Aerobic interval training improves maximal oxygen uptake and reduces body fat in grapplers

Karsten ØVRETVEIT [1] *

[1] * Department of Sociology and Political Science, Norwegian University of Science and Technology, Dragvoll, 7491, Trondheim, Norway, e-mail: karsten.ovretveit@ntnu.no

ABSTRACT

BACKGROUND: Despite regularly engaging in high-intensity grappling, Brazilian jiu-jitsu (BJJ) athletes have a moderate maximal oxygen uptake ($\dot{V}O_{2max}$). The aim of this study was to evaluate the efficacy and feasibility of high-intensity aerobic interval training as an accessory to BJJ training for improvements in $\dot{V}O_{2max}$.

METHODS: Twelve active male BJJ practitioners (age: 30.3 ± 4.0 (SD) years; height: 183.0 ± 5.3 cm; body mass: 82.7 ± 8.3 kg; body fat: 11.9% ± 3.8%) with 5.6 ± 5.8 years of experience and a training volume of 9.9 ± 4.6 hours·week^{-1} were randomly allocated to either a training group (TG) or control group (CG). The TG incorporated two high-intensity aerobic interval training sessions·week^{-1} comprising four 4-minute intervals at 85-95% of maximal heart rate (HR_{max}) separated by 3-minute active breaks at 70% of HR_{max}.

RESULTS: After six weeks, the TG increased their $\dot{V}O_{2max}$ by 8% ± 3% (95% CI = 3.84, 12.73; $p = 0.04$; ES = 0.64), from 52.7 to 56.8 ml·kg^{-1}·min^{-1}. This was accompanied by a 1% ± 1% reduction in absolute body fat (95% CI = -0.13, -2.2; $p = 0.04$; ES = 0.64). No changes in $\dot{V}O_{2max}$ (p=0.12) or body composition (p=0.34) were detected in the CG.

CONCLUSIONS: These findings reveal compelling short-term effects of low-volume high-intensity aerobic interval training on $\dot{V}O_{2max}$ and body composition in active BJJ athletes. There may be a ceiling effect in terms of developing $\dot{V}O_{2max}$ in supine, intermittent grappling sports, making alternative approaches to aerobic conditioning particularly relevant for this athlete population.

Key words: Oxygen Consumption; Aerobic Exercise; Physiological Adaptation; Body Fat; Martial Arts; Jujitsu

Introduction

Brazilian jiu-jitsu (BJJ) is a grappling-based combat sport focused on ground fighting. Match regulation time typically ranges from 5 to 10 minutes and the winner is determined by positional dominance or a submission[1]. BJJ combat involves work at different intensities and requires frequent adjustments to changes in metabolic demand[2]. This requires both aerobic and anaerobic energy supply, with the maximal rate of aerobic adenosine triphosphate resynthesis appearing to be of particular importance to the sustainability of physiological performance[3]. Measurements of acute physiological responses to BJJ combat have revealed significant post-match increases in blood lactate concentration ($[La^-]_b$), with values often exceeding 10 mM[3-6]. This indicates considerable reliance on anaerobic processes and a limited capacity for aerobic energy yield. The typical maximal oxygen uptake ($\dot{V}O_{2max}$) of a BJJ athlete is approximately 50 $ml \cdot kg^{-1} \cdot min^{-1}$, independent of rank, experience, and training volume[7, 8], which is moderate compared to other athlete populations[9] and reflects a recreational fitness level[10].

Past training recommendations for BJJ athletes have emphasized the development of anaerobic endurance[11], and simulating the energy demands of combat[5, 6], rather than directly targeting improvements in specific performance determinants, such as $\dot{V}O_{2max}$. However, sport-specificity may be a suboptimal approach to improvements in aerobic endurance in grappling sports. Recently published training data reveal an inverse relationship between $\dot{V}O_{2max}$ and physiological markers of exertion during unrestricted BJJ sparring, which suggest that a higher $\dot{V}O_{2max}$ can delay the fatigue process and improve exercise tolerance in BJJ[3]. Moreover, these observations are indicative of the limitations of a sport-specific approach to athlete conditioning due to insufficient exercise intensity in trained (> 55 $ml \cdot kg^{-1}$)[10] athletes.

Interestingly, the intensity and duration of BJJ training rounds are ostensibly similar to training protocols that have been shown to induce marked improvements in $\dot{V}O_{2max}$[3], i.e. > 85% of the athlete's maximal heart rate (HR_{max}) and ~6 minutes[12, 13]. However, the technical, tactical, metabolic, and postural aspects of grappling might negate these improvements[3, 8]. There is substantial evidence for a high training intensity as a mediator of aerobic endurance improvements[12-16], with a notable lack of interchangeability between intensity and other training variables such as volume[13]. High-intensity aerobic exercise has been shown to elicit substantial cardiovascular adaptations over short time periods, thereby representing a potent training approach for athletes seeking the minimum effective dose for developing their aerobic endurance.

The comparably low $\dot{V}O_{2max}$ of BJJ athletes despite a high training intensity warrants exploring alternative approaches to aerobic conditioning in this population. Eliminating the potentially blunting effects of a supine body position, fluctuating metabolic demand, and energy conservation strategies is likely to produce aerobic adaptations beyond the levels seen in BJJ at a similar fraction of HR_{max}. Thus, the aim of this study was to determine the efficacy and feasibility of high-intensity aerobic interval training as a low-volume adjunct to regular BJJ training. It was hypothesized that incorporating two high-intensity aerobic interval training sessions per week using an upright exercise modality alongside BJJ would significantly improve $\dot{V}O_{2max}$. Additionally, body composition was assessed pre- and post-intervention to determine if the interval training would alter body fat and/or mass.

Materials & Methods

Participants

Athletes were recruited at a local BJJ academy and a questionnaire was used to assess eligibility. To participate in the study, the athletes had to be active competitors with ≥ one year of consistent BJJ training or hold the rank of blue belt or higher. Additionally, they had to be able to complete two high-intensity aerobic interval training sessions per week in addition to their regular training schedule for six weeks. Twelve active male BJJ practitioners (age: 30.3 ± 4.0 years; height: 183.0 ± 5.3 cm; body mass: 82.7 ± 8.3 kg; body fat: 11.9% ± 3.8%) ranked from white to purple belt, with 5.6 ± 5.8 years of experience and a training volume of 9.9 ± 4.6 hours·week^{-1}, were included in the study sample. The study was reviewed by the Regional Committee for Medical and Health Research Ethics (2017/556/REK midt) and carried out in accordance with the Declaration of Helsinki. Written informed consent was obtained from all athletes prior to participation.

Study design

The participants underwent baseline cardiopulmonary exercise testing and were subsequently randomly assigned to either a training group (TG) or a control group (CG). The training intervention consisted of two unsupervised high-intensity aerobic interval training sessions per week for six weeks (12 sessions). Recently, this training volume was shown to produce significant improvements in strength in this population[17]. Each session included a warm-up for 10 minutes at 70% of the athlete's maximal heart rate (HR_{max}) followed by four 4-minute intervals at 85 - 95% of HR_{max} separated by 3 minutes of active recovery at 70% of HR_{max} on a treadmill adjusted to ≥ 5% inclination[12, 13]. The prescribed treadmill resistance allowed for a gradual rise in HR during the first 60 - 90 seconds until target intensity was reached. Individual HR zones were calculated from the baseline HR_{max} for each participant, with the intensity being self-monitored with a heart rate strap (H2, Polar Electro, Finland) during each training session. The TG recorded all training in a diary for the duration of the study. Weekly check-ins were implemented to promote adherence. All participants were instructed to maintain their BJJ training schedule, which was documented with a questionnaire at baseline and follow-up questions at the post-test, and regular academy visits during the study period. The BJJ training sessions were 120 minutes long, with the first half consisting of a warm-up and technical drilling and the second half of sparring.

Testing procedures

Oxygen uptake ($\dot{V}O_2$) was measured (SensorMedics Vmax Spectra 229d, Yorba Linda, CA, USA) during incremental exercise on a motorized treadmill at 3º inclination (PPS 55 Med, Woodway GmbH, Weil am Rhein, Germany). The participants warmed up at 7 $km \cdot h^{-1}$ for 10 minutes and the average $\dot{V}O_2$ during the last minute was used to determine running economy (C_R)[13]. Treadmill speed was subsequently increased by 1 $km \cdot h^{-1}$ every minute until exhaustion, which occurred within 5 to 10 minutes. HR was continuously monitored (M400, Polar Electro, Finland) and the maximal HR achieved was defined as HR_{max}. After test completion, the participants rated their level of perceived exertion[18], and blood was sampled from the fingertip and analyzed for $[La^-]_b$ (Biosen C-Line, EKF Diagnostics GmbH, Barleben, Germany). The highest 30-second average $\dot{V}O_2$ was calculated and accepted as $\dot{V}O_{2max}$ if ≥ two of the following criteria were achieved: a $\dot{V}O_2$ plateau despite increased workload; respiratory exchange ratio (RER) ≥ 1.1, $[La^-]_b \geq 8$ $mmol \cdot L^{-1}$; and/or a proximity of ≤ 5 $beats \cdot min^{-1}$ to HR_{max} if this was known. $\dot{V}O_{2max}$ was expressed as absolute ($L \cdot min^{-1}$), body mass relative ($ml \cdot kg^{-1} \cdot min^{-1}$), and body mass independent ($ml \cdot kg^{-0.75} \cdot min^{-1}$) values[19].

Body mass and composition were assessed with segmental multifrequency bioelectrical impedance analysis (MC-980-MA, Tanita Corp., Tokyo, Japan). The participants were instructed to avoid same-day exercise prior to testing and be in a euhydrated state with empty bladder and bowel at the time of the test.

Statistical analyses

Statistical analyses were performed using IBM SPSS Statistics 24 (Chicago, IL, USA). Graphics were made with GraphPad Prism 6 (San Diego, CA, USA). The Wilcoxon signed rank test was used to detect within-group changes from pre- to post-test and the groups were compared with the Mann-Whitney U test. Effect sizes (ES) were calculated as $r = Z/\sqrt{N}$ and interpreted as small (> 0.1), medium (> 0.3) or large (> 0.5). Data are presented as mean ±

standard deviation (SD) with 95% confidence intervals (CI) unless otherwise stated. The α level was set at 0.05.

Results

No differences in body mass ($p = 0.70$), body fat ($p = 0.43$), $\dot{V}O_{2max}$ ($p = 0.66$), and BJJ training experience ($p = 0.70$) and volume ($p = 0.94$) were detected between groups at baseline. All participants in the TG completed the prescribed training sessions within a 6.0 ± 0.6-week period for an adherence rate of 100% with no adverse events reported. The TG significantly improved their $\dot{V}O_{2max}$ by 8 ± 3% (95% CI = 3.84, 12.73; $p = 0.04$; ES = 0.64, large) following the intervention period, with no change in the CG ($p = 0.12$) (Figure 1; Table 1). Due to inconsistencies in the pulmonary gas exchange analyses, $\dot{V}O_2$ and HR data from one participant in the TG were excluded. This athlete, however, increased his peak running speed by 1 km·h^{-1} at the post-test, indicating improved aerobic endurance.

---*Figure 1*---

---*Table I*---

In addition to the improved $\dot{V}O_{2max}$, absolute body fat dropped by 1 ± 1% (95% CI = -0.13, -2.2; $p = 0.04$; ES = 0.64, large) in the TG, with no change in the CG ($p = 0.34$) (table 1). Both groups reported a maintained BJJ training volume throughout the study, with the exception of two participants (TG = 1; CG = 1) who reduced their training volume slightly due to injuries not related to this study. The TG logged an average total of 39.3 ± 25.1 hours of BJJ training and 5.7 ± 7.5 hours of other activities. Each 4 x 4 session lasted 35 minutes for an intervention total of 7 hours. Accordingly, the 4 x 4 protocol amounted to 23 ± 17% of the participants' total training volume during the intervention period.

Discussion

Although BJJ athletes regularly engage in high-intensity sport-specific training[3], they have a moderate $\dot{V}O_{2max}$ compared to other athlete populations[7, 8]. The present study sought to assess the effects of low-volume high-intensity aerobic interval training as a supplement to BJJ training. By incorporating approximately one hour of interval training per week for six weeks, athletes in the TG improved their $\dot{V}O_{2max}$ by 8% and reduced their absolute body fat by 1%. No improvements were apparent in the CG. With the intervention protocol constituting only 23% of the TG's total training volume, these findings suggest that a small dose of high-intensity aerobic interval training can produce considerable improvements in $\dot{V}O_{2max}$ and body composition in this athlete population.

High-intensity aerobic interval training has previously been shown to elicit a 0.3 – 0.7% increase in $\dot{V}O_{2max}$ per session in 8- to 12-week long interventions[12]. The present athletes were in the higher range of the expected training response, with an approximate increase of 0.7% per session. This is notable, as the participants were already active prior to the intervention. Moreover, the TG was compared to other active athletes, who demonstrated no improvements at the post-test. This observation offers novel support for both the notion of a ceiling effect of BJJ on $\dot{V}O_{2max}$ [8], as well as the utility of high-intensity aerobic interval training as a low-volume conditioning accessory for grapplers. The concomitant reduction in body fat, likely mediated by factors such as improved insulin sensitivity and decreased lipogenesis[20], represents an additional benefit for these athletes, as they typically compete in weight divisions.

Despite an apparent limited aerobic exercise response, BJJ has previously been shown to induce physiological improvements in certain populations. Queiroz et al.[21] reported improvements in several parameters of strength, flexibility, and endurance following 12 weeks of BJJ training in elderly men. In a similar study on younger athletes, Ribeiro et al.[22] compared the effects of a high-intensity interval training approach to BJJ to regular BJJ training. High-intensity BJJ appeared to elicit greater improvements in aerobic endurance than traditional training following the 10-week intervention period. Important to note, however, is both these studies were done in subjects with low baseline fitness levels, which can overestimate the effects of a training intervention[23]. Moreover, aerobic endurance was estimated rather than directly measured, implicating data validity. Indeed, the lack of direct measurements of $\dot{V}O_{2max}$ in BJJ athletes has been identified as a major weakness in the current literature[8].

While high-intensity BJJ training has been successfully implemented as an alternative approach to traditional BJJ, recent findings suggest that a high training intensity might be the default, with a self-selected average sparring intensity of 85% of HR_{max}[3]. Interestingly, this intensity adjoins the lower boundary of the target HR range in the 4 x 4 intervals, but the lack of improvements in the CG indicates that sparring is less efficient than running at a similar HR. There are several key differences between sparring and running that might explain this discrepancy in chronic aerobic adaptations. For instance, HR during BJJ combat might overestimate actual work due to factors such as short work periods, the involvement of arm work, and isometric muscle contractions[3, 24]. Moreover, the considerable postural variation has implications for $\dot{V}O_{2max}$, $\dot{V}O_2$ kinetics, cardiac output, and lactate accumulation[25-27]. The $\dot{V}O_2$ response at the onset of exercise is affected by the lag in the cardiorespiratory adjustment to the increased metabolic demand, which appears to be delayed in the supine position[25], and is further challenged by the intensity characteristics of BJJ[2]. This can affect exercise tolerance and ultimately aerobic adaptations. Conversely, maintaining a high dynamic exercise intensity beyond the cardiorespiratory rest-to-work transition period provides a powerful exercise stimulus[13, 15]. Thus, although HR might be similar during BJJ and dynamic large muscle mass exercise, there are important physiological distinctions between the two. As evident by the present findings, running at a high aerobic intensity for similar durations as a sparring round has a greater impact on $\dot{V}O_{2max}$ than the typical effort pattern seen in BJJ[3].

As opposed to Helgerud et al.[13], who observed reductions in the oxygen cost of submaximal running following 4 x 4 training, C_R remained unchanged in both groups in the present investigation. This might be due to differences in training volume and frequency, with the participants in the former study completing 24 sessions over 8 weeks, while this intervention only spanned 6 weeks for a total of 12 sessions. Consistent with previous findings, BJJ athletes do not appear to be particularly efficient runners[8]. However, because a low cost of running reduces the intensity at a given speed, improving C_R is not necessarily desirable for populations who use running as a means of improving fitness[28].

Several participants in the TG described the training intervention as surprisingly easy. The intensity in 4 x 4 interval training is capped at 95% of HR_{max}, which, while high, only occurs after a gradual physiological adjustment to the external load. In contrast, intensity in BJJ is unpredictable and fluctuating, with the added element of a resisting opponent. Differences in perceived strain might have been further exacerbated by the 50% longer duration of the sparring rounds, with considerably shorter breaks. Although adherence to unsupervised training interventions can be challenging to maintain, the present study sample comprised active athletes accustomed to high-intensity exercise, therefore, unsupervised training was assumed to be viable. Indeed, the TG reported a 100% adherence rate, which was supported by the large improvements observed at the post-test. Interestingly, the participants expressed that the additional training had no meaningful impact on their general fatigue levels, indicating that the volume and intensity of the present intervention is an appropriate accessory to BJJ. In addition to the unsupervised intervention, other limitations to the study were the small sample size, the reliance on self-reported data, such as training diaries, and the lack of dietary control.

When aiming for improvements in distinct physiological function, the training design should be governed by principles that efficiently target the given attribute, not by sport-specificity. Therefore, BJJ athletes should include non-specific large muscle mass upright exercise, e.g. running, rowing or cycling, to develop their $\dot{V}O_{2max}$ beyond the levels typically found in the literature. Although a moderate $\dot{V}O_{2max}$ does not seem to preclude an athlete from progressing in rank or doing well in tournaments[7], developing this attribute offers a physiological performance advantage[3], which likely becomes increasingly important as the number of competitors continues to grow.

Conclusions

The present study provides evidence for the efficacy and feasibility of high-intensity aerobic interval training as an efficient auxiliary conditioning approach for grapplers seeking an increased $\dot{V}O_{2max}$. The concomitant reduction in body fat may provide additional benefits for these weight class athletes. The ability to make physiological and anthropometric improvements over a short time period can have a major impact on performance in sports with an unstructured competition season and limited preparation time, such as BJJ.

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TABLE

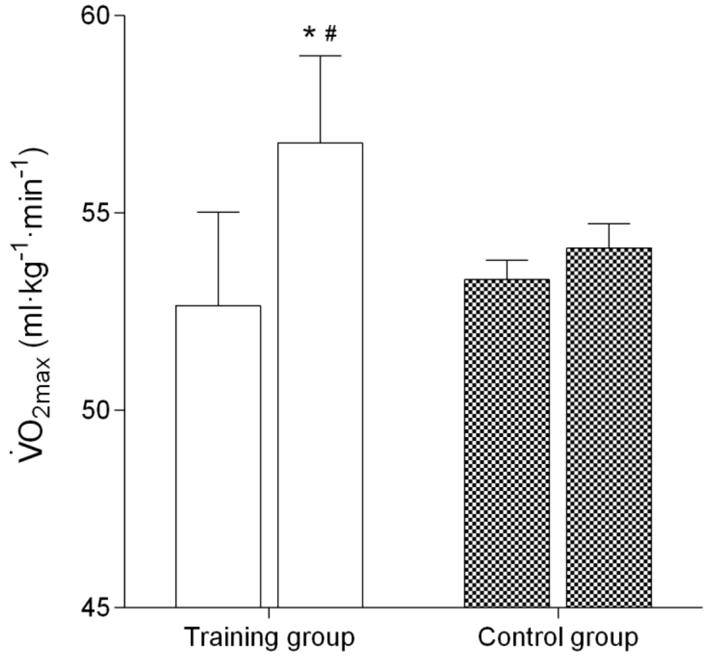
Table I. *Anthropometric and physiological measurements*

	Training group		Control group	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
Body mass (kg)	85.4 ± 10.3	84.8 ± 10.8	81.2 ± 7.2	81.0 ± 6.0
Body fat (%)	12.7 ± 3.8	11.7 ± 4.5*	11.2 ± 4.1	10.8 ± 3.2
$\dot{V}O_{2max}$				
($L\cdot min^{-1}$)	4.3 ± 0.7	4.6 ± 0.6*#	4.3 ± 0.4	4.4 ± 0.3
($ml\cdot kg^{-1}\cdot min^{-1}$)	52.7 ± 5.3	56.8 ± 4.9*#	53.3 ± 1.2	54.1 ± 1.5
($ml\cdot kg^{-0.75}\cdot min^{-1}$)	157.9 ± 17.5	169.9 ± 16.4*#	159.9 ± 4.4	162.3 ± 5.2
HR_{max} ($beats\cdot min^{-1}$)	193 ± 7	192 ± 9	189 ± 5	187 ± 11
$\dot{V}_E$ ($L\cdot min^{-1}$)	160.6 ± 21.1	167.5 ± 17.8	149.8 ± 15.2	142.0 ± 14.1*
$[La^-]_b$ ($mmol\cdot L^{-1}$)	14.3 ± 1.8	15.8 ± 1.6	12.3 ± 2.8	11.5 ± 1.3
RER	1.26 ± 0.05	1.26 ± 0.03	1.23 ± 0.05	1.18 ± 0.07*
RPE (6 – 20)	18 ± 1	18 ± 1	18 ± 1	19 ± 1
Running economy				
$\dot{V}O_2$ ($ml\cdot kg^{-0.75}\cdot m^{-1}$)	0.86 ± 0.09	0.85 ± 0.06	0.87 ± 0.06	0.89 ± 0.04
HR ($beats\cdot min^{-1}$)	156 ± 9	149 ± 12	148 ± 15	148 ± 21
RER	0.96 ± 0.01	0.98 ± 0.03	0.97 ± 0.02	0.93 ± 0.04

*Data are presented as mean ± SD. $\dot{V}O_{2max}$, maximal oxygen uptake; $v\dot{V}O_{2max}$, velocity at maximal oxygen uptake; HR_{max}, maximal heart rate; $\dot{V}_E$, pulmonary ventilation; $[La^-]_b$, blood lactate concentration; RER, respiratory exchange ratio; RPE, rating of perceived exertion; * significant difference within group ($p < 0.05$); # significant difference between groups from pre- to post-test ($p < 0.01$).*

FIGURE

Figure 1. *Changes in maximal oxygen uptake ($\dot{V}O_{2max}$)*



*Data are presented as mean ± standard error (SE); * significant difference within group ($p < 0.05$); # significant difference between groups from pre- to post-test ($p < 0.01$).*