 ± 2.56 cm.

Discussion

Similar to judo, BJJ demands both aerobic and anaerobic metabolism(Franchini et al., 2007). Anaerobic metabolism provides quick energy atmaximal muscular explosion times during combat, while the aerobic

metabolism contributes to the maintenance of the effort throughout the combatand also torecover energy during the shortrest or effort reduction periods (Franchini et al., 2005; Thomas et al.,1989).

Degoutte et al.(2003)have found aHR_{rest} of 54.7 bpm and $HR_{max}$of 182.4 bpm during judo combats. The present study showsHR_{rest} of 72.87 ± 5.64 bpm and 65.63 ± 10.50 bpm, for M and W respectively. HR_{max} was 190.62 ± 6.56 and 182.63 ± 21.10 bpm, for M and W during BJJ combats demonstrating that both martial arts lead to similar changes in HR.The matches' average intensity was calculatedallowing theclassificationas vigorous intensity (ACSM, 2010)with maximal effort moments, as demonstrated by the HR_{ave} and HR_{max} during combats.

Laskowski et al. (2008)have found increased aerobic powerinlong-term judo practitioners, due to morphological and functional myocardial changes. The present study showsincreased aerobic powerin a short-term BJJ practice (6 weeks), as demonstrated by the increase in VO_{2max} for M (Pre: 46.28 ± 4.30 ml/kg/min; Post: 50.57 ± 5.29 ml/kg/min) and W (pre: 38.34 ± 4.85 ml/kg/min; Post: 43.73 ± 7.91 ml/kg/min). VO_{2max} value for the Canadian Judo Team athletes was 59.2 ml/kg/min (4.49 l/min) on thetreadmill test (Thomas et al., 1989). In a systematic review, Andreato et al. (2017) encountered VO_{2max} values between 42 and 52 mL/kg/min for BJJ practitioners of different competitive levels, with no discrimination between competitive level and $VO_{2max.}$

Franchini et al. (2011)reported that an excellent level of physical fitness isnecessaryfor an athlete to be successful in international competitions. However, VO_{2max} values tend not to differ among different levels of competitive athletes, beingaround 50-55 ml/kg/min for men and 40-45 ml/kg/min for women judo practitioners(Franchini et al., 2005). These values were found after 6 weeks of BJJtraining in this study. In another study,Franchini et al. (2007)have observed that most of the judo practitionerspresent VO_{2max}around 50-60 ml/kg/min.Gariod et al. (1995)have found a higher rate of phosphocreatine resynthesis in judo practitioners with higher VO_{2max}than practitioners with lowerVO_{2max}.

This characteristicis important in intermittent sports likeBJJ, in which athletes must performhigh-intensity tasks with short recovery periods(Franchini et al., 2007).

The physiological profile of successful wrestlers involves high anaerobic power, which can vary from 11.5 to 19.9 W/kg(Horswill,1992). Long-term judo practitioners have greater anaerobic power than sedentary individuals(Laskowski et al., 2008). Canadian Judo Team playershave maximum anaerobic power of 13.7 W/kg for lower limbs (Thomas et al., 1989), while the present study shows 4.63 ± 0.53 W/kg for M and 3.61 ± 0.33 W/kg for W.Anaerobic power shows the highest differences among athletes from different competitive level and martial arts modalities. There was a majordifference between our study results (short period of BJJtraining)andprevious studies results involving experienced athletes from sports with similar characteristics to BJJ.

Flexibility is an important factor inBJJfor the application of some techniques and injury prevention. It is developed during training and is considered as a determinant capacity in the sport. However, Horswill(1992)have reported medium flexibility insuccessful wrestlers,higher than those found in the present study that showed regular flexibility (28.87 ± 8.0 cm) for M and medium forW (33.12 ± 11.20 cm).Andreato et al. (2016) found poor average flexibility among experienced BJJ athletes (11 ± 4 years of training). The improvements found on our study exclusively on M can be attributed to a poorer level of flexibility at starting point, while the W, because of anatomical and physiological characteristics, started from a higher flexibility level.

BJJtraining involves muscle contractions at all times. To execute a technique,it is necessary to hold, push or pull the opponent, while exerting excessive forearm muscular contraction (Almeida Junior et al., 2019). In our study, the results of these contractions were assessed by two different tests. The first test showed that the handgrip strength increasedfor the W non-dominant hand.Andreato et al. (2017)found isometric handgrip strength values between 48 and 57 kg force for M. When dissecting the results by experience level our results of 49.87 ± 9.26 kg (dominant) and 49.12 ± 7.68 kg (non-dominant) for Mwere slightly higher than the value found by Adreato et al. (2017) for novices, 43.6 ± 7.1 and 43.3 ± 6.6, and white belts,46.7 ± 6.5 and 47.2 ± 5.8,for right and left hands respectively.

On the second test,there was an increase for M and Wlower limbs strength, as showed on the squat 1-RM. Schmidt et al.(2005)have evaluated squat and bench press 1-RM in college wrestlers of the Division III National Collegiate Athletic Association.Data were 157.9 ± 25.15, 150.8 ± 25.2 and 161.4 ± 25.6 kg for squat and 103.4 ± 25.5, 98.3 ± 25.4 and 106.4 ± 26 kg for bench presspre-season, season and post-season, respectively(29). Franchini et al. (2007)have found 110 ± 25 kg for team A and110 ± 23 kg for B and C on the Brazilian Judo Team bench press 1-RM.

These investigators also found 104 ± 27 kg for the team A and 104 ± 18 kg for B and C on squat 1-RM. The present study shows 108.75 ± 31.36 kg for M squat and 81.5 ± 20.38 kg forM bench press after BJJtraining. The difference amongthe study values are probably related to weight difference among athletes and regular practice experience. The difference between M and W 1-RM found on our study is also related to M higher body mass and therefore higher lean body mass.

Conclusion

We conclude that: (1) BJJ matches are vigorous intensity activities; (2) short-term BJJ training can improve several physical fitness variables, such as aerobic power, anaerobic power, muscular strength and flexibility in M and W. It is noteworthy that these capacities alone are not necessarily predictive of performance in this sport, considering that technical and tactic skills are also extremely important for success in BJJ.

BJJ is an effective sport modality for health improvement, as demonstrated by the enhancement of the volunteers'overall physical fitness. BJJ can also have an important role in the cardiorespiratory and anaerobic fitness due to the vigorous intensity during combats. The strength can be increased, as well as the flexibility for those with a poor initial level. Despite the ACSM(2010)exercise recommendations, it is possible to achieve physical fitness improvements with 2 hour of BJJ training per week.

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