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Swimming Performance Post Blood Flow Restriction Training in Collegiate Swimmers

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SWIMMING PERFORMANCE POST BLOOD FLOW RESTRICTION TRAINING IN COLLEGIATE SWIMMERS

By

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Swimming Performance Post Blood Flow Restriction Training in Collegiate Swimmers

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ABSTRACT

SWIMMING PERFORMANCE POST BLOOD FLOW RESTRICTION TRAINING IN COLLEGIATE SWIMMERS

By

Amy E. Boettcher

PURPOSE: To determine if blood flow restriction (BFR) training improved performance and physiological factors in collegiate swimmers. **METHODS**: Participants (n=10) separated into 2 groups (control [CON] & experimental [OCC]), completed 9 supervised trainings within 3 weeks. Pre- and post-testing included: VO_{2max}, Wingate, swim time trials (TT), strength, and DEXA. Training was identical except OCC underwent bilateral thigh BFR [blood pressure (BP) cuffs inflated 70-90% of systolic BP]. Training: treadmill walking 20 minutes (5x3-minutes at 3 mph, 5% grade, 1-minute rest), followed by bodyweight strength training (squats, lunges & step-ups). Pain levels (scale: 1-10) were taken after the second set of lunges, cuff inflated (PainA), and after all lunges, cuff deflated (PainB). Paired t-tests determined significant change within groups, independent t-tests determined significance between groups, ReANOVA determined significance of pain levels. **RESULTS**: Both groups increased 1 RM leg press CON: 18.0 ± 8.155 (kg) (p=0.008) and OCC: 15.200 ± 5.805 (p=0.004); 1 RM chest press (kg) increased significantly in OCC (p=0.031). Mean peak power (W/kg) increased 1.530 ± 2.389 (p=0.225) CON and 3.772 ± 3.088 OCC (p=0.052). Pain levels were significantly different between days (p=0.012), and between PainA vs PainB (p=0.008). No significant change in swimming TT, VO_{2max}, total work, fatigue index, or body fat occurred. **CONCLUSION:** This BFR training program did not improve swimming performance but indicated adaptation to pain may occur.

Key Words: hypoxia, pain adaptations, strength training, anaerobic power

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CHAPTER I: Journal Manuscript

INTRODUCTION

Blood flow restriction training was first studied years ago in Japan, and was utilized as an addition to resistance exercise to restrict venous return from peripheral limbs (1). Accordingly, as a specific limb is occluded and arterial flow to the muscle is continued but venous outflow is diminished, slow-twitch muscle fibers become fatigued more rapidly, which stimulates an increased recruitment of fast-twitch muscle fibers during low-intensity work. The slow-twitch muscle fibers are oxidative fibers, which thrive when an adequate amount of oxygen (O_2) is available, therefore the hypoxic state (i.e., decreased O_2 availability) within the muscle causes the slow twitch fibers to fatigue rapidly (2–4). Additionally, as muscles are manipulated into a hypoxic state with BFR training, researchers believe additional metabolites (lactate and H^+) are produced. Thus, the sustained hypoxic environment within the occluded area increases metabolite production and increases muscle fiber recruitment during low intensity resistance training with BFR (5). Further, the amplified tension and stretch within the muscle from fluid accumulation during exercise and rest intervals with BFR increases hormonal secretion. This hormonal response leads to enhanced muscle protein synthesis, and ultimately muscular adaptation (6).

Investigators have reported increased strength in exercised muscles not occluded as BFR training takes place elsewhere (i.e., increases seen in arms when legs under BFR). Increased levels of noradrenaline, growth hormone (GH) and insulin-like growth factor-1 (IGF-1) are speculated to be the leading factors stimulating muscular hypertrophy with BFR training (6).

This may signify strength adaptions occur because of altered systemic endocrine levels, specifically noradrenaline, GH and IGF-1, caused by BFR training instead of, or in addition to, local muscular adaptations to hypoxia. However, researchers' found circulating hormones will only assist with increasing strength when combined with an exercise stimulus (7, 8).

Numerous low intensity BFR training programs have demonstrated an increase in muscular strength in various populations (e.g., athletes, elderly, clinical) (7, 9–12). This is a relatively novel idea to boost muscle strength versus the more common heavy resistance or high intensity training [70% - 85% of 1 repetition maximum (1RM) for 8-12 reps], as discussed by the American College of Sports Medicine (ACSM) (5, 13). Therefore, low intensity, low load resistance BFR protocols potentially enable athletes (or deconditioned populations) to train at lower intensities and achieve similar strength gains typically observed with high intensity training (14). This might be especially useful for select athletes who normally complete high intensity training but feel increasingly overloaded. With BFR, a decreased intensity training program could be implemented with potential of creating similar end results from a customary exercise program. Ultimately, BFR training could serve as an integral part of a yearly, periodized training program in various populations for athletes.

Though BFR training has been employed by numerous researchers and utilized with many populations, specific guidelines should be followed to ensure all training occurs in a safe manner (15). To date, limited guidelines exist when beginning a BFR program. For example, researchers' have reported conducting strength training protocols with BFR at 130% of systolic blood pressure (SBP); others have increased the pressure as high as 220 mmHg for all participants. Yet others applied elastic bands around the proximal thigh and increased pressure by decreasing the circumference of the band by 7.6 cm for all participants (7, 9, 10). Although each study had a novel approach, using a standardized percent of systolic blood pressure (SBP) in healthy populations (excluding those with hypertension) may provide a practical solution to monitoring BFR training safety throughout a given program. Diminishing venous return from the legs induces blood pooling and ultimately causes an increased pain response normally reported with restricted blood flow (16). For BFR training to occur safely, with optimized results, and without adverse effects, the cuff pressure should be individualized to each participant, and an attempt made to moderate self-reported pain.

Proper technique and equipment usage should be addressed before any BFR training occurs to ensure the training is completed safely. For instance, many techniques to occlude the limbs have been tested and researchers have shown wider cuff sizes (versus narrow cuffs) require less pressure to diminish venous return. Therefore, pressure should be standardized based on the width of cuff used, keeping in mind larger cuffs require less pressure due to their increased surface area (17, 18). Because BFR is still a relatively new method of training, it should be approached with caution. If done properly the training may lead to increased muscular strength, likely caused by increased endocrine levels and increased fast-twitch muscle fiber recruitment (and training) through low intensity body weight exercises (8, 19).

While BFR training has been incorporated into training for various types of athletes, no practical BFR training method has been published for collegiate swimmers. Due to the specificity associated with swimming, the contribution of dryland training programs are likely effective but limited. Consequently, it is inconclusive as to how useful they might be at improving sport specific, in-water performance. This is especially noteworthy for collegiate swimmers and coaches who want to utilize training time effectively throughout a season. Some researchers have discovered dryland training paired with in-water sprint training showed in-water success, while others found that dryland training did not improve in-water performance (20, 21). Still, many collegiate swim teams incorporate dryland training into their seasonal training programs to increase muscular strength, thus the novelty of low intensity BFR training may have appeal, especially if part of a seasonal training program. The current research design combined aspects of previous studies (7, 10), including a walk training regimen and low intensity body weight strength training sessions to improve swim time trial (TT) performance. Therefore, this training protocol was designed to provide a broader perspective on whether or not BFR, coupled with dryland training, had an effect on in-water TT performance.

Purpose

The purpose of this study was to determine if BFR training would improve swim TT performance and other physiological factors (e.g., anaerobic power, muscular strength, aerobic capacity) in competitive, collegiate swimmers. Further, we aimed to determine if BFR might provide a practical overload during dryland training in the immediate post-season (e.g., post championship phase). The two primary hypotheses were: (1) BFR during low intensity dryland training will have a positive effect on anaerobic power, muscular strength, and maximal oxygen uptake (i.e., performance factors) of collegiate level swimmers, and (2) BFR training will improve swim TT performance during immediate post-season training of collegiate swimmers.

METHODS

Participants

The institutional review board approved this study (APPENDIX A); every participant was required to sign the informed consent (APPENDIX B) before beginning any form of testing. The participants involved in this project were recruited from a Division II swim team. Though researchers' attempted to recruit 30 swimmers, only fourteen (male=10) volunteered and only ten (male=6) successfully completed the training protocol by attending all nine training sessions. Requiring 100% adherence rate allowed for accurate analysis of the effects of the BFR training protocol and pain fluctuations from the beginning of training to the last training session. Fourteen participants participated and were randomized into two groups for the concurrent walk and strength training program: (1) control group (CON, no occlusion) and (2) blood flow occlusion (OCC) group.

Inclusion/Exclusion Criteria

The swimmers involved in the study participated in eight hours of mandatory swim and weight training with the swim team per week, post-championship phase (notably they did not participate in the extra 12 hours of training offered). Participants were not taking any medications and did not have any diagnosed medical condition, which would put them at any risk during the study. Additionally, the participants did not have high blood pressure (BP) as noted on the PAR-Q (APPENDIX C) (i.e., high BP > 140/90 mmHg), and did not miss any of the swim season due to prolonged illness or injury (22). Resting BP was taken on two separate occasions by researchers to determine if the swimmer was eligible to participate.

Pre Testing

Laboratory Visit 1. The initial visit to the Exercise Science lab consisted of a Wingate test and strength tests; the strength tests were completed in the university recreation center. First, participants were taken to the recreation center in pairs and completed a 5-10 RM chest press on a Precor Chest Press Machine *(Woodinville, WA 98072 USA*) followed by a 5-10 RM leg press (*Precor, Woodinville, WA 98072 USA*). 5-10 RM was determined when participants completed at least 5 repetitions but could not complete more than 10. This number was then converted to a 1 RM using the equation published by Lander (23) (100 x Weight) / (101.3 – 2.67123 x Reps).

Following strength tests (after a minimum 10-min rest) each participant completed a five minute warm up on the cycle ergometer (*Lode, Excalibur Sport, Groningen, Netherlands*). Participants then completed the Wingate test, a maximal exertion, 30-second cycle sprint against 7.5% of their measured body weight (e.g., standardized pedal resistance). The variables analyzed from this test were: (a) mean power, (b) mean peak anaerobic power, (c) total work, and (d) fatigue index. Following the Wingate test, each participant cooled down on the bike for two minutes.

Laboratory Visit 2. Day two of testing consisted of body composition testing with a DEXA (*General Electric Company, Boston MA, USA*) scan at a local clinic (*1414 W Fair Ave #190, Marquette, MI*). The post-training DEXA scan (same machine, but moved) took place at the NMU Kinesiology and Exercise Oncology Research Laboratory (*841 Washington St, Marquette, MI*).

Laboratory Visit 3. Day three entailed VO_{2max} testing for all participants. Each test was unique to the participant and was based on their self-reported 10k (running) race pace. After a five minute warm up on the treadmill (*Trackmaster TMX428CP, Newton KS, USA*), participants were fitted with a silicone mask (*7450 Series Silicone V2™ Oro-Nasal Mask, Shawnee KS, USA*) and connected to a Parvomedics TrueOne Metabolic Cart (*OUSW 4.3.4; Sandy UT, USA*) to begin testing. The flow calibration of metabolic cart was completed using a three liter syringe and gas calibration utilized gases of the following concentrations: O_2-16.00%, CO_2–4.00% and balanced N_2. The protocol began at the participants' determined speed, which remained consistent throughout the test, and a 0% grade; each minute the grade increased by 1% until volitional fatigue occurred and a cool down began. Each participant's heart rate was monitored with a Polar Heart Rate Monitor (*Bethpage, NY*) throughout and a rating of perceived exertion

(RPE) was recorded every two minutes (scale, 0 = rest, 5 = hard/comfortably hard, 10 = all out max).

Laboratory Visit 4. Lastly, swim TT took place the day following the VO_{2max} test at the university pool. All participants completed a self-selected warm up which closely mimicked a race day warm up before the first TT. Then, the participants completed a 500 yard TT, followed by a rest period of approximately two minutes. Finally, participants completed a 20 yard TT width wise across the diving well, a routine test during regular season training.

Training Protocol

Participants signed up for three training sessions per week to undergo supervised group training (i.e., standardized treadmill walking + body weight leg exercises). Each training visit lasted approximately 50 minutes with multiple participants training at once, including a mix of OCC and CON groups. The participants in OCC applied X-large thigh blood pressure cuffs (*LotFancy Aneroid Sphygmomanometer*) to each leg at the highest, proximal location and increased the pressure to their individually targeted pressure, determined by 90% of their resting SBP (between 95mmHg and 110 mmHg on average). CON participated in the identical training protocol without a blood pressure cuff and without occlusion.

First, participants walked at a 5% grade at a speed of 3 mph for three minutes followed by one minute of rest with the cuff inflated, repeated five times. Following the walk training, participants rested for five minutes without any pressure in the cuffs before beginning the strength exercises.

To begin the body weight strength training, participants performed 3 sets of 30 squats followed by one minute of rest between sets (cuff inflated). Following two minutes rest (cuff deflated) after the squats, participants began 3 sets of 30 forward lunges (15 lunges per leg) with

1 minute rest in between each set (cuff inflated). Following two minutes of rest (cuff deflated) post lunges, participants completed 3 sets of 2 minutes of step-ups (approximately 8 inches high) with one minute rest (cuff inflated) between each set. Immediately following this, the participants deflated their cuff and the training day was completed. Throughout the body weight strength exercises (squats, lunges, step-ups), participants followed a metronome set to 60 beats per minute; each beat of the metronome signaled movement to keep tempo for the exercise (e.g., one beat signaled the down-phase of a squat, the next beat signaled up-phase of a squat). Throughout the training, following the third set of each exercise, OCC decreased the pressure in their cuffs to normalize limb blood flow before beginning the next exercise after the two minutes of rest.

During the training, pain scale ratings (scale, 0 = no pain, 5 = somewhat painful, 10 = very very painful) were taken approximately half way through walk training (minute 11), immediately following walk training, following the second set of lunges with cuffs inflated (PainA), following all sets of lunges with cuffs deflated (PainB) , and after completion of the training day.

Post-Testing

All post-tests were conducted in the same order as pre-tests, including day of week and time of day, similar to the pre-test lab day visits described prior. Post-testing began two days following the last day of the training protocol in order to complete all post testing within one week of the last day of training.

Variables

The independent variables in this study included training with BFR and without BFR.

The dependent variable categories were: (1) swimming performance, (2) anaerobic adaptations, (3) body composition, (4) muscular strength, (5) maximal oxygen uptake.

Statistical Analysis

Independent t-tests compared descriptive variables for each group, CON vs OCC, at baseline and compared changes between groups. Paired t-tests compared pre to post changes within CON and OCC to determine if significant changes resulted from the training program. A three-way repeated measures ANOVA was enacted to determine any significant differences between pain levels on days two, five, and nine for PainA and PainB. Statistical significance was set to $p \leq 0.05$ for all tests.

RESULTS

Descriptive statistics and baseline values of all participants (n=10; male=6) who successfully completed the required nine days of training are reported in Table 1. Independent t-tests were run comparing changes between groups, CON (n=5) vs OCC (n=5), to determine if BFR training had any effect (Table 2).

Anaerobic Adaptations

While no significant changes were found in any dependent variables between groups, the anaerobic test did not elicit changes within CON (Table 3), but did in OCC (Table 4), determined by paired t-tests from pre- to post-testing. Specifically, mean peak power (W/kg) increased by 1.530 ± 2.389 (p=0.225; d=0.837) in CON and by 3.772 ± 3.088 (p=0.052; d=1.388) in OCC. Mean power (W/kg) decreased in CON and OCC by -0.206 ± 0.508 (p=0.416; d=0.347) and -0.138 ± 0.833 (p=0.763; d=0.330), respectively. Fatigue index (%) increased by 7.056 ± 6.269 (p=0.066; d=1.867) in CON and by 0.665 ± 2.730 (p=0.659; d=0.107) in OCC (note: lower fatigue index = less fatigued throughout the 30 second sprint). Lastly, total work (Joules) decreased in CON by 487.630 ± 1150.706 ($p=0.397$; $d=0.174$) and increased in OCC by 2692.887 ± 5050.712 ($p=0.380$; $d=0.579$). No significant anaerobic changes were seen within either group; however OCC approached significance with their increase in mean peak anaerobic power.

Swimming Performance

CON decreased their 20 yard TT (seconds) by -0.078 ± 0.164 ($p=0.348$; $d=0.157$) while OCC increased 0.820 ± 0.223 ($p=0.456$; $d=0.150$). Overall, CON group decreased their 500 TT (seconds) by -3.400 ± 3.975 ($p=0.128$; $d=0.180$) while OCC increased by 1.00 ± 3.536 ($p=0.561$; $d=0.060$).

Body Composition

No significant changes were found in body fat, trunk fat, or leg fat percentages from pre to post testing. CON increased total body fat (%) and total trunk fat (%) by 0.640 ± 0.921 ($p=0.195$; $d=0.120$) and 0.260 ± 0.991 ($p=0.589$; $d=0.058$) respectively, but decreased total leg fat (%) by -0.840 ± 1.815 ($p=0.359$; $d=0.129$). OCC increased body fat (%) by 0.320 ± 1.050 ($p=0.533$; $d=0.028$), total trunk fat (%) by 0.380 ± 1.750 ($p=0.653$, $d=0.033$), and total leg fat (%) by 0.340 ± 0.820 ($p=0.407$; $d=0.028$).

Muscular Strength

1 RM leg press (kg) significantly increased in CON and OCC by 18.0 ± 8.155 ($p=0.008$; $d=0.296$) and 15.200 ± 5.805 ($p=0.004$; $d=0.029$), respectively. 1 RM chest press (kg) also increased in both groups (CON = 4.0 ± 3.808, OCC = 8.80 ± 6.058); whereby only OCC increased significantly ($p=0.031$, $d=0.283$), versus CON did not ($p=0.079$, $d=0.145$).

Aerobic Capacity

Relative VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) tended to increase more in CON (2.075 ± 4.417, p=0.417, d=0.363) vs. OCC (0.540 ± 4.19, p=0.788; d=0.067). Peak heart rate (bpm) decreased in CON by -2.60 ± 6.309 (p=0.409; d=0.351) and increased in OCC by 2.0 ± 2.915 (p=0.200; d=0.666), though not significantly in either case.

Pain Adaptations

Refer to Table 5 for mean pain levels for OCC and CON. There was a statistically significant difference in reported pain levels between the three training days (p=0.012), between both groups (p=0.001), between PainA (following second set of lunges with cuff inflated) vs PainB (following third set of lunges with cuff deflated) (p=0.008), and there was an interaction between time and group (p=0.008). Figure 1 and Figure 2 show the changes in PainA and PainB over the three days for CON and OCC respectively. Both groups showed decreased pain levels from day two to days five and nine. The significant interaction between the time and group prompted paired t-tests to be run comparing pain levels on each day for both the OCC and CON, with an adjusted alpha of 0.0083. There was a significant difference (p=0.003) as pain levels decreased from Day 2 PainA and Day 9 PainA in OCC, but no other significant differences were found.

DISCUSSION

The primary purpose of this study was to determine if blood flow restriction training improved swimming performance in collegiate swimmers, and secondly to determine if performance factors were improved (i.e., anaerobic power, muscular strength, aerobic capacity). While CON decreased their mean time in the 20 yard TT and the 500 yard TT, OCC increased in both; though neither group showed any significant change, indicating the training program had no effect on swimming performance. The training protocol took place immediately following the participants regular swim season (post nationals); therefore their sport specific (e.g., in-water) training time decreased by roughly half. Though swimming performance did not improve following three weeks of BFR training, several factors should be considered.

Swimming Performance

Ultimately, a detraining effect is not uncommon to occur in athletes following a training season. Mujika et al. (1995) discussed a correlation between swimming sprinters performance and intensity; meaning, as intensity increased so did performance during the training season. Swimmers will typically see signs of detraining when practice time has been cut by 70% from their typical training (24). The participants in the current study saw roughly a 50% decrease in training from their regular season; however, some sport specific detraining effects may have occurred (i.e., swimming performance declined but physiological factors did not). Further, there is inconclusive research related to how much dryland training actually effects swimming performance; this may be due to the extreme specificity of the sport (20, 21). Consequently, the current study protocol attempted to provide a practical, dry-land protocol to augment off-season swim training. However, due to the non-significant swimming results, a strict endorsement for utilizing BFR in dryland, off-season training to augment or maintain in-water performance for a collegiate swim team, is not yet warranted.

Body Composition

There were no significant changes in body composition in either group. Both CON and OCC tended to increase by less than 1% in their total body fat. These findings were supported by previous research by Park et al. (2010), who reported no significant changes in body composition following a two week BFR walk training protocol. Importantly, the athlete's in the current study had completed their competitive swim season at this point and therefore may have altered their diet and had dramatically decreased their training time which may contribute to the slight alterations in body composition.

Anaerobic Adaptations

Park et al. (2010) also found an increase in absolute peak anaerobic power in athletes following an intensive BFR training protocol. Rather than determining absolute power, the current study analyzed relative peak power (W/kg) within each group and found a 12.78% increase ($p=0.225$; $d=0.837$) in CON and a 26.59% increase ($p=0.052$; $d=1.338$) in OCC. Notably, the effect size of both groups was large; however, it was greater in OCC, who tended to increase by a greater amount and approached significance (vs. CON). The increase found in OCC compared to CON demonstrated the possibility of anaerobic adaptations with BFR training. While an increase in mean peak anaerobic power was observed from the test, these findings did not translate to in-water TT performance. Interestingly, CON decreased their 20 yard TT time, whereas OCC increased, though not significantly in either case. Hawley et al. (1992) determined a positive relationship between anaerobic power and swimming performance in both sprinters and distance swimmers, thus the decreased practice time during the post-season likely contributed to decreased/consistent TT performance while anaerobic power tended to increase post BFR training (25).

Muscular Strength

The results of the present study partially support findings in previous studies of strength gains in areas of the body not occluded during a training program (7) and of strength gains in the occluded area (2). For instance, OCC significantly increased 1RM chest press ($p=0.031$; $d=0.145$) while the CON group did not improve significantly ($p=0.079$; $d=0.283$). Importantly, the present study did not include any upper extremity work, therefore while it does support the results reported by previous research, the altered study design should be accounted for when drawing conclusions (7). Madarame et al. (2008) incorporated non-occluded, upper body training as part of their training protocol; the current training protocol did not use the arms in any capacity apart from the pre- and post-testing. Thus, while a significant increase in 1RM chest press was seen in the current study and may have been attributed to beginning a BFR training protocol, extra activities outside of the training program and familiarization to the equipment might have affected the results.

While noradrenaline, GH, and IGF-1 were not analyzed in the current study, it is suspected the increased secretion of these hormones, which are closely associated with muscular hypertrophy, had a role in increasing not only leg strength but also upper body strength. The upper body strength gains are theorized because of the gains seen in the 1 RM chest press in OCC but not in CON, and is supported by previous research which have discussed a systematic effect of BFR based on the increased circulating hormones following BFR training (1, 7, 8). Specifically, Madarame et al. (2008), discussed how hormonal adaptations influenced muscular hypertrophy in non-occluded limbs (arms) which engaged in muscular activity while other areas were occluded (legs). The main hormones measured by those researchers were noradrenaline, IGF-1, GH, and they suspect noradrenaline caused the most significant change, though all hormones were elevated following BFR training. Again, no hormone levels were measured and no upper body training was employed in the present study. Therefore, while hormone levels may have been altered because of the BFR training, the increased 1 RM chest press may have occurred due to reasons outside of the realm of this study (outside training, familiarization, motivation).

While neural adaptations to resistance exercise occur before muscular hypertrophy, that theory is not particularly relevant to these results; there were no upper body exercises to cause this neural adaptation (7, 14, 19). Hydration levels can greatly affect a DEXA scan which did not allow for an accurate analysis of lean mass pre- and post-testing to determine if muscular hypertrophy did occur, though it is suspected (26). Further, the National Strength and Conditioning Association (NSCA) states that muscular hypertrophy can occur following 16 strength training sessions, while this study only included nine overall workouts, the athletes were still training with their team which equated to more than 16 workouts within the three week period (27).

Aerobic Capacity

Park et al. (2010) reported an increase in VO_{2max} following a two week walk training program. The results from the current study do not support those findings. CON increased their relative VO_{2max} ($ml \cdot kg^{-1} min^{-1}$) by 2.075 ± 4.417 (p=0.417) while OCC increased by 0.540 ± 4.197 (p=0.788). The Parvomedics TrueOne 2400 gas analysis system has roughly four percent absolute percentage error in regards to VO_2 and VCO_2, therefore the 3.25% change seen in CON and 0.49% change in OCC could be attributed to standard error associated with the metabolic cart instead of any changes in aerobic capacity (28).

Nevertheless, the in-water aerobic TT (500 swim) supports the change seen in relative VO_{2max} within each group. CON increased their VO_{2max} by 3.25 % which is supported by their decreased 500 TT by 3.400 ± 3.975 seconds (p=0.128; d=0.180). In comparison, OCC only increased their relative VO_{2max} by 0.49 % and increased their TT by 1.00 ± 2.887 seconds (p=0.561; d=0.060). Though these changes were not significant in either group, the data trend presented shows increased aerobic capacity tends to translate to improved swimming performance in aerobic events.

Pain Adaptation

The current study instructed participants to keep the pressure near 90% of SBP and included 360 minutes of training time (within three weeks) while occluded. The study conducted by Park et al. (2010) had an increased pressure (220 mmHg) for a total of 456 minutes of occlusion time within two weeks. Therefore, the present study provides a practical approach to increasing relative peak anaerobic power with a decreased amount of occlusion time and (likely) decreased pain.

As mentioned previously, this novel approach to a resistance training method should be closely monitored as increased pain levels are typically associated with the training (17). The pain levels observed in the current study only included the two pain scales associated with the lunges, PainA (taken following the second set of lunges with cuff inflated) and PainB (taken following the third set of lunges with cuff deflated), these two pain scales indicate the middle of the strength training program. Predictably, the data shows a significant difference between pain levels with the cuff inflated (PainA) versus after the pressure is removed (PainB). This demonstrated high pain levels associated with BFR training decrease substantially directly following the release of the limb occlusion pressure. Previous researchers reported increased discomfort may limit BFR training to only highly motivated individuals, which supports the results found in this research (3). However, following a BFR training session any residual pain or discomfort may mimic what would be felt after a similar workout without occlusion; although, during the training significantly more discomfort is felt.

The significant decrease in pain following the second set of lunges on day nine compared to day two, showcases how adaptations to the discomfort may occur over time in regard to BFR training. Initially, the pain levels reported were quite high in the OCC group, 7.2 ± 1.31 versus the final day of training where the pain levels had decreased to 5.2 ± 1.92. The CON group also showed a decline in pain ratings but not significantly. Therefore, while BFR training may be difficult to adapt to initially (3), as the training program progresses, adaptations in a person's psycho-physiology may occur which could allow the training to become more tolerable.

Limitations and delimitations

A primary limitation of this study was that participants completed BFR training after their competitive swim season ended. Therefore, they had already completed a season of training and were at their peak performance following Nationals, which was part of the rationale to attempt to augment or maintain their performance in the post season. Still, BFR training did not replace the amount of training they were doing during their regular swim season and therefore it was likely difficult to maintain swimming performance with decreased pool time. Further, the current dryland training protocol and dryland pre/post-tests were non-specific to swimmers. Lastly, due to limited time, the some of the pre- and post-testing occurred on the same day as another test (strength & Wingate) or the next day (VO_{2max} & swim TT) which may have negatively affected the test results as noted by NSCA testing guidelines (27). However, the tests were conducted in the same order for both pre- and post-testing.

A delimitation was that BFR was not used while swimmers trained in the water. The end goal of this study was to determine if BFR during dryland training could improve swimming performance, therefore utilizing BFR in the water would interrupt this observation. Lastly, collegiate swimmers were involved in the study to determine if BFR would improve swimming performance in well-trained swimmers, therefore other populations (e.g., other athletes, sedentary population, the elderly) were excluded from the study.

CHAPTER II: Literature Review

The purpose of this study was to determine if BFR training would improve swimming performance in collegiate swimmers. There is indication that BFR training improves several physiological factors (e.g., VO_{2max}, anaerobic power, muscular strength) in collegiate athletes; however, sport specific outcomes have not been extensively studied to determine if BFR may improve athletic performance factors.

A study done by Park et al. (2010) enhanced the aforementioned physiological factors and provided a time intensive training protocol, which may not be practical to collegiate athletes who already participate in daily practice and must balance school work. Therefore, this study, which combines walk training and body weight leg resistance exercise for roughly one hour/day over three days/wk for three weeks, may provide a practical addition to dryland training of collegiate swimmers. The two primary questions were: (1) will the use of BFR during low intensity dryland training for three weeks provide an adequate training stimulus to have an effect on maximal oxygen uptake, anaerobic capacity, and strength (i.e., physiological factors) of collegiate level swimmers, and (2) will BFR improve swimming performance (i.e., swimming time trials) during post-season training of swimmers? This literature review will be separated into several sections as follows: i) introduction to BFR training, (ii) physiological adaptations to BFR; (iii) safety of BFR training; (iv) populations utilizing BFR.

Introduction to BFR Training

Blood flow restriction (BFR) training, introduced over 30 years ago by Yoshiaki Sato in Japan, uses a cuff to restrict blood flow, creating blood pooling in a specific limb(s) (1). BFR, also known as KAATSU training, was implemented initially with the sole purpose of causing muscle hypertrophy by restricting the amount of blood flow leaving a muscle (i.e., inhibiting venous return). Sato introduced the concept by experimenting on himself in attempt to become stronger. After being diagnosed with a pulmonary embolism, he began to experiment with ways to make KAATSU safe for himself and others. He found that the same cuff pressure cannot be applied to everyone; limb and blood vessel size and amount of adipose tissue in the limbs are all factors which need to be considered (15).

Creating an altered environment to muscles in the arms or legs via blood flow occlusion has been shown to quickly fatigue slow-twitch fibers and therefore increase the number of fast-twitch fibers recruited during low intensity work (2, 3). In order to do this properly and safely, the cuff pressure must be individualized to each participant. Determining complete occlusion based on systolic blood pressure (SBP) is not well documented; however, researchers have observed wider cuffs, used to occlude a limb(s) during exercise training, do not necessarily require an extremely high pressure(18). Multiple investigators have reported completing strength training protocols with BFR at 130% of SBP. This has been reported to diminish venous return from the legs, induce blood pooling, and ultimately cause a "throbbing" sensation normally reported during BFR training (16). Ultimately, using a percentage of SBP may provide a practical, individualized, and effective occlusion pressure for future BFR researchers.

Physiological Adaptations

Utilizing BFR training causes the body to adapt to new training mechanisms while going through relatively simple movements. While muscles are manipulated into a hypoxic state, researchers believe additional metabolites are produced, and more muscle fibers are recruited to complete the low intensity resistance training (5). In addition, Madarame et al. (2008) theorized an enhanced endocrine response with increased secretion of noradrenaline, growth hormone (GH), testosterone, and insulin-like growth factor-1 (IGF-1) likely influence strength gains during BFR exercise programs. GH and IGF-1 are produced more rapidly during stretch and overload of a muscle which both occur during BFR programming and traditional resistance training. However, investigators also observed cross-transfer effects of increased arm strength after resistance training with only the legs occluded. The cross-transfer effect only affected muscle which was participating in work as a separate limb was occluded. This indicates an increased affinity for hormonal binding in muscles worked or overloaded without occlusion because of the increased circulating levels of noradrenaline, GH and IGF-1. Importantly, the exercises done in this previous research were completed at low intensity and performed twice weekly, suggesting BFR induced substantial increase in hormones aiding in physiological changes. This seems to indicate many gains from BFR occur because of the effects of hypoxia on the endocrine response systemically, instead of only an isolated response locally (7, 8).

The cellular mechanisms which enhanced muscular hypertrophy during BFR were somewhat unknown until a study completed by Fujita et al. (2007). They found that activation of mTOR (mammalian target of rapamyocin) was an important contributor to muscle protein synthesis (MPS). Typically mTOR, which initiates MPS, becomes increasingly more activated during the rest phase of strength training. This initiation of MPS increases muscular size (i.e., causes muscular hypertrophy) and leads to increased strength in the muscle. The investigators' recruited six male participants who underwent 30 bilateral leg extensions at 20% of 1 RM. Three participants performed the exercise with a cuff initially and then returned three weeks later to do the exercises without the cuff. The other three performed the exercises initially without BFR and secondly with BFR. Importantly, results showed that while typically 70% of 1 RM is needed to achieve muscle hypertrophy, merely completing resistance training exercises with BFR at 20 % of 1 RM increased muscle protein synthesis (MPS) for up to three hours post-exercise in each group following the BFR training. Therefore, the investigators reported training at a low percent of 1 RM with BFR is enough stimulus to increase MPS versus having to train at a much higher intensity (i.e., above 70% 1 RM) to experience muscle hypertrophy without BFR (29). Notably, providing a low intensity resistance training program with BFR may decrease the amount of overload typically seen in resistance training routines and still yield results.

Muscle hypertrophy is often discussed in unison with neural adaptations to new strength training programs. Typically in recreational athletes, the first increases noticed in strength occur because of neural adaptations to the new stimuli which have been introduced to the muscles being activated (30). This should not be confused with the overload of a stimulus, which causes muscular hypertrophy. Muscular hypertrophy takes place when tears in the muscle occur from progressive overload, this increases the secretion of growth hormone which ultimately influence satellite cells to repair the muscle (31). Additionally, the overload of the muscle increases the amount of sarcomeres and myofibrils within the muscle, which ultimately increases the contractile protein (actin and myosin) count and results in strength gains from muscular hypertrophy (30, 31).

In a study conducted by Fry et al. (2010), MPS increased by 56% in men age 68-72, following an acute bout of exercise (data was collected from one session of seated leg raises) with BFR. The blood pressure cuff was set to a pressure of 200 mmHg. No change was observed in the control group performing the same exercises as the group of men exercising with BFR (11). This information is especially useful as the elderly population is already at increased risk of falling; therefore, providing a practical exercise solution which does not pose many risks in healthy adults (e.g., researchers for this study screened for underlying health issues such as cardiac disease, liver and kidney function, and a physical examination) and increases strength may be warranted. Further, utilizing BFR training with the elderly population allowed them to exercise at low intensities with BFR, but reap the benefits of higher intensity exercises (32).

Safety of BFR Training

When proper technique and equipment are utilized, BFR training is potentially a safe mechanism for initiating muscular hypertrophy. Loenneke et al. (2011) published a review of potential safety issues associated with BFR training. Researchers reported wider blood pressure cuffs do not need to be set to as high of a pressure as smaller cuffs to elicit similar results. Larger cuffs apply pressure over a larger section of the muscle, therefore restricting venous return at lower pressures in comparison to a smaller cuff which would need to be set to a higher pressure because of the smaller surface area of the muscle being restricted (17, 18). Still, occluding blood flow to limbs through any mechanism will cause blood pooling in the area, which does not occur without risk.

Klatsky et al. (2000) noted of 300,000 training sessions, less than one percent of participants reported an incidence of venous thrombosis, notably this is lower than reported in the general population. Accordingly, BFR training does not seem to increase the risk of blood clotting. Additionally, Loenneke et al. (2011), observed that BFR training did not have a negative effect, or increase risk of health concerns, as compared to traditional resistance training when comparing cardiovascular response, oxidative stress, and muscle damage (33).

BFR training programs are demanding and require driven individuals to complete them which is why most studies conducted have been on athletes who possess those types of qualities (11, 13). While it is understood that BFR causes discomfort throughout training in the occluded limb(s), specific pain levels during training have not been reported. Therefore, it is not well known if participants adapt throughout a training program and if the feeling of discomfort changes as the program progresses (34, 35). As discussed above, blood pooling occurs in occluded peripheral limbs, therefore it is important to monitor all participants pain levels as they participate in this novel exercise program (15).

Populations utilizing BFR

BFR training has been used to increase muscular strength in athletes, the elderly, and post-operative patients (7, 9–12). High intensity and/or "high-load resistance training" (5) is the conventional means to attain muscular strength gains. The authors of the 2009 the American College of Sports Medicine (ACSM) position stand on progression models in resistance training for healthy adults stated that muscular hypertrophy occurred most in novice individuals at moderate intensity resistance training [i.e., 70% - 85% of 1 repetition maximum (1RM) for 8-12 reps] or for advanced athletes at high intensity resistance training (i.e., 70%-100% of 1 RM for 1–12 reps) (36).

Post-operative patients often have restrictions during rehabilitation (e.g., non-weight bearing, limit range of motion, avoid high overload). The guidelines set forth by ACSM for muscular hypertrophy do not provide rehabilitation patients the opportunity for strength gains, due to the high intensity nature of the exercises. For example, directly following knee surgeries, patients might be faced with restrictions such as: non-weight bearing, partially weight bearing, or fitted with a knee brace for a period of time, as alluded to prior. Therefore, patients must modify lower body exercises in an attempt to decrease the chance of atrophy from occurring in the leg(s). As a case in point, Ohta et al. (2003) discovered utilizing BFR within the first 16 weeks following anterior cruciate ligament reconstruction surgery induced significant recovery of leg muscular recruitment. In total, 44 participants completed identical rehabilitative exercises with the exception of 22 participants completing the exercises with BFR. All of the participants completed the first week of rehabilitation without BFR. The routine consisted of hip abductions and straight leg raises. At the beginning of the second week of these two exercises, the BFR group began to do the exercises with restriction. Beginning at week 8, a hip adduction exercise was introduced to the program. Weeks 9-12, half squats and tubing exercises were added; and finally, by weeks 13-16, walk training exercises were introduced into the program. As outlined above, introducing low load resistance exercise with BFR post surgery decreased the amount of strength loss during the recovery process. The finding reported by the researchers of this study are especially interesting because it offers a strength training mechanism shortly after ACL reconstruction surgery, which is substantially sooner than many participants can return to full weight bearing (usually about 4 months) activities and begin to regain muscular strength (12).

Low intensity, low load resistance protocols paired with BFR training have potential to increase strength in targeted muscles throughout the body - meaning athletes could train at lower intensities with restricted blood flow to attain the same gains associated with high intensity resistance training (14). Current researchers have shown diminished blood flow (BFR) to the legs throughout two weeks of walk training improved maximal oxygen uptake (VO_{2max}) in collegiate athletes (10). However, the researchers' protocol, which demonstrated increased VO_{2max} and anaerobic power, included 25 minutes of walk training twice a day, 6 days a week, for two weeks. Clearly, this type of training protocol is time consuming and may not provide a practical solution for athletic teams looking to enhance their training through the use of BFR to improve VO_{2max} or anaerobic power, which *may* increase sport performance. Especially for collegiate level athletes, participating in dryland training twice a day, 6 times a week, is probably not ideal.

CHAPTER III: Conclusion and Recommendations

In conclusion, if properly conducted, a BFR training program can elicit improved physiological factors but not necessarily increased sport specific performance post-season. Nine visits within three weeks is a small window to elicit strength gains and increase anaerobic power, but is supported by prior research. In accordance, this practical, short term training program demonstrated how BFR could indeed induce positive physiological benefit in our small sample size. Further, muscular hypertrophy is hypothesized to occur through BFR training which may provide a beneficial way for athletes to increase strength without participating in high intensity work. While other physiological factors (e.g., maximal oxygen uptake, fatigue index, total work) did not improve significantly in this training protocol, a longer training program or the same program performed at a different time in an athletic season may elicit more favorable results.

As a BFR training program progresses, pain levels during exercises may decrease. While participation in the training program will likely still require motivated individuals to complete it, observed pain levels during and post exercises should decrease as the body adapts to the BFR training. Following any given training day with BFR, discomfort should closely resemble the discomfort which may be felt after completing a similar workout without BFR.

Further research should be done to determine if swimming performance was effected because of the decreased in water training time or because of the training protocol. Secondly, a complete control group, which did not participate in the training protocol as part of OCC or CON, should be included to determine if the training program was enough to maintain performance. Research regarding pre- and in-season training protocols should be implemented to see how the timing of a BFR training program can possibly augment swim training and improve in-water performance.

This study focused on collegiate swimmers, further research should consider other athletes who may benefit from BFR training, such as power athletes. Lastly, all training sessions were carefully monitored and pain scales were recorded to ensure no adverse or harmful effects occurred during the training protocol. It is advised to closely monitor all participants who participate in a novel training protocol such as the current study.

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TABLES and FIGURES

Table 1. Descriptive information (mean ± SD) for participants at baseline.

	CON (n=5)	OCC (n=5)	α
Age (yrs)	21.60 ± 2.70	20.00 ± 0.89	0.318
Height (cm)	177.00 ± 5.04	183.40 ± 11.54	0.457
Weight (kg)	72.08 ± 8.83	83.64 ± 13.17	0.142
Sex	male=3	male=3	n/a
Total Body Fat (%)	18.320 ± 5.239	23.860 ± 11.352	0.351
Total Trunk Fat (%)	18.520 ± 4.552	26.620 ± 11.568	0.237
Total Leg Fat (%)	20.60 ± 6.262	24.180 ± 11.931	0.569
1 RM Leg Press (kg)	168.80 ± 62.639	142.60 ± 52.743	0.495
1 RM Chest Press(kg)	72.0 ±28.116	72.40 ± 28.702	0.983
Mean Power (W/kg)	8.236 ± 0.643	7.630 ± 0.0	0.103
Mean Peak Anaerobic Power	15.036 ±2.766	14.190 ± 1.781	0.581
Fatigue Index (%)	60.738 ± 6.426	69.213 ± 5.555	0.076
Total Work (J)	17828.816 ± 3266.828	16567.235 ± 3895.578	0.613
Peak HR (bpm)	203.0 ± 7.416	193.60 ± 3.131	0.031*
Relative VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	62.660 ± 6.776	56.740 ± 6.332	0.191
20 Yard Swim (sec)	8.740 ± 0.524	8.458 ± 0.609	0.455
500 Yard Swim (sec)	334.0 ± 20.433	331.60 ± 17.068	0.845

* Significant at < 0.05 level

Table 2. Between group statistics (mean ± SD) of total change (i.e. post – pre-test scores) for each dependent variables (n=10, male=6).

	CON	OCC	α	Cohen's d
Δ Total Body Fat (%)	0.640 ± 0.921	0.320 ± 1.050	0.662	0.325
Δ Total Trunk Fat (%)	0.260 ± .991	0.380 ± 1.750	0.897	0.088
Δ Total Leg Fat (%)	-0.840 ± 1.815	0.340 ± 0.820	0.222	0.896+
Δ 1 RM Leg Press (kg)	18.0 ± 8.155	15.20 ± 5.805	0.549	0.401
Δ 1 RM Chest Press(kg)	4.0 ± 3.808	8.80 ± 6.058	0.172	0.973+
Δ Mean Power (W/kg)	-0.206 ± 0.508	-0.138 ± 0.833	0.883	0.101
Δ Mean Peak Anaerobic Power	1.530 ± 2.389	3.772 ± 3.088	0.235	0.819+
Δ Fatigue Index (%)	7.056 ± 6.269	0.665 ± 2.729	0.102	1.421+
Δ Total Work (J)	-487.630 ± 1150.706	2592.888 ± 5050.712	0.312	0.993+
Δ Peak HR (bpm)	-2.60 ± 6.309	2.0 ± 2.915	0.177	0.997+
Δ Relative VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	2.075 ± 4.417	0.540 ± 4.197	0.610	0.357
Δ 20 Yard Swim (sec)	-0.078 ± 0.164	0.082 ± 0.223	0.975	0.021
Δ 500 Yard Swim (sec)	-3.40 ± 3.975	1.0 ± 3.536	0.102	1.171+

* Significant at < 0.05 level

+ Medium to Large Effect Size

Table 3. Group statistics (mean ± SD) representing total change (i.e., post – pre-test scores) and percent change (i.e. ((post-pre)/pre-test score)*100) within CON group (n=5; male =3).

	Δ	% Change	α	Cohen's d
Total Body Fat (%)	0.640 ± 0.921	3.84	0.195	0.120
Total Trunk Fat (%)	0.260 ± .991	1.830	0.589	0.058
Total Leg Fat (%)	-0.840 ± 1.815	-4.521	0.359	0.129
1 RM Leg Press (kg)	18.0 ± 8.155	13.35	0.008*	0.296
1 RM Chest Press(kg)	4.0 ± 3.808	7.91	0.079	0.145
Mean Power (W/kg)	-0.206 ± 0.508	-2.28	0.416	0.347
Mean Peak Anaerobic Power (W/kg)	1.530 ± 2.389	12.78	0.225	0.837[+]
Fatigue Index (%)	7.056 ± 6.269	12.67	0.066	1.867[+]
Total Work (J)	-487.630 ± 1150.706	-1.98	0.397	0.174
Peak HR (bpm)	-2.60 ± 6.309	-1.24	0.409	0.351
Relative VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	2.075 ± 4.417	3.25	0.417	0.363
20 Yard Swim (sec)	-0.078 ± 0.164	-0.85	0.348	0.157
500 Yard Swim (sec)	-3.40 ± 3.975	-0.98	0.128	0.180

* Significant at < 0.05 level

[+] Medium to Large Effect Size

Table 4. Group statistics (mean ± SD) representing total change (i.e., post – pre-test scores) and percent change (i.e. ((post-pre)/pre-test score)*100) within OCC group (n=5; male=3).

	Δ	**% Change**	**α**	**Cohen's d**
Total Body Fat (%)	0.320 ± 1.050	0.63	0.533	0.028
Total Trunk Fat (%)	0.380 ± 1.750	0.94	0.653	0.033
Total Leg Fat (%)	0.340 ± .820	0.80	0.407	0.028
1 RM Leg Press (kg)	15.200 ± 5.805	11.51	0.004*	0.029
1 RM Chest Press(kg)	8.80 ± 6.058	11.93	0.031*	0.283
Mean Power (W/kg)	-0.138 ± 0.833	-1.80	0.763	0.330
Mean Peak Anaerobic Power (W/kg)	3.772 ± 3.088	26.59	0.052	1.338⁺
Fatigue Index (%)	0.665 ± 2.730	0.88	0.659	0.107
Total Work (J)	2692.887 ± 5050.712	18.20	0.380	0.579⁺
Peak HR (bpm)	2.0 ± 2.915	1.04	0.200	0.666⁺
Relative VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	0.540 ± 4.197	0.49	0.788	0.067
20 Yard Swim (sec)	0.820 ± 0.223	1.08	0.456	0.150
500 Yard Swim (sec)	1.0 ± 2.887	0.31	0.561	0.060

* Significant at < 0.05 level

⁺ Medium to Large Effect Size

Table 5. Pain levels on days two, five and nine for CON and OCC (mean ± SD).

	CON (n=5)	**OCC (n=5)**
Day 2 Pain A	2.70 ± 1.10	7.20 ± 1.30
Day 2 Pain B	2.30 ± .45	3.40 ± 2.70
Day 5 Pain A	1.70 ± .45	5.50 ± 2.35
Day 5 Pain B	1.60 ± .55	1.60 ± .55
Day 9 Pain A	1.40 ± .55	5.20 ± 1.92*
Day 9 Pain B	1.50 ± .71	2.20 ± .84

* Significant difference from Day 2 Pain A at < 0.0083 level.

CON Group Pain Levels

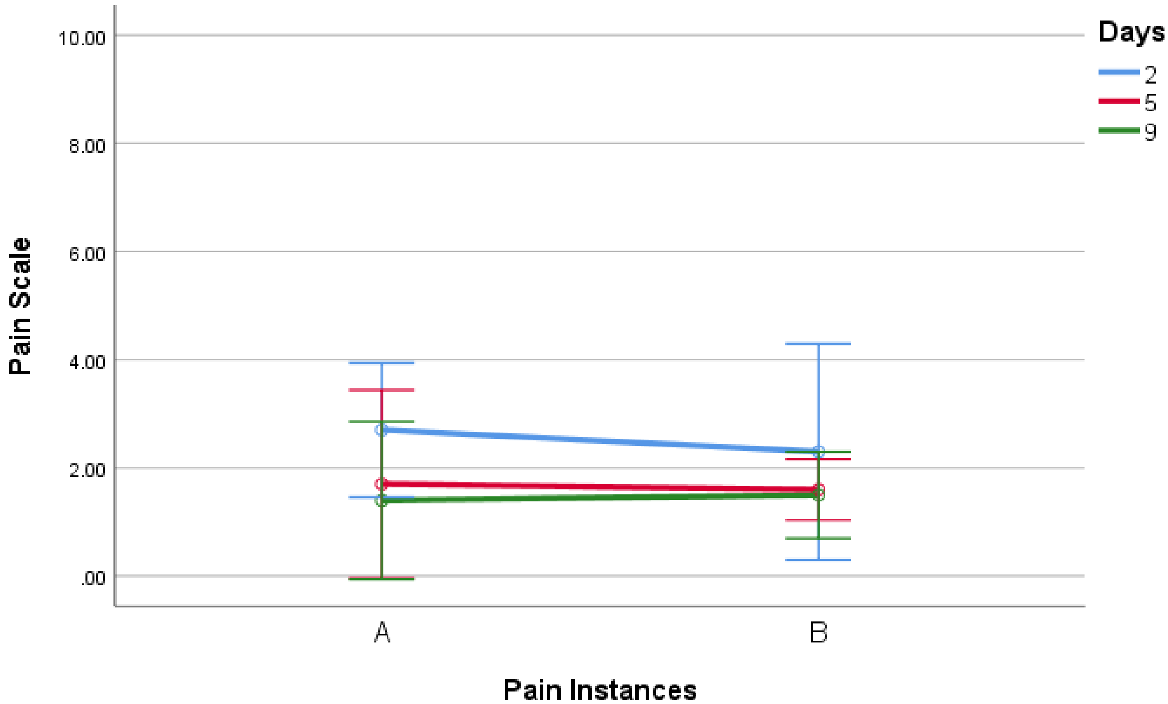

Figure 1. CON group comparisons of PainA (after second set of lunges) and PainB (after completion of lunges) each day.

OCC Group Pain Levels

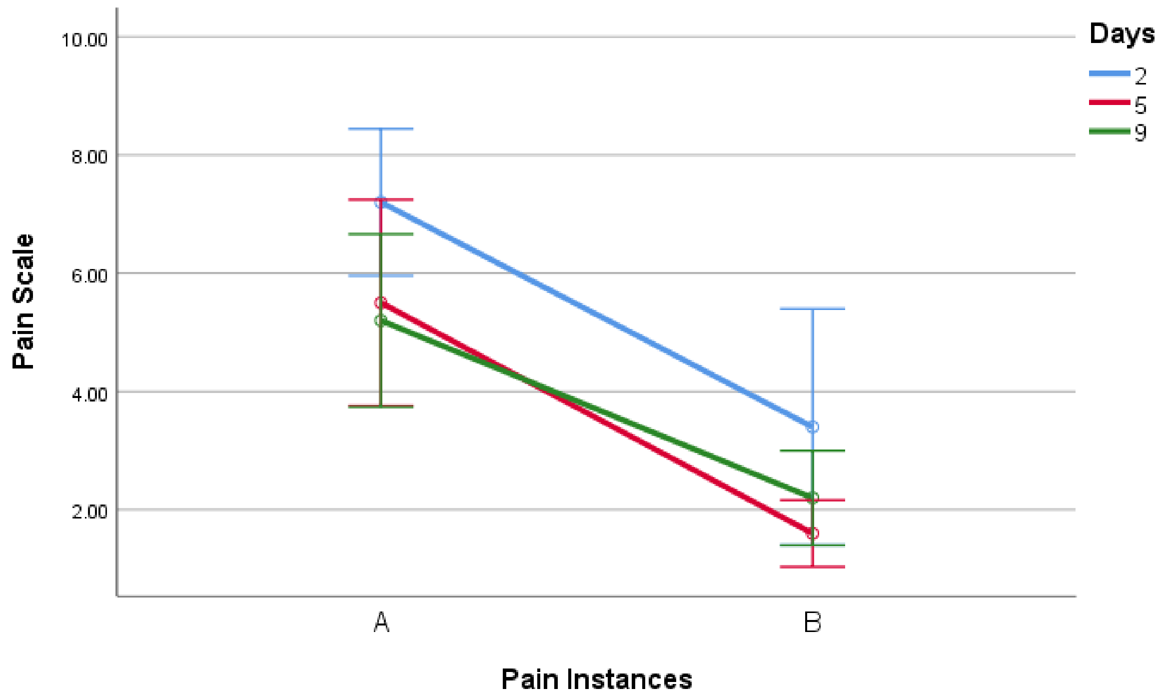

Figure 2. OCC group comparisons of PainA (after second set of lunges, cuff inflated) and PainB (after completion of lunges, cuff deflated) each day.

APPENDICIES

APPENDIX A: IRB Approval

NORTHERN MICHIGAN UNIVERSITY

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Memorandum

TO: Amy Hoeh
School of Health and Human Perfonnance

CC: Scott Drum
School of Health and Human Performance

DATE: March 5, 2018

FROM: Robert Winn, Ph.D.
Interim Dean of Arts and Sciences/IRS Administrator

SUBJECT: **IRB Proposal** HS18-931
IRB Approval Dates: 3/5/18-3/4/19
Proposed Project Dates: 3/5/2018 - 5/4/20 I 8
"Swimming Performance Adaptations Post Blood Flow Restriction Training"

The Institutional Review Board (IRB) has reviewed your proposal and has given it final approval. To maintain permission from the Federal government to use human subjects in research, certain reporting processes are required.

A. You must include the statement "Approved by lRB: Project# HS18-931" on all research materials you distribute, as well as on any correspondence concerning this project.

B. If a subject suffers an injury during research, or if there is an incident of non-compliance with !RB policies and procedures, you must take immediate action to assist the subject and notify the IRB chair (dereande@nmu.edu) and NMU's IRB administrator (rwinn@.nmu .edu) within 48 hours. Additionally, you must complete an Unanticipated Problem or Adverse Event Form for Research Involving Human Subjects

C. Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding. Informed consent must continue throughout the project via a dialogue between the researcher and research participant.

D. If you find that modifications of methods or procedures are necessary, you must submit a Project Modification Form for Research Involving Human Subjects before collecting data.

E. If you complete your project within 12 months from the date of your approval notification, you must submit a Project Completion Fann for Research Involving Human Subjects. If you do not complete your project within 12 months from the date of your approval notification, you must submit a Project Renewal Form for Research Involving Human Subjects. You may apply for a one-year project renewal up to four times.

NOTE: Failure to submit a Project Completion Form or Project Renewal Form within 12 months from the date of your approval notification will result in a **suspension of Human** Subjects Research privileges for all investigators listed on the application until the form is **submitted and approved.**

All forms can be found at the NMU Grants and Research website: http://www.nmu.edu/grantsandrescarch/node/I02

APPENDIX B: Informed Consent

Swimming Performance Post Blood Flow Restriction Training in Collegiate Swimmers

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Introduction

You are invited to participate in a research study which will be taking place at the upcoming Great Lakes Sports Medicine and Life Performance Institute (? Washington Avenue, Marquette, MI) as well as the pool and exercise science lab at Northern Michigan University. You are being contacted because you are a current swimmer on the Northern Michigan Swim Team. Exercise Science Masters student Amy Hoeh and Dr. Scott Drum, current NMU faculty member, will be conducting the research, with assistance from fellow graduate students and NMU faculty.

The purpose of this study is to evaluate the effectiveness of a 3-week, supervised walk training (on a treadmill will both legs occluded by an x-large blood pressure cuff, if in the intervention group) and body weight exercise training protocol (i.e., dryland training) to analyze if there is a change in physiological measurements (e.g., aerobic and anaerobic power), muscular strength, leg balance, and swimming performance.

Inclusion Criteria

- 18-35 years of age
- Current swimmer on the NMU swim team
- Not currently on any medication
- Not recently injured
- Completed the entire season without a prolonged absence from team training

Exclusion Criteria

- Currently on medication due to a medical condition
- Missed part of the swim season due to prolonged illness or injury

Experimental Protocol and Brief Risk Summary

Where will participation take place: Exercise Science Laboratory at NMU, Room/PEIF 146 and the Great Lakes Sports Medicine and Life Performance Institute (Washington St, Marquette, MI).

Experimental Overview – What will you, as a participant, be doing?

We will use a randomized two-group, pre/post, longitudinal study design with 30 participants.

- Eligible and consented individuals will complete:
    1. **Identical pre- and post-training measurements**– The first two days of initial testing will consist of a DEXA body scan, one repetition max bench press followed by a one repetition maximum leg press, lastly a Wingate test will be performed on a cycle ergometer. The following three days will consist of VO_{2max} testing which will be conducted on a treadmill. The last day of testing will consist of two different swimming time trials. The first will be a 20 yard freestyle sprint width wise across the NMU pool, next the participants will complete a timed 500 yard swim. The participants will have 3-5 minutes of rest between each of these time trials.
- Subsequently, participants will be randomly assigned to either a **Blood flow occlusion group (OCC)** or control (CON) training group.
- **What is BFR exactly?** BFR includes placing a large or x-large blood pressure cuff around the upper most point of the leg and pumping the cuff up to an assigned pressure (based on a percentage of each participants resting systolic pressure) to restrict the amount of blood getting into the legs. This occlusion will place the muscles in a hypoxic state, making a workout which is normally not very intensive much more difficult, it will place the body in an anaerobic state which may cause adaptations within the body to occur.
- **The CON (control) group will perform the same training without any BFR.**
- **Both groups will walk at 3 mph at a 5 % grade** for 3 minutes followed by a 1 minute break, this will be repeated 4 more times. Directly following the 25 minutes the OCG group will deflate the blood pressure cuffs. Both groups will have a 3-5 minute break before beginning the strength exercises.
- **Both Groups will perform 3 sets x 30 reps with 1-min rest** (maintaining BFR or cuff inflated) between sets and 2**-min rest between exercises** (without BFR or cuff deflated) in a series of "3" exercises.
    - **The 3 exercises include**:
        - body weight squat;
        - forward lunges lunge;
        - 2-min, 8-inch step-up/step-down exercise
    - **Each training session takes about 45 min**.

***Following training**, participants will return for the post-training testing.

BENEFITS

We cannot guarantee participants will see improvement in swimming performance from participating in this study. Each participant will however, be provided the results from the study once the information has been analyzed by the researchers. Information from this study may have an effect on current dryland training protocols, therefore BFR may be incorporated into try land training to possibly improve swimming performance.

COMPENSATION

You will not be compensated for your participation in this study.

COST OF PARTICIPATION

There will be no cost to you for participating in this research.

RESEARCH RELATED INJURY

In the event of physical and/or mental injury resulting from participation in this study, Northern Michigan University do not provide any medical, hospitalization or other insurance for participants in this study, nor will NMU provide any medical treatment or compensation for any injury sustained as a result of participation in this study, except as required by law. If you are taking medications, it is your responsibility to consult with your physician regarding your participation in this study. Do not volunteer for this study if you have been instructed to abstain from this study (or type of activity prescribed in the study) by a physician. Any problems you experience throughout this study should be discussed immediately with your physician.

CONFIDENTIALY OF RECORDS

We will treat your identity with professional standards of confidentiality. The data from this study may be published, but your identity will not be shown. The NMU Institutional Review Boards (IRB) reserve the right to inspect both the research data collected and your experimental records.

WITHDRAWAL

Your participation is completely voluntary, Amy Hoeh and Dr. Scott Drum will answer any questions you have about the study. Any significant findings which develop during the course of the study which in our opinion may affect your desire to participate will be provided to you as soon as possible. Taking part in this research study is completely voluntary. If you decide not to be in this study, or if you stop participating at any time, you won't' be penalized or lose any benefits for which you otherwise qualify. If you withdraw yourself during the actual testing, no penalty will be incurred.

PARTICIPANT'S RIGHTS INFORMATION

The Northern Michigan U. Institutional Review Board has reviewed the researchers' request to conduct this project.

If any unanticipated problems arise involving human participants, you (the study participant at NMU) **must immediately notify the** NMU **IRB Chair**, Dr. Derek Anderson at **(dereande@nmu.edu** or 906.227.1873**) and NMU's IRB administrator**, Dr. Rob Winn at **(rwinn@nmu.edu** or 906-227-2700 **), and** you **must submit an Unanticipated Problem/Adverse Event form.** Lastly, do not hesitate to contact the NMU researcher, Dr. Scott Drum at sdrum@nmu.edu or 970-371-2620 with study questions or concerns.

I,____________________________________, have read through this consent form. The investigator provided me an opportunity to ask questions and I wish to voluntarily participate in this study.

__________________________________ __________________________________

Signature of Participant Date

APPENDIX C: PAR-Q

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	**Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5.	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____________________

SIGNATURE ____________________ DATE ____________________

SIGNATURE OF PARENT ____________________ WITNESS ____________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

 Supported by: Health Canada Santé Canada

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