THE EFFECTS OF BLOOD FLOW RESTRICTION ON MEASURES OF GROSS MOTOR COORDINATION DURING THE WINGATE ANAEROBIC TEST

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To date little research has addressed the impact of blood flow restriction (BFR) training upon gross motor coordination measures (GMCM) during a wide variety of maximal activities. The purpose of this study was to assess the effects of BFR on GMCM exhibited during maximal cycling. The performance of 14 females between the ages of eighteen and thirty-five were analyzed during the Wingate Anaerobic Test (WAnT). The participants completed the test under two conditions, using BFR and without. Results showed statistically significant differences ($p \leq 0.05$) between conditions for dependent variables assessed throughout this common 30 second test of maximal cycling. These findings suggest that BFR negatively influenced GMCM exhibited during the WAnT.

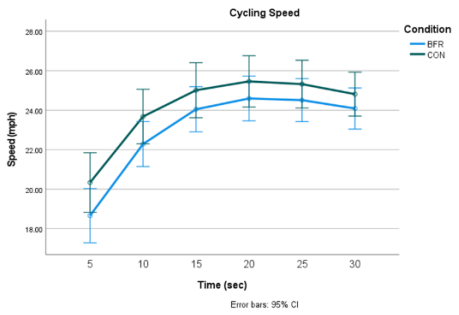
INTRODUCTION: The utilization of blood flow restriction (BFR) training and rehabilitation programs have spread widely in the past decade, as sport-specific coaches, trainers, and therapists increasingly understand that regular use of BFR positively effects interventions aimed at improving muscular strength and hypertrophy (Bennett & Slattery, 2019). Such clinical outcomes have obvious merit within athletic performance and/or rehabilitation settings. Yet, while this intervention also has seen a marked increase in attention within the sport science literature in recent years (Abe et al., 2012; Joshi et al., 2020; Tangchaisuriya et al., 2021), the mechanisms by which it may potentially influence a wide variety of gross motor activities are not fully understood. In particular, there is little published on issues such as how this modality may acutely influence forms of high intensity exercise other than resistance training (Bennett & Slattery, 2019; Tangchaisuriya et al., 2021) or the acute effects of BFR upon gross motor coordination measures (GMCM) of the musculoskeletal system (Centner & Lauber, 2020; Kilgas et al., 2022).

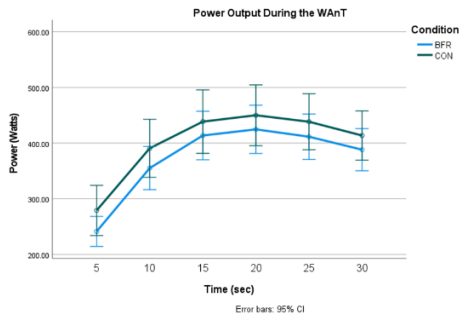
Beyond resistance training, cycling is another form of high intensity gross motor activity bearing inherent GMCM characteristics (Dixon et al., 2013; Holliday et al., 2023), regardless of whether it occurs in laboratory environments or real-world scenarios. The Wingate Anaerobic Test (WAnT), measuring power output during a 30 second bout of maximal cycling, is widely used in laboratory. The WAnT is used to assess, for example, anaerobic power and can assess a person's ability to produce maximal power while using both ATP-PCr and anaerobic glycolysis energy systems, metabolic systems which are reportedly acutely influenced by the BFR intervention (Bennett & Slattery, 2019; Inbar, 1996). Similarly, the Velotron (Racermate, Seattle, WA, USA) is a valid and reliable computer-controlled cycle ergometer (Astorino & Cottrell, 2012) widely used in research, and it possesses the capacity to instantaneously assess numerous biomechanical variables throughout any test period. These variables include cycling speed, power output in watts, cadence (rpm), percentage power (% left vs right lower extremity), average torque angle (ATA) for left and right lower extremities, and SpinScan™ (SS). SpinScan™ is the Velotron's composite measure of pedaling efficiency, which is a specific form of gross motor coordination of the musculoskeletal system, or GMCM. Thus, while much research has been done to analyze such acute metabolic effects of BFR, few studies to date have addressed the acute impact of BFR upon measures of neuromuscular performance while cycling (Held et al., 2023; Kilgas et al., 2022; Lauver et al., 2022). This current void in the scientific literature stands out given the widespread familiarity of the WAnT. More research in this area may help facilitate greater understanding of the ways in which the biomechanics or

GMCM change during high intensity physical activity involving BFR. In turn, this may help to better prevent and rehabilitate injuries, such as the ACL injuries that occur more commonly among female athletes. The purpose of this study, then, was to assess the effects of BFR on GMCM exhibited during short term, maximal cycling.

METHODS: Data collection occurred at Western Michigan University in Kalamazoo, Michigan (USA), receiving approval from the Institutional Review Board (IRB) prior to its start. Inclusion criterion included individuals between the 18-35 years of age who regularly exercise and assessed as low risk on the ACSM risk stratification guidelines. Individuals with known lower extremity pathology or who regularly cycle were excluded. Fourteen women (n=14) between the ages of eighteen and thirty-five (26.85±3.01 yr, 170.65±4.81 cm, 68.66±8.46 kg) completed the study. Each participant performed the WAnT on two occasions. Before and after each of two data collection sessions, participant's heart rate, blood pressure, and respiratory rate were taken. Using a counterbalanced design, each participant completed one session that included a standardized BFR protocol at 40% limb occlusion pressure during the WAnT (Wei et al., 2021). The second trial, or control (CON), performed during another visit to the laboratory at least 3 but no more than 7 days later, involved the WAnT protocol but did not include the BFR. The WAnT was completed using the Velotron, and all conditions were computer-controlled and computer-assessed. Independent variables included BFR condition (BFR versus CON). Dependent variables used to assess GMCM included the following measures collected continuously during each WAnT: cycling speed, watts, rpm, heart rate (HR), peak power (PP), % power (% left vs right lower extremity), average torque angle (ATA), SpinScan™ (SS), and left (LSS) and right SpinScan™ (RSS), respectively. Repeated measures analysis of variance was conducted using SPSS 28 (IBM SPSS, Armonk, NY, USA). Statistical significance was set at the customary level ($p \leq 0.05$).

RESULTS: Significant differences were found between conditions for the entire 30 seconds of the WAnT for cycling speed ($F(1,13)=12.23$, $p \leq 0.004$) and watts ($F(1,13)=10.05$, $p \leq 0.007$). Significant interactions ($F(1,5)=7.64$, $p \leq 0.001$) between condition and time were found for RPM over the 30 second time frame. Significant differences were found between 5 sec time intervals over the entire 30 seconds of the WAnT protocol for the following variables: Cycling speed, $F(1,5)=97.62$, $p < .001$; watts, $F(1,5)=109.20$, $p < .001$; RPM, $F(1,5)=249.57$, $p < .001$; HR, $F(1,5)=4.96$, $p < .001$; SS, $F(1,5)=108.56$, $p < .001$; LSS, $F(1,5)=83.24$, $p < .001$; RSS, $F(1,5)=127.772$, $p < .001$; LATA, $F(1,5)+23.15$, $p < .001$; RATA, $F(1,5)+14.91$, $p < .001$; and PP, $F(1,5)=34.86$, $p < .001$.





DISCUSSION: The purpose of this study was to assess the effects of BFR on GMCM exhibited during short term, maximal cycling. Researchers have described the Velotron's proprietary SS as a composite measure of pedaling efficiency while cycling (Dixon et al., 2013). This measure

is a synthesis of the wattage, cadence, left and right % power measures, and average torque angles of the left and right crank arms generated throughout the 360º of the pedal stroke. Efficient pedaling requires more than high force application upon the pedals while cycling; rather, the timing and angle of force application are also critical elements (Holliday et al., 2023). In other words, a degree of GMCM is inherent with pedaling, and this coordination is fundamental whether the participant is a novice learning to ride a bicycle or a Category I racer with many years of experience. The characteristics of GMCM while pedaling are widely acknowledged to change subject to fatigue or differing intensities (Galindo-Martínez et al., 2021; Holliday et al., 2023). The impact of BFR upon GMCM is less well-known.

The findings in the present study suggest that BFR produced both statistically significant and clinically meaningful acute effects upon GMCM measures during maximal cycling, as the BFR condition clearly had an impact on measures of GMCM assessed in this study. Participants exhibited statistically-significant lesser values in the cycling speed and power output (watts) for the 30 second time frame, suggesting the acute stress induced by BFR made the WAnT test more difficult for participants. This finding was expected, as it is consistent with previous studies on both BFR while cycling under different experimental conditions (Bennett & Slattery, 2019; Tangchaisuriya et al., 2021) and BFR during various forms of resistance training (Abe et al., 2012).

The statistically significant interaction demonstrated between condition and time further suggests the BFR condition increasingly made the WAnT protocol more difficult as the test transpired. Again, this finding is not highly surprising given the maximal intensity exhibited during the WAnT and the consistent reports in the literature of the general tendency of performance degradation over the 30 seconds of the WAnT test (Inbar, 1996). Significant differences also were found between 5 second time intervals over the entire 30 seconds of the WAnT for cycling speed, watts produced, cadence (RPM), HR, PP, SS, LSS, RSS, LATA, and RATA. Each of these variables measures a component of motor efficiency while pedaling, and the statistical significance demonstrated in these variables further suggest the WAnT protocol was increasingly more difficult for participants under the BFR condition. This finding potentially has implications for clinical meaningfulness, as this information may be useful for shaping training and rehabilitation regimens for specific aims (Abe et al., 2012; Centner & Lauber, 2020).

Strengths of the present study include its treatment of a topic which broadens the spectrum of activities that have been assessed when using BFR, as few studies have investigated the impact of BFR upon performance measures during cycling in general or the WAnT in particular. Similarly, while much is known about the impact of BFR upon muscular force production within the context of traditional resistance training, little is known about the ways in which BFR may acutely influence biomechanics generally or GMCM specifically. This is an important consideration given the role of force production in the creation and control of coordination motor activity, which has been linked to musculoskeletal injuries, such as those to the ACL. A limitation of the present study is the delimitation of the participants to apparently healthy young women. They may have responded to BFR in ways inconsistent with other populations. Consequently, future study should investigate the impact of BFR on GMCM during maximal cycling among other physically active populations.

CONCLUSION: Given the few studies on the effects of BFR on GMCM, these results have both scientific and clinical value. Participants demonstrated decreased laboratory measures of GMCM when completing the WAnT while simultaneously using BFR at 40% limb occlusion pressure, when compared to a no-BFR condition. The findings may help coaches, trainers, and therapists make better use of BFR routines in training and rehabilitation.

REFERENCES:

Abe, T., Loenneke, J. P., Fahs, C. A., Rossow, L. M., Thiebaud, R. S., & Bemben, M. G. (2012). Exercise intensity and muscle hypertrophy in blood flow-restricted limbs and non-restricted muscles: A brief review. *Clinical Physiology and Functional Imaging*, *32*(4), 247–252. https://doi.org/10.1111/j.1475-097X.2012.01126.x

Astorino, T. A., & Cottrell, T. (2012). Reliability and validity of the velotron racermate cycle ergometer to measure anaerobic power. *International Journal of Sports Medicine*, *33*(3), 205–210. https://doi.org/10.1055/s-0031-1291219

Bennett, H., & Slattery, F. (2019). Effects of Blood Flow Restriction Training on Aerobic Capacity and Performance: A Systematic Review. *Journal of Strength and Conditioning Research*, *33*(2), 572–583. https://doi.org/10.1519/JSC.0000000000002963

Centner, C., & Lauber, B. (2020). A Systematic Review and Meta-Analysis on Neural Adaptations Following Blood Flow Restriction Training: What We Know and What We Don't Know. *Frontiers in Physiology*, *11*, 887. https://doi.org/10.3389/fphys.2020.00887

Dixon, M., Wong, R., Csicsery, K., Popich, A., Klassen, D., Mehndiratta, V., & Higginson, B. (2013). The effects of aerobic fatigue on joint kinematics and torque production in cyclists. *International Journal of Exercise Science: Conference Proceedings*, *8*(1). http://digitalcommons.wku.edu/ijesab/vol8/iss1/6

Galindo-Martínez, A., López-Valenciano, A., Albaladejo-García, C., Vallés-González, J. M., & Elvira, J. L. L. (2021). Changes in the Trunk and Lower Extremity Kinematics Due to Fatigue Can Predispose to Chronic Injuries in Cycling. *International Journal of Environmental Research and Public Health*, *18*(7), 3719. https://doi.org/10.3390/ijerph18073719

Held, S., Rappelt, L., Wiedenmann, T., Deutsch, J.-P., Röttgen, J., & Donath, L. (2023). Blood Flow Restricted Cycling Impairs Subsequent Jumping But Not Balance Performance Slightly More Than Non-Restricted Cycling: An Acute Randomized Controlled Cross-Over Trial. *Journal of Sports Science & Medicine*, *22*(1), 44–50. https://doi.org/10.52082/jssm.2023.44

Holliday, W., Theo, R., Fisher, J., & Swart, J. (2023). Cycling: Joint kinematics and muscle activity during differing intensities. *Sports Biomechanics*, *22*(5), 660–674. https://doi.org/10.1080/14763141.2019.1640279

Inbar, O. (1996). *The Wingate Anaerobic Test*. Human Kinetics.

Joshi, S., Mahoney, S., Jahan, J., Pitts, L., Hackney, K. J., & Jarajapu, Y. P. (2020). Blood flow restriction exercise stimulates mobilization of hematopoietic stem/progenitor cells and increases the circulating ACE2 levels in healthy adults. *Journal of Applied Physiology*, *128*(5), 1423–1431. https://doi.org/10.1152/japplphysiol.00109.2020

Kilgas, M. A., Yoon, T., McDaniel, J., Phillips, K. C., & Elmer, S. J. (2022). Physiological Responses to Acute Cycling With Blood Flow Restriction. *Frontiers in Physiology*, *13*. https://www.frontiersin.org/articles/10.3389/fphys.2022.800155

Lauver, J. D., Moran, A., Guilkey, J. P., Johnson, K. E., Zanchi, N. E., & Rotarius, T. R. (2022). Acute Responses to Cycling Exercise With Blood Flow Restriction During Various Intensities. *Journal of Strength & Conditioning Research*, *36*(12), 3366–3373.

Tangchaisuriya, P., Chuensiri, N., Tanaka, H., & Suksom, D. (2021). Physiological Adaptations to High-Intensity Interval Training Combined with Blood Flow Restriction in Masters Road Cyclists. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/MSS.0000000000002857

Wei, J., Nassis, G. P., Gu, Z., Zou, Y., Wang, X., & Li, Y. (2021). Acute physiological and perceptual responses to moderate intensity cycling with different levels of blood flow restriction. *Biology of Sport*, *38*(3), 437–443. https://doi.org/10.5114/biolsport.2021.100146