

The Relationship Between the Jiu Jitsu Anaerobic Performance Test and Physiological Markers in Trained Jiu Jitsu Practitioners

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ABSTRACT

Jiu Jitsu relies on aerobic and anaerobic energy systems. A relationship has been demonstrated between the Jiu Jitsu Anaerobic Performance Test (JJAPT) and anaerobic performance. The relationship between the JJAPT and aerobic performance has yet to be quantitatively defined. The purpose of this study was to determine if there is a relationship between the JJAPT and maximum oxygen uptake and ventilatory threshold (VT). Twenty-five Jiu Jitsu subjects participated in two test sessions a minimum of 48 hours apart. During one test session, descriptive statistics were collected, a self-guided treadmill warm-up was completed, followed by the Bruce graded exercise protocol. Ventilatory threshold was determined by computer plotting VO_{2peak} and ventilation onto a line chart and confirmed by two researchers. Ventilatory threshold percentage was calculated by hand. The second test session included a JJAPT familiarization warm up and the JJAPT. Pearson correlation was used to determine the relationship between the JJAPT and VO_{2peak} and between the JJAPT and VT. The main findings revealed a significant moderate positive correlation between VO_{2peak} and the JJAPT, ($r = 0.40$, $p = 0.025$). Research has shown that Jiu Jitsu has dispersed lower intensity aerobic periods with more reliance on the anaerobic system. The moderate correlation with VO_{2peak} is consistent with the energy

system requirements for Jiu Jitsu. This study, in combination with previous studies, indicates the JJAPT provides reliable measures of Jiu Jitsu competition performance. It's been concluded that the JJAPT could be used to evaluate BJJ athletes and track performance improvements.

INTRODUCTION

Brazilian Jiu Jitsu (BJJ) is a ground-based martial art that focuses on grappling with the intention of incapacitating the opponent, therefor removing the threat. Both self-defense and sport BJJ rely on leverage and proper technique to control the opposition. As a combat sport, a win can occur by points, however the goal is submission of the opponent using techniques such as a choke hold or joint locks (16, 20). Within BJJ, there are several additional techniques used to gain an advantageous position or initiate an attack. One common technique used by athletes is a sweep, which takes the opponent off balance. The butterfly sweep is a ground sweep which occurs from the guard and when mastered, is a highly effective technique relying on timing and leverage.

In addition to the use of leverage and technique, BJJ also demands an elevated level of strength and power as well as well-developed aerobic and

anaerobic energy systems to sustain repeated high-intensity efforts for the entirety of the match (3, 14). Match durations, per the International Brazilian Jiu-Jitsu Federation (IBJJF), can last up to 5–10 minutes (5). In comparison to other combat sports such as Judo or wrestling where the effort/pause ratio is only 2:1 (4), Brazilian Jiu Jitsu relies heavily on both the aerobic and the anaerobic energy systems (14, 16, 22, 31) with reported effort/pause ratios of 6:1-13:1 (20, 22, 30), therefore success in the sport requires a high level of fitness and training of both energy systems.

Aerobic capacity provides the ability to sustain ongoing effort and delay fatigue (5). Cardiovascular and muscular endurance allow the athlete to sustain higher levels of intensity and keep up with the pace of the match (5). Competition Jiu Jitsu often requires 4-6 matches or more to achieve tournament victory, thereby requiring the athlete to recover quickly in between matches (5, 14). The proficiency of the attacks and their effectiveness have shown a dependence on the level of maximum oxygen uptake (VO_{2max}) (2). As such, BJJ athletes should develop and maintain an optimal level of aerobic capacity to elicit the highest level of performance (2). The different studies showed VO_{2max} values between 42 and 52 mL/kg/min (5).

Anaerobic capacity allows for the ability to complete short, fast bursts of movement throughout the match (14, 30, 32). These decisive actions require strength/power of the upper and lower limbs to take a more strategic position during the match (16). Previous BJJ studies incorporated the use of the Wingate test to measure anaerobic performance (5, 16). However, few studies were found that investigated lower-limb anaerobic fitness of BJJ athletes using the Wingate test (5, 16) and only one study was found to look at upper body anaerobic fitness in BJJ athletes (6). Although the Wingate is the gold-standard for assessing anaerobic capacity, the test cannot mimic the effort/pause dynamics, or the biomechanics expected during BJJ matches.

The literature on sport-specific fitness testing for BJJ athletes is scarce. Recent years have produced several performance tests such as the Special Brazilian Jiu-Jitsu Fitness Test (SBJJFT), the BJJ Fitness Test, the Guard Passing Test (GPT), the Jiu Jitsu Anaerobic Performance Test (JJAPT), and the Brazilian Jiu-Jitsu Cardiorespiratory Fitness Test (BJJ-CRFT) (8, 17, 28, 31, 32). Tests like the SBJJFT were developed for high-level competitors (32). Anaerobic performance can be measured

using the JJAPT, while general fitness-oriented measures of muscle endurance and technical performance can be tested by the BJJ Fitness Test (17, 31). Although not yet evaluated for reliability and validity, at the time of this writing, the GPT has been suggested as an efficient training protocol (28). Published immediately before this writing, the BJJ-CRFT was introduced in a pilot study offering a means of assessing cardiorespiratory fitness (8). Although a few different testing protocols have been introduced, the JJAPT has had several additional studies determining validity, reliability, and the ability to discriminate novice from advanced practitioners. Determining whether this test can be used to assess both energy systems could provide coaches, trainers, and athletes with a single, sport-specific performance measure.

The Jiu Jitsu Anaerobic Performance Test (JJAPT) is a five round test designed to assess anaerobic performance (31). It has been suggested that the JJAPT showed higher sensitivity to discriminate BJJ athletes than traditional cycle ergometer fitness tests (14). It has been shown that the later rounds have strong positive associations with BJJ competition regarding blood lactate concentration in the fourth ($r = 0.83, p \leq 0.05$), and fifth ($r = 0.82, p \leq 0.05$) bouts (31). The development of the JJAPT, by Villar et al (2018), has provided a sport specific anaerobic test for BJJ athletes (31). It was concluded by da Silva Junior et al (2022) that the reliability of the JJAPT as a sport specific test is excellent and it was able to discriminate between novice and advanced BJJ athletes (15). Further, a study by Penteadó et al (2020) confirmed good reliability and the absence of a learning effect (23).

With the interaction of aerobic and anaerobic performance in BJJ, coaches and exercise professionals are faced with the challenge of creating a unique exercise prescription and periodization plan as well as a method to monitor improvements (31). The JJAPT was found to reasonably replicate simulated BJJ combat with regards to blood lactate concentration (in the later rounds) and heart rate (HR) (in the early rounds) (30, 31). With intense bouts mixed with short periods of rest, BJJ relies on both aerobic and anaerobic energy systems (1). Previous studies have demonstrated a relationship between the JJAPT and anaerobic performance (30, 31). However, the relationship between the JJAPT and aerobic performance has yet to be quantitatively defined. This would provide a quantifiable measurement for coaches and trainers that is more ecologically

valid to the demands of BJJ. For the JJAPT to truly replicate Jiu Jitsu performance the test would need to represent the aerobic component required during a Jiu Jitsu competition. Therefore, the purpose of this study was to determine if there is a relationship between the Jiu Jitsu Anaerobic Performance Test (JJAPT) and the physiological performance markers of maximal oxygen uptake (VO_{2max}) and ventilatory threshold (VT). It was hypothesized that aerobic measures would have a positive correlation with the JJAPT.

METHODS

Subjects

Twenty-five competitive and club BJJ athletes, (Males = 17 and Females = 8), with a minimum of one year of training volunteered to participate in this study. Belt rank included: White ($n = 12$), Blue ($n = 7$), Purple ($n = 1$), Brown ($n = 4$), and Black ($n = 1$), subjects with a blue belt and above were considered upper belted athletes. Descriptive statistics for subjects can be found in Table 1. The subjects were instructed to keep their normal dietary and hydration routine and to make no drastic changes. All subjects were instructed to avoid alcohol and vigorous exercise for 24 hours prior to testing. Additionally, subjects were instructed to avoid large meals within two hours of testing. The study was approved by the Liberty University Institutional Review Board (IRB) IRB-FY24-25-368 and subjects completed an informed consent prior to participation. Subjects were screened for health-related issues and injuries using the Physical Activity Readiness Questionnaire (PAR-Q).

Procedures

Two days of testing were completed to determine if there was a correlation between the JJAPT and aerobic performances. The study was conducted as a within subject design where the subjects functioned as their own controls. As the commonly accepted gold standard aerobic assessment, VO_{2max} testing using gas exchange measurements was chosen as the aerobic performance metric (1, 2, 3, 5, 13, 23, 27). The term VO_{2peak} was used as not all subjects reached the criteria for VO_{2max} . As

a measure of anaerobic threshold, VT was used to determine the subject's physical performance and help define aerobic exercise intensity and complement aerobic fitness assessments (7).

Subjects completed two days of testing. One day of testing consisted of anthropometry and the VO_{2max} test. A second day of testing consisted of the JJAPT. The time in between testing days was at least 48 hours. Subjects were tested in the Liberty University Human Performance Lab with the Bruce graded exercise protocol. The JJAPT was completed at the home training gym of each athlete. The lead researcher ran all JJAPT tests, counted lifts, and ensured proper completion of lifts. Athletes were matched with a partner close in size and at or within 5% of their body mass. For the graded exercise protocol, subjects were instructed to wear their normal running attire and to wear Gi or no Gi uniform, per their competition and training requirements, during the JJAPT.

Anthropometry

Anthropometric data were collected in the Human Performance Laboratory prior to participation in the graded exercise protocol. Height (cm) was measured using a stadiometer (Seca, Chino, CA). Body mass (BM), body mass index (BMI), and body fat (BF) were calculated using the InBody 770 (Cerritos, CA).

VO_{2max}

To determine peak oxygen consumption, subjects completed a graded exercise protocol (Bruce Protocol) on a treadmill (Trackmaster, FullVision, Inc., Newton, KS). Bruce protocol provides a greater likelihood of achieving respiratory exchange ratio (RER) ≥ 1.00 for a max effort for nearly all participants (25). Oxygen consumption, CO_2 production and minute ventilation (VE) were measured using automated indirect calorimetry (TrueOne 2400, ParvoMedics, Sandy UT). The TrueOne 2400 was calibrated per manufacturer's instructions prior to each testing session. Heart rate (HR) was measured with a Polar H10 elastic strap sensor (Polar Electro, Kempele, Finland) and tracked by the Metabolic Cart. The subjects completed a five-minute warm up at a self-guided pace. Immediately following the

Table 1. Physical characteristics of subjects ($n=25$).

		Mass (kg)	Height (cm)	Age (yrs)	Body Fat (%)	Training (yrs)
Male	($n=17$)	83.29 \pm 12.48	172.88 \pm 14.01	27.35 \pm 6.98	15.65 \pm 7.13	7.03 \pm 7.19
Female	($n=8$)	67.81 \pm 16.51	164.33 \pm 7.91	28.38 \pm 9.49	25.21 \pm 8.86	3.81 \pm 2.4

warm-up, subjects completed the graded exercise protocol. The subjects were verbally encouraged throughout the process and RER and HR were monitored.

Ventilatory Threshold

To determine VT, VO_{2peak} and VE were plotted across time by computer onto a line chart. The VT was determined at the point where VE deviated from linearity from VO_2 and was confirmed as such by two researchers. Ventilatory threshold percentage of VO_{2peak} was then calculated by hand (24).

Jiu Jitsu Anaerobic Performance Test

On a separate day, subjects completed the JJAPT. Testing began with a five-minute familiarization trial as a warm-up. During the warmup the subject's form was critiqued and corrective feedback was given. There were five minutes of rest between the familiarization and the JJAPT. The JJAPT consisted of five, 60 second rounds of the butterfly lift, as described by Villar et al, with 45 seconds rest between rounds (31). Subjects were verbally encouraged throughout the test to extract a maximum performance. Only the lifts that were completed correctly and fully, per JJAPT instructions, within the 60 second timeframe were counted (31). Lifts for all rounds of all subjects were recorded, and the video was reviewed to recount the repetition to ensure accuracy.

Statistical Analysis

Mean and standard deviation were calculated for the key variables. Pearson correlation was used to determine the relationship between the JJAPT and

VO_{2peak} and between the JJAPT and VT.

Correlations for both dependent variables were run for the following groups: all subjects, male athletes, upper belted athletes, and white belted athletes. No separate correlations were run for the women as there were an inadequate number of subjects. Correlation was considered significant at alpha of <0.05 (one tailed). All statistics were performed using SPSS 28 statistical analysis software (v. 28; SPSS Inc., Chicago, IL, USA).

RESULTS

Table 2 presents the descriptive statistics for all variables included in the correlation analysis. The mean scores and standard deviations for VO_{2peak} were: for the total sample ($M = 43.908$, ± 6.87), males ($M = 45.982$, ± 6.23), upper belts ($M = 42.792$, ± 7.32), and white belts ($M = 45.117$, ± 6.44). The mean scores and standard deviations for the JJAPT were: for the total sample ($M = 74.88$, ± 8.80), males ($M = 75.82$, ± 9.57), upper belts ($M = 75.154$, ± 9.35), and white belts ($M = 74.908$, ± 8.56). The mean scores and standard deviations for VT were: for the total sample ($M = .74$, $\pm .105$), males ($M = .509$, $\pm .091$), upper belts ($M = .523$, $\pm .103$), and white belts ($M = .576$, $\pm .105$).

Figure 1 presents the correlations between VO_{2peak} and the JJAPT. There was a significant moderate positive correlation found between VO_{2peak} and the JJAPT ($r = 0.40$, $p = 0.025$) for all subjects. It was found that a significant moderate positive correlation existed for the male athletes between VO_{2peak} and the JJAPT ($r = 0.46$, $p = 0.031$). There was a significant moderate positive correlation

Table 2. Descriptive statistics total sample and by subgroup.

		N	M	SD
		(# of subjects)	(mean)	(Std. deviation)
VO_{2peak} ($mL \cdot kg^{-1} \cdot min^{-1}$)	Total Sample	25	43.908	± 6.87
	Males	17	45.982	± 6.23
	Upper Belts	13	42.792	± 7.32
	White Belts	12	45.117	± 6.44
JJAPT	Total Sample	25	74.88	± 8.80
	Males	17	75.82	± 9.57
	Upper Belts	13	75.154	± 9.35
	White Belts	12	74.583	± 8.56
VT (%)	Total Sample	25	.74	$\pm .105$
	Males	17	.509	$\pm .091$
	Upper Belts	13	.523	$\pm .103$
	White Belts	12	.576	$\pm .105$

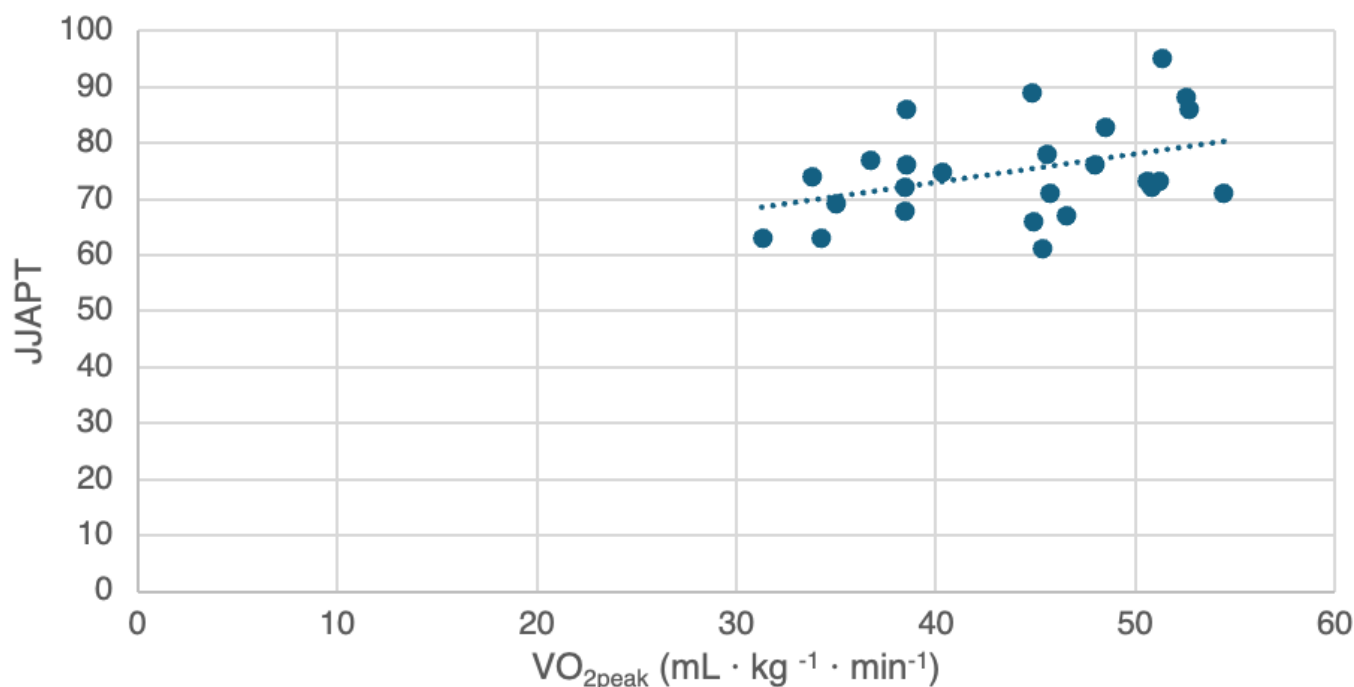


Figure 1. Correlation between VO_{2peak} and the Jiu Jitsu Anaerobic Performance Test (JJAPT).

found for upper belt athletes (blue and above) between VO_{2peak} and the JJAPT ($r = 0.54$, $p = 0.029$). There was no correlation found for white belt athletes between VO_{2peak} and the JJAPT ($r = 0.23$, $p = 0.232$). No significant correlation was found between VT and the JJAPT ($r = 0.05$, $p = 0.413$).

DISCUSSION

Sport-specific testing not only allows for the assessment of the athlete but also provides objective markers to help prevent injuries by identifying imbalances or weaknesses. Coaches and trainers use sport-specific testing to gauge and update athlete programs. The availability of testing that can be completed at any point throughout training and competition to evaluate an athlete's performance is invaluable as Jiu-Jitsu athletes typically do not have an off-season. Further, testing that is all encompassing, easily implemented, and easy to understand could allow coaches, trainers, and athletes to streamline the evaluation process.

It has been suggested that comparing the JJAPT to gold standard physiological measures could help determine the test as a performance predictor and/or to monitor training progress (23). Previous studies found a relationship between the JJAPT and anaerobic performance markers (31). This study aimed to determine if a relationship existed between the JJAPT and the aerobic physiological markers maximal oxygen uptake and VT by using gold standard VO_{2max} testing with the Bruce protocol. The

existence of a correlation suggests that the JJAPT may be used as an overall performance measure for BJJ athletes that can be used throughout training.

Previous research has shown the JJAPT to be a sport specific anaerobic test that simulates competition Jiu Jitsu (31). In addition to showing excellent reliability, it can show sensitivity to athletes with varying technical profiles as well as discriminating between athlete skill levels (16). It has been shown that Jiu Jitsu has interspersed lower-intensity aerobic periods with more reliance on the anaerobic system for the intermittent, but repeated explosive movements during offense, defense, and counterattacks (1, 3, 13, 14, 16, 22, 28). The correlation for all subjects ($n = 25$) between VO_{2peak} and the JJAPT was moderate and significant ($r = 0.40$, $p = 0.025$). With a high effort to pause ratio between 6:1-13:1, anaerobic demand is mainly activated during combat however the aerobic energy system is also called into play (4, 15, 20, 22, 30). Due to the demands of a BJJ competition, it is logical that the dependence on the aerobic energy system was supported by the moderate correlation between VO_{2peak} and the JJAPT.

Although there was an inadequate number of female subjects to calculate a separate correlation, the male athletes ($n = 17$) showed a significant moderate correlation between VO_{2peak} and the JJAPT ($r = 0.46$, $p = 0.031$). While moderate correlation for males was similar compared to the overall results, the correlation between the JJAPT and VT for men was slightly higher. This could be due to

the significant differences of respiratory structure and function between men and women (12, 19, 21, 29). While still a moderate correlation, the upper belted athletes ($n = 13$) did show a slightly larger significant correlation between VO_{2peak} and the JJAPT ($r = 0.54$, $p = 0.029$). This could be due to the greater consistency and quality of training.

Correlations for VT and the JJAPT were run for all groups, however, no significant correlations were found ($r = 0.05$, $p = 0.413$). The lack of correlation is reasonable as VT is a more sensitive indicator that can be affected by several factors. Highly trained individuals can exercise at a higher intensity before the ventilation response experiences a significant change (10, 11). Considerations include individual adaptations such as muscle fiber type, respiratory efficiency, and lactate metabolism. The amount of Type I muscle fiber has been shown to have a significant correlation with VT (9). Additionally, the higher the percentage of relatively fatigue resistant Type I fibers, the greater the initial rise in oxygen uptake, which is above the lactate threshold (10, 18, 26).

Although great care was taken to ensure study quality, it should be noted that the inclusion of beginner and novice athletes (white belts), as well as female athletes, could possibly have influenced the correlations. For further comparison, the groups were subdivided into white belts, resulting in no significant correlation, and upper belts, resulting in a significant correlation. The lack of correlation for the white belts could be due to the athlete's technique or the lower number of subjects for statistical analysis within the subgroups. Female hormonal fluctuations or contraception use were not accounted for. Further studies could investigate a larger sample of athletes, allowing for comparisons between male and female, as well as at each belt rank. It may be worth exploring how the VTs and VO_{2peaks} of elite level professional athletes correlate to their performance of the JJAPT compared to the relatively lower levels of expertise of the athletes presented in this study. Further, exploring how elite level female athletes specifically compare with regards to VO_{2peak} and the JJAPT correlation.

CONCLUSION

In conclusion, Jiu Jitsu has been shown rely on both anaerobic and aerobic energy systems. The moderate correlation between VO_{2peak} and the JJAPT appears to be in line with the moderate aerobic

requirements of the sport. Previous research has established the anaerobic component, the reliability, and the repeatability of the JJAPT. Additionally, the JJAPT has been shown to provide reliable measures of Jiu Jitsu competition performance. Therefore, based on the correlations with both anaerobic and aerobic fitness, and based on the reliability of the JJAPT, it is suggested that this sport-specific assessment can be used as both a performance test and a monitoring tool for BJJ athletes.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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ETHICAL APPROVAL

The study was approved by the Liberty University Institutional Review Board (IRB) IRB-FY24-25-368 and subjects completed an informed consent prior to participation

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