

BLOOD FLOW RESTRICTION DOES NOT AFFECT ACUTE MEASURES OF POWER AND FATIGUE DURING MAXIMAL CYCLING AMONG WOMEN

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While it is known that blood flow restriction (BFR) can positively affect training and rehabilitation progression timelines, the physiological basis of this intervention is not fully understood. The purpose of this study was to determine the short-term impact of BFR upon power and fatigue performance measures during maximal cycling. In this study, maximal cycling was assessed using the Wingate Anaerobic Test (WAnT). Using a counterbalanced design, fourteen female participants completed standardized BFR and non-BFR protocols while completing the WAnT. No statistically-significant differences ($p \leq 0.05$) were found between conditions for measures of peak power (PP), low power (LP) or fatigue index (FI). These findings suggest that BFR had no statistically-significant acute effect on these performance measures commonly assessed during the WAnT.

INTRODUCTION: Blood flow restriction (BFR) may be one of the most important training and rehabilitation interventions to emerge in the past half-century, as it is widely known that regular use of blood flow restriction (BFR) positively influences clinical interventions aimed at improving muscular strength and hypertrophy (Bennett & Slattery, 2019). Such clinical outcomes have obvious merit in athletic performance and/or rehabilitation settings, contributing to the increasing use of BFR as a treatment modality within these settings over the past decade. However, while this treatment modality also has seen a marked increase in attention within the medical literature in recent years (Abe et al., 2012; Joshi et al., 2020; Tangchaisuriya et al., 2021), the acute and chronic mechanisms by which this intervention may affect exercise performance, as well as how this intervention may potentially influence a wide variety of gross motor activities, are not fully understood. In particular, there is scant research on topics such as the acute effects of BFR upon gross motor coordination measures (GMCM) of the musculoskeletal system (Centner & Lauber, 2020; Kilgas et al., 2022) or how this modality may influence forms of high intensity exercise other than resistance training (Bennett & Slattery, 2019; Tangchaisuriya et al., 2021).

Cycling is one such continuous motor task well suited for laboratory studies and may be used to assess GMCM. A common high intensity cycling test is the Wingate Anaerobic Test (WAnT). This test is widely used in laboratory settings, as it measures power output during a maximal 30 second cycling bout (Rana, 2006). The WAnT is used to assess anaerobic power and can assess a person's ability to produce maximal power while using both ATP-PCr and anaerobic glycolysis energy systems (Powers & Howley, 2006). While countless studies have used the WAnT (Rana, 2006), little research exists on the biomechanics or GMCM exhibited during this test. Similarly, no studies have addressed the immediate impact of BFR on WAnT performance. A deeper understanding between GMCM measures, BFR, and acute fatigue characteristics during the WAnT may lead to a better understanding among sport scientists of how to best integrate BFR into training and rehabilitation regimens. Therefore, the purpose of this study was to assess the acute effect of BFR on measures of power and fatigue while completing a maximal bout of anaerobic cycling.

METHODS: Fourteen ($n = 14$) females (26.85 ± 3.01 yr, 170.65 ± 4.81 cm, 68.66 ± 8.46 kg) participated in this study. Inclusion criteria included women between the ages of 18 and 35 who were apparently healthy and physically active (30 min/day, 3 days/week for at least 3 months). Individuals with lower extremity pathology or who regularly cycle were excluded. The study received approval from the Institutional Review Board (IRB) prior to its start. Each participant visited the laboratory on two occasions. At the beginning and end of each testing session, her heart rate, blood pressure, and respiratory rate were taken and recorded. Using a counterbalanced design, participants completed a BFR protocol or non-BFR (control, or CON) protocol. The BFR protocol used in this investigation was based on methodology used in previous studies, consisting of 40% limb occlusion pressure bilaterally (Wei et al., 2021). Following a standardized 10 minute warm-up and short rest period, participants completed the WAnT, riding at maximal intensity for 30 seconds.

Cycling conditions for the WAnT occurred on the Velotron, an electronically-braked ergometer (Racermate, Seattle, Washington, USA) and were controlled and continually measured by computer. The following variables were assessed continuously during each trial: speed, watts, cadence, and measures of cycling efficiency (SpinScan™, and average torque angle (ATA) throughout the 360° of pedal travel). Measures of peak power (PP), mean power (MP), minimum or low power (LP), and fatigue index (FI) were calculated using 5 second time intervals. Fatigue index was calculated using the following equation:

$$FI: [(Peak\ Power\ Output - Min\ Power\ Output) / Peak\ Power\ Output] \times 100$$

SPSS 28 (IBM SPSS, Armonk, NY, USA) was used for all statistical analysis. Paired t-tests were conducted to assess for differences between conditions, and correlational analyses were conducted to assess the extent that the variables were linearly related. Statistical significance was set at the $p \leq 0.05$ level.

RESULTS: Conditions (BFR versus CON) differed for measures of PP ($t(13) = -2.56$, $p \leq 0.02$), MP ($t(13) = -3.17$, $p \leq 0.007$), and LP ($t(13) = -2.42$, $p \leq 0.03$), but they did not differ between conditions for FI ($t(13) = 1.63$, $p \leq 0.13$). Each of these dependent variables was also significantly correlated between the two conditions: PP ($r = .927$, $p \leq 0.001$), MP ($r = .802$, $p \leq 0.000$), and LP ($r = .67$, $p \leq 0.009$), but they did not highly correlate linearly for FI ($r = .397$, $p \leq 0.16$).

Table 1. Comparison of power measures by condition.

Condition (n=14)	BFR Mean \pm SE	CON Mean \pm SE	t score	P value	Correlation	P value
Peak Power (PP)	429.23 \pm 20.02	454.59 \pm 25.02	-2.56	0.02	.927	0.0011
Mean Power (PP)	372.41 \pm 16.61	410.76 \pm 22.59	-3.17	0.007	.933	0.001
Low Power (LP)	241.35 \pm 12.47	279.07 \pm 20.85	-2.42	0.03	.668	0.009
Fatigue Index (FI)	43.24 \pm 2.47	38.85 \pm 2.43	1.63	0.13	.397	0.16

DISCUSSION: These findings suggest that the acute power measures collected during this short-term maximal activity were negatively affected by BFR; however, the BFR intervention did not influence the fatigue index measure. As noted above, few studies to date have investigated the acute effects of BFR upon neuromuscular function or GMCM while cycling maximally, limiting the informed application by clinicians of BFR during maximal exercise other than resistance training. The lack of evidence in this area limits the capacity of clinicians to apply the specificity principle when directly prescribing exercise or developing training programs. Nonetheless, the current findings seem to support the previous findings of (Lauver et al., 2022), (Kilgas et al., 2022), and (Held et al., 2023), respectively. (Lauver et al., 2022) found significantly higher surface EMG measures of the vastus lateralis during repeated bouts of maximal cycling, demonstrating the greater neuromuscular output necessary to generate force during BFR conditions. (Kilgas et al., 2022) investigated post-exercise changes in knee extensor function following short maximal cycling bouts (2 min) under different BFR conditions. These authors found that knee extensor torque decreased by approximately 18% and 40% following BFR done at 60% and 80% occlusion pressures, respectively. (Held et al., 2023) had participants perform depth jumps and balance tests immediately prior to and following 20 minute bouts of low intensity cycling (40% of power at maximal oxygen uptake) completed with and with BFR. These authors found statistically significant impairment of depth jump measures but not balance testing following the BFR condition used in this study. Each of these previous findings of acutely impaired neuromuscular function with BFR is consistent with the present findings, in which measures of PP, MP, and LP were significantly less during the BFR condition at 40% occlusion pressure. Numerous studies have demonstrated that the hypoxic condition induced by the BFR intervention essentially makes moderate to high intensity exercise more stressful on a metabolic level, which when applied over time contributes to the adaptations necessary for greater muscular force production (Abe et al., 2012; Centner & Lauber, 2020; Joshi et al., 2020; Tangchaisuriya et al., 2021). While the authors of these aforementioned studies did not report findings for PP, MP, LP, or FI, which are commonly reported findings in studies involving the WAnT, these studies (Held et al., 2023; Kilgas et al., 2022; Lauver et al., 2022) and the present findings give insight into how BFR acutely influences the neuromuscular response to this form of training intervention. Still, additional studies are needed in this area, so as to allow practitioners who may wish to use BFR methodologies in training or rehabilitation individuals using maximal cycling toward the goal of greater specificity but who are hindered presently by the lack of empirical evidence as to what BFR training variables may be more advantageous.

The strength of this study was its focus on the impact of BFR upon power output and fatigue characteristics during the WAnT, a topic unaddressed to date in the sport science literature. Such research is vital to understanding the impact of BFR during anaerobic activity. This type of research can, for example, help coaches better train athletes so as to improve athletic performance and decrease odds of injury, or help physical therapists to better refine training loads during exercise sessions, which is an important consideration when constructing any rehabilitation program.

CONCLUSION: Authors have linked differing measures of GMCM, power output, and fatigue to musculoskeletal injuries, as well as to their effective rehabilitation. BFR training regimens have been increasingly associated with more timely rehabilitation timelines and better outcome measures. As such, this study has scientific value as the first known investigation on the acute effect of BFR upon fatigue characteristics during vigorous cycling. These findings may help

sport scientists better understand the impact of BFR methodologies in improving performance and injury.

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