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Physiological Responses to Increasing Battling Rope Weight During two 3 Week High Intensity Interval Training Programs

Derek Bornath
University of Windsor

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During two 3 Week High Intensity Interval Training Programs

By

Derek Bornath

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By

Derek Bornath

APPROVED BY:

R. Carriveau

Department of Civil and Environmental Engineering

K.J. Milne

Department of Kinesiology

K.A. Kenno, Advisor

Department of Kinesiology

June 14th, 2017

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ABSTRACT

The purpose of this study was to determine the effect of increasing battling rope (BR) weight during 6 weeks of BR high intensity interval training (HIIT) on upper body oxygen consumption and skeletal muscle strength, endurance and power performance.

Eighteen recreationally active men and 15 women (23±2y) performed ten, 30 sec bouts of all-out exercise separated by 60 secs of rest, 3x/week, for 6 weeks. Males and females exercised at a minimum of 85% of their predicted maximum heart rate, with post exercise blood lactates peaking at 10.79 mmol/L and 8.33 mmol/L, respectively, alternating between the double whip and alternating whip exercises. For the first 3 weeks, women used 40 foot, 1.5 inch, 20 lb ropes, and men used 50 foot, 1.5 inch, 25 lb ropes, after which the BR weight was increased by 10 lb for a second 3 week period of BR HIIT. After 3 weeks and 6 weeks of BR HIIT, males and females increased maximum isometric shoulder flexion and extension, shoulder power output, push-ups, sit-ups, and maximal oxygen consumption. These increases in aerobic and skeletal muscle measurements are similar to previous HIIT studies involving treadmills, cycle ergometers, and stair climbing. Battling rope HIIT produced adaptions in skeletal muscle and aerobic performance in as little as 3 weeks, and with increases in BR weight displaying further improvements after 6 weeks of BR HIIT. These data support the implementation of progressive resistance loading during BR HIIT protocols for strength and conditioning benefits.

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ABBREVIATIONS

ACSM – American College of Sport Medicine

AVG - Average

BLa – Blood Lactate

BR – Battling Ropes

ft – Foot

HIIT – High Intensity Interval Training

HR – Heart Rate

KB – Kettlebell

kg – Kilograms

lb - Pound

lbs – Pounds

min – Minute

mins - Minutes

ml – Millilitres

MVIC – Maximum Voluntary Isometric Contraction

N - Newtons

RM – Repetition Maximum

RPE – Rate of Perceived Exertion

SD – Standard Deviations

sec – Second

secs - Seconds

VO_2 – Oxygen consumption

VO_2 max – Maximal oxygen consumption

Wks - Weeks

INTRODUCTION

High intensity interval training (HIIT) is a form of cardiorespiratory training typically performed at 80 -100% of maximum oxygen consumption (VO_2 max) for 15- 90 seconds on a cycle ergometer or treadmill (Gibala et al., 2012; Gibala & McGee, 2008). Each HIIT exercise bout is separated by a period of low-intensity work or inactivity with work to rest ratios ranging from 3:1 to 1:11, (Gosselin et al., 2012; Laursen & Jenkins, 2002), repeated 4-10 times per session, with 1-7 workouts per week (Green et al., 2000; Rodas et al., 2000), for 1 to 15 weeks (Simoneau et al., 1985; 1987).

Multiple studies have shown that HIIT yields the same oxygen consumption (VO_2) improvements as classical 12-16 weeks of aerobic conditioning, but with up to 90% less training time (Burgomaster et al., 2008). Two weeks of HIIT produced significant increases in VO_2 max, cycle endurance time (increased 81-169%), and aerobic enzyme activity (citrate synthase, cytochrome c oxidase, succinate dehydrogenase, and malate dehydrogenase) (Burgomaster et al., 2005; Little et al., 2011). HIIT also improved anaerobic threshold (Astorino et al., 2012; Bayati et al., 2011), and anaerobic enzyme activity (hexokinase, phosphofructokinase, and lactate dehydrogenase) (Pilegaard et al., 1999; Ziemann et al., 2011). All of these HIIT improvements in anaerobic/aerobic metabolic function may potentially lead to an increased time to volitional fatigue (Juel et al., 2004).

In most studies, HIIT is performed on a motor driven treadmill (Cheetham et al., 1986; Gosselin et al., 2012), or cycle ergometer (Gibala et al., 2006; Jacobs et al., 2013; Mckay et al., 2009) focusing on VO_2 training improvements in the lower body. Given the success of lower body HIIT, investigations began looking at the effects of upper body HIIT on VO_2 and skeletal muscle performance. Le Foll-de Moro et al. (2005) examined the effect of upper body HIIT on VO_2 in male and female wheelchair bound individuals using their wheelchairs and an electromagnetic ergometer to apply propulsion resistance. This upper body (wheelchair) HIIT consisted of a 1:4 work to rest ratio (i.e. 1 minute (min) work: 4 mins active recovery) for 6 sets, 3 times/week for 6 weeks, which resulted in a 36% increase in upper body VO_2 max (Le Foll-de Moro et al., 2005). Recently, Osawa et al. (2014) reported on a combined HIIT arm-leg cycle ergometry protocol with the arm HIIT being 4 sets working at 90% arm ergometer VO_2 max at a 1:1 work to rest ratio (60 seconds (secs): 60 sec active recovery), 2 times/week for 16 weeks. Arm-leg combined HIIT resulted in a significant 20% increase in arm ergometry peak watts suggestive of an increase in arm VO_2, and an increase in muscle cross sectional area of the psoas major, anterolateral abdominal muscles and the quadriceps femoris. HIIT arm-leg induced skeletal muscle hypertrophy also correlated (r=0.90) strongly with an improved VO_2 max (Osawa et al., 2014).

In the last decade, exercising with large diameter ropes (1-2.5 inches) called battling ropes has emerged as a form of HIIT for upper-body cardiovascular training and strength development. Battling ropes (BR) are typically 40-50 feet in length and anchored to the floor creating two equal 20-25 foot lengths weighing between 20-75 pounds (lb). Typically, participants position their bodies with knees and trunk slightly bent while grasping the BR ends and moving their arms/shoulders up and down rapidly in the sagittal plane performing a double whip exercise with both arms moving in unison (Figure 1), and/or an alternating whip exercise with the arms moving opposite to one another (Figure 2).

Figure 1: *Double whip motion. The starting position of the double whip exercise (with the ropes in a downward position) followed by the participant whipping the rope up, and then downward back to the final position, representing one complete cycle.*

Figure 2: *Alternating whip motion. Participants create battling rope motion with arms and shoulders alternating in movement. This shows both the starting and finishing point at which one full cycle is completed.*

Compared to HIIT cycling or treadmill exercise, which are leg dominant, BR HIIT primarily involves activation of upper body musculature (i.e. deltoids, biceps, triceps, and forearms), and trunk musculature (external oblique abdominals and lumbar erector spinae) (Calatayud et al., 2015).

In an acute BR study, Ratamess et al. (2015a) compared VO_2 responses of BR HIIT training to a series of standard resistance exercises and body weight exercises. The BR HIIT training used a 50 foot, 1.5 inch diameter rope weighing 25 lb with subjects training at a 1:4 work to rest ratio (10 sec of alternating whip, 10 sec of double whip, and 10 sec of rope slams, with 2 mins of rest) and this was compared to resistance exercises (squat, bench press, bent-over barbell row, deadlift) for 3 sets, 10 repetitions at 75% 1RM, and to body weight exercises (burpees, planks, push-ups) for 3 sets, 10-20 repetitions per exercise, with 2 min rest intervals between all exercise modalities. They reported that the BR HIIT routine elicited the highest mean VO_2 response (24.6 ± 2.6 ml kg^{-1} min^{-1}) compared to both burpees (22.9 ± 2.1 ml kg^{-1} min^{-1}) and squats (19.8 ± 1.8 ml kg^{-1} min^{-1}), and also produced the greatest heart rate response (153.5 ± 13.9 b min^{-1}) compared to all other exercises (Ratamess, et al., 2015a).

Peak VO_2 and heart rate (HR) responses to double whip BR HIIT were also examined by Fountaine & Schmidt (2015) completing a 1:3 work to rest ratio (15 sec work: 45 sec rest), in male and female subjects using a 50 ft, 1.5 inch, 35 lb BR. The BR HIIT protocol resulted in heart rate responses that were 86% of age predicted HR max, and a peak VO_2 of 40.2 ± 3 ml kg^{-1} min^{-1} in males and 31.3 ± 9 ml kg^{-1} min^{-1} in females (Fountaine & Schmidt, 2015). Similarly, Ratamess et al. (2015b) examined BR peak VO_2 responses following 8 sets of either at a 1:4 work to rest ratio (30 sec work: 120 sec rest), versus responses to a 1:2 work to rest ratio (30 sec work: 60 sec rest), performing alternating whip action for 15 sec, followed immediately by 15 sec of double whip exercise. The 1:2 work to rest ratio elicited a higher peak VO_2 response in both male and female groups (31.6 ± 3.5 and 26.3 ± 5.4 ml kg^{-1} min^{-1}) compared to the 1:4 work to rest ratio (27.5 ± 4.3 and 21.9 ± 6.8 ml kg^{-1} min^{-1}) (Ratamess et al., 2015b), suggesting a shorter work: rest ratio would result in a higher BR HIIT VO_2 training response.

In our lab, unpublished data by McAuslan (2013) examined VO_2 responses to 4 weeks of BR HIIT in males using a 50 ft, 1.5 inch rope weighing 25 lbs, and in females using a 40 ft, 1.5 inch rope weighing 20 lb for 10 sets, 3 times/week, at a 1:2 work to rest ratio (30 sec: 60 sec). The BR HIIT protocol, produced a significant 7% increase in arm ergometer female VO_2 max (pre 31.1 ± 4.0 ml kg^{-1} min^{-1} vs. post 33.5 ± 3.2 ml kg^{-1} min^{-1}), but did not significantly increase male VO_2 max (McAuslan, 2013). McAuslan (2013) also analyzed male and female blood lactate values following 4 weeks of BR HIIT as an indirect measure of anaerobic glycolysis and exercise intensity following an arm ergometer VO_2 max. When comparing pre and post BR HIIT blood lactate values after 4 weeks of training, females remained similar to pre BR training indicating an increase in BR weight may have evoked a further increase in female blood lactate and VO_2 max. However, male blood lactate values decreased by 9% immediately post exercise, and by 7% 5 minutes post exercise following 4 weeks of BR training. Data indicated that the 25 lb BR did not provide an adequate stimulus to significantly increase anaerobic metabolism (blood lactate), rate of perceived exertion, or evoke a significant change in male VO_2 max.

It is interesting to note that Ratamess et al. (2015a) used a 25 lb BR with a 1:4 work to rest ratio (30 sec: 120 sec), peak VO_2 responses were 38.6 ± 4.7 ml kg^{-1} min^{-1} while in a study by Fountaine & Schmidt (2015), using a 35 lb BR with a 1:3 work to rest ratio produced a greater peak VO_2 response (40.2 ± 3 ml kg^{-1} min^{-1})(Fountaine & Schmidt, 2015), suggesting that increasing BR weight, similar to that of traditional progressive resistance training protocols, may provide the critical stimulus to elicit increases in both male and female VO_2 max and blood lactates.

Collectively, various upper body BR HIIT training programs clearly indicate that upper body (arm) HIIT stimulates increases in both peak (Fountaine & Schmidt, 2015; Ratamess et al., 2015a) and VO_2 max (McAuslan, 2013) similar to that reported for lower body HIIT programs, and it has been suggested that increases in BR weight may create the necessary stimulus to further increase VO_2 max with BR HIIT.

While HIIT is traditionally thought of as a form of cardiovascular training, changes in skeletal muscle characteristics following upper body HIIT have also been reported. Meier et al., (2015) studied a combination of BR HIIT exercises and kettlebell (KB) exercises and their effect on altering muscular strength. Their BR and KB training protocol involved 20 minutes 3 times/week for 5 weeks, with 4 sets lasting 2.5 minutes, at a 1:1 work to rest ratio (15 sec work: 15sec rest), with no additional rest when switching between the BR and KB exercises. Surprisingly, Meier et al. (2015) only reported a significant increase in right hand grip strength, and the relative contribution of either BR or KB to the increases in right hand grip strength could not be determined. McAuslan (2013) examined the effects of 4 weeks of BR HIIT with males using 50 ft rope weighing 25 lbs, and in females using a 40 ft rope weighing 20 lb for 10 sets, 3 times/week, at a 1:2 work to rest ratio (30 sec: 60 sec). The data indicated a 10% increase in males, and a 27% increase in female upper body skeletal muscle performance/strength development (push-ups until failure), and increased female abdominal skeletal muscle strength as evidenced by a 10% increase in female sit-up scores.

Along with changes in skeletal muscle characteristics due to upper body HIIT, improvements in skeletal muscle power production have been reported. Driller et al., (2009) analyzed the effects of HIIT arm-leg rowing in male and female rowers following 7 HIIT rowing sessions over 4 weeks consisting of 8 work intervals at 90% of each rower's peak power. They reported HIIT arm-leg rowing significantly improved 2000m power (watts) 6%, and VO_2 peak 7%, compared to traditional high volume, low intensity conditioning arm-leg rowing approach

(Driller et al., 2009). Kramer et al. (2015) comparing BR HIIT and KB training investigated whether skeletal muscle power, as determined by the Wingate arm ergometer testing, was improved more with BR HIIT or KB training following 12 training sessions over 4 weeks at a 1:3 work to rest ratio (15 sec: 45 sec), with 10 intervals per session. Kettlebell training weights were based on each subject's body weight and exercises consisted of 5 standard KB exercises, versus 5 BR HIIT exercises. Kramer et al. (2015) reported that only BR HIIT increased peak Wingate upper body power output by 12.5%.

These studies demonstrated that upper body HIIT and BR HIIT can lead to significant increases in upper body skeletal muscle strength/endurance and/or power and indicate that increasing the BR weight has the potential to generate additional increases in skeletal muscle performance similar to that traditionally seen with increasing weight during resistance training (Driller et al., 2009; Kramer et al., 2015; McAuslan 2013; Meier et al., 2015).

In summary, acute BR HIIT exposure has a significant effect on increasing upper body male and female peak VO_2 (Fountaine & Schmidt, 2015), increases in BR weight further increased peak VO_2 (Fountaine & Schmidt, 2015; Ratamess et al., 2015a), and 4 weeks of BR HIIT increased arm VO_2 max in females by 7%, but no improvement in male VO_2 max (McAuslan, 2013). Additionally, upper body HIIT improves skeletal muscle power (watts) by 4% (Kramer et al., 2015), and strength/endurance as evidenced by increases in push-ups till failure for both male and female subjects, and increased female abdominal skeletal muscle strength (sit-up scores) (McAuslan, 2013). McAuslan suggested that the failure to significantly increase male VO_2 max after of 4 weeks BR HIIT may have been due to the BR weight (25 lbs) being an inadequate stimulus to evoke an increase in upper body VO_2 max, indirectly indicated by reductions in rate of perceived exertion and blood lactates post BR HIIT. His suggestion is supported indirectly by Fountaine & Schmidt (2015) who used a BR that was 10 lbs heavier than the BR used by Ratamess et al. (2015a) and elicited a 4% higher peak VO_2 response. Data suggested that increases in BR weight, similar to increasing load in progressive resistance training protocols, may provide the adequate stimulus to evoke increases in both male and female upper body VO_2 max, as well as elicit additional increases in skeletal muscle strength/endurance and/or power.

Therefore, the purpose of this study is to determine the upper body cardiovascular and skeletal muscle responses to increasing battling rope weight 10 lbs during two 3 week upper body HIIT programs.

The specific objectives were to determine the progressive changes in:

1. upper body arm VO_2 max during the BR HIIT programs
2. upper body strength/endurance, and power due to increasing BR weight
3. heart rate and rating of perceived exertion during and following the BR HIIT programs
4. blood lactate accumulation (immediately post, and 5 min post exercise) during and following BR HIIT programs

METHODS

Session 1- Documentation and Familiarization session

This study recruited 18 males and 18 female recreationally active individuals from the University of Windsor who had been exercising a minimum of 2x/week, for the past 3 months. The population was chosen due to their familiarity of regular exercise (i.e. fatigue, muscle soreness, and exercising heart rates). Participants were recruited from the University campus and the local community via posters, e-mail, social media, and word of mouth (Appendix A, Appendix B). This BR HIIT study was approved by the Research Ethics Board of the University of Windsor allowing participants to engage in these tests and training protocols (REB# 16-239). When a potential participant replied to a recruitment posting, they were sent a letter of information (Appendix C) via email, giving them a better description of what the study entails. Individuals still interested in participating were asked to come to the Multipurpose Research Lab (room 202) in the Human Kinetics building, at the University of Windsor, where they were informed of the study intentions both verbally and in writing, and asked to sign a written consent form (Appendix D). Subsequently, participants were asked to complete the Physical Activity Readiness Questionnaire Plus (PAR-Q+, Appendix E) that determines whether participants are free of any known risks that would indicate potential issues in partaking in the physical exercise prescribed. If the potential participants passed the PAR-Q+, they were asked to fill out the participant information questionnaire (Appendix F), to collect demographic data including age, month/year of birth, height, and weight, and to confirm inclusion/exclusion exercise criteria stated during the recruitment process. Participants were then asked to schedule a date for their baseline testing session following a 24 hour exercise and alcohol hiatus, and were asked to fast for at least 4 hours prior to testing. No exercise for 24 hours prior to testing minimized any muscle fatigue that would interfere with testing data (Calatayud et al., 2015).

Participants were shown and explained the experimental design (Table 1). The first "baseline testing" was done prior to the start of BR training, the second testing session was completed post 3 weeks of BR HIIT, before rope weight was increased 10 lbs, and the last testing session was completed at the end of the 6 week BR HIIT protocol (another 9 sessions).

Table 1: The order of testing and data collection: "x" represents data collection. Baseline testing, during training weeks 1-3, post 3 weeks of BR HIIT, during training weeks 4-6, and post 6 weeks of BR HIIT. The first 3 wks BR size for males was 50 ft, 1.5 inches, 25lbs, and for females was 40 ft, 1.5 inches, 20lbs. The last 3 wks battling rope size for males was 50 ft, 2 inches, 35lbs, and for females was 40 ft, 2 inches, 30 lbs.

Variables Measured	0 Wks	Wk1 HIIT	Wk2 HIIT	Wk3 HIIT	Post 3 Wks	Wk4 HIIT	Wk5 HIIT	Wk6 HIIT	Post 6 Wks
Blood Lactate (Resting)	X				X				X
Flexion MVIC	X				X				X
Extension MVIC	X				X				X
Medicine Ball Slams	X				X				X
Push-ups	X				X				X
Sit-ups	X				X				X
Arm Ergometer VO_2 Max	X				X				X
Heart Rate	X	X	X	X	X	X	X	X	X
Rate of Perceived Exertion (RPE)	X	X	X	X	X	X	X	X	X
Blood Lactate (Immediately Post Exercise)	X				X				X
Blood Lactate (5 min Post Exercise)	X				X				X

Testing consisted of skeletal muscle shoulder flexion/extension Maximum Voluntary Isometric Contractions (MVICs), medicine ball slams, the American College of Sports Medicine

(ACSM) push-up test, YMCA sit-up test, and upper body Astrand arm ergometer VO_2 max protocol. As well, heart rate (HR), pre/post earlobe blood lactate (REB# 30-455, 16-031, 16-239), and rating of perceived exertion (RPE) data was collected during the VO_2 max test.

During the familiarization session participants were given time to practice the BR alternating and double whip HIIT techniques to familiarize themselves with BR prior to the training sessions. At this point the investigator gave feedback to the participants about the proper form while completing the BR exercise, so that for the first training session, participants gained an understanding of how the training exercises should be performed. Participants were told that they will perform 10 intervals, at a 1:2 work to rest ratio, with 30 sec bouts of all-out exercise separated by 60 secs of rest. An emergency action plan for medical emergencies during exercise testing and/or training was established as a precautionary measure (Appendix G).

Session 2: Baseline Testing Session

The baseline testing session took place in the Multipurpose Research Lab (room 202) of the University of Windsor's Human Kinetics building. Each testing session required approximately 80 minutes of participation time including warm up, rest intervals, testing exercises, and post exercise stretching. Participants were reminded via email to fast for 4 hours, and to be alcohol and exercise free for 24 hours before all testing sessions. All participants maintained their regular nutritional and exercise habits outside of testing dates. All testing and training sessions were separated by a minimum of 24 hours, to provide time for muscle recovery. Before all testing sessions and all training sessions participants were fitted with a Polar HR monitor (Model E40) (Figure 3), to become accustomed to the feeling of wearing these devices during exercise.

Figure 3: *A is the Polar Heart Rate Monitor (Model E40) watch and the corresponding chest strap. B is the proper placement of the Polar Heart Rate Monitor chest strap. The chest strap should rest below the nipples and be centered just below the sternum.*

On testing days, once the HR monitor had been fitted, participants were seated for 10 minutes of rest prior to the collection and determination of baseline earlobe blood lactate concentration. Increases in baseline blood lactate concentrations following exercise testing (arm ergometry) represented the contribution of anaerobic metabolism to energy demand and exercise intensity (Gibala & Mcgee, 2008; Ziemann et al., 2011). For blood lactate determination, the standard earlobe technique (Figure 4A-F) was used. (REB #09-197; 16-031; 30-455; 16-239).

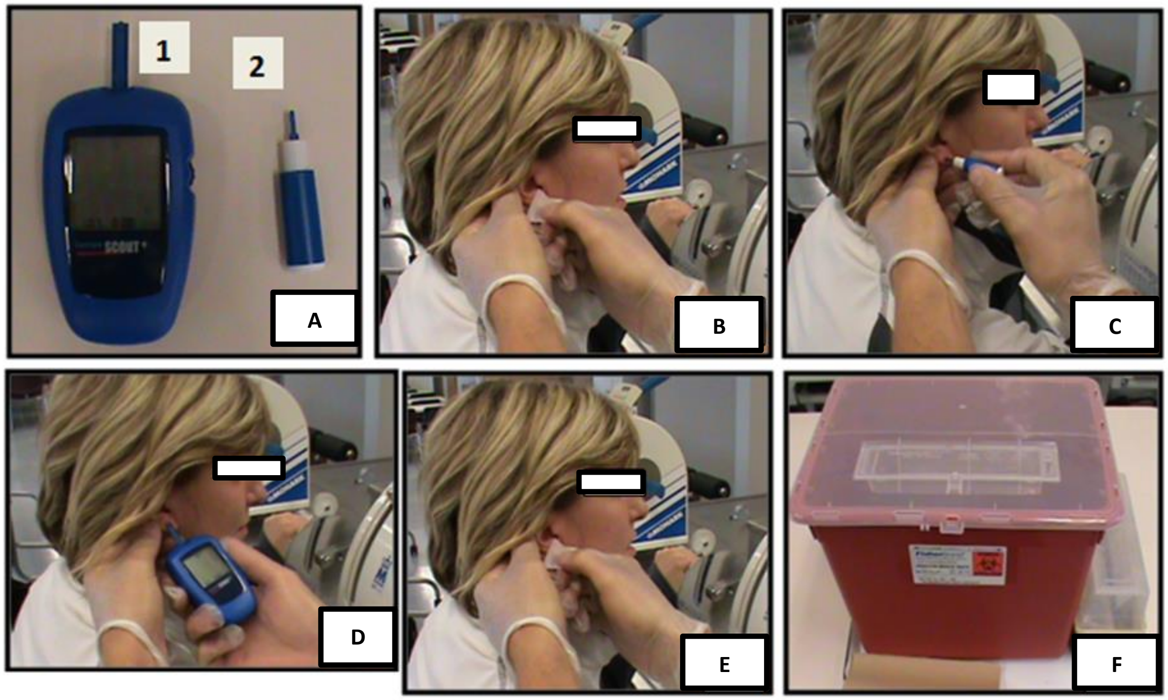

Figure 4: *A is the Lactate Scout Analyzer (1) and Medlance 1.8 mm, 21G Autolancet (2) which was used for obtaining a single blood droplet and analyzing it for lactic acid concentrations. B is the participant's ear being cleaned with an alcohol swab while the investigator was wearing protective gloves and safety glasses, before obtaining a blood droplet. C is the use of the Medlance Autolancet which was held against the earlobe and pressed until it clicks and then disposed of into the sharps container (only simulated in this photo). D is the Lactate Scout testing strip touched to the droplet of blood on the earlobe. Once the droplet touches the strip adequately and a reading is given by the Lactate Scout, the testing strip will be disposed of into the sharps container. E is the earlobe being cleaned with a different alcohol whip post sample. The Medlance Autolancet lactate testing strip and alcohol wipe were disposed of into the sharps container which is seen in F. All areas used were disinfected post-test, with the liquid disinfectant found in the lab.*

Participants with long hair were asked to have their pulled back to expose their ears. The tester wore goggles and disposable latex gloves, and wiped the earlobe of the participants with an alcohol wipe and dried the area (Figure 4B). The earlobe was then pricked with a single use Medlance 1.8mm, 21G autolancet for the collection of a single drop of venous blood (Figure 4C) onto a Lactate Scout Analyzer disposable lactate test strip (Figure 4D). Immediately following collection, the investigator wiped the earlobe with another alcohol wipe (Figure 4E), recorded the lactate value from the Lactate Scout, and immediately disposed of the lactate testing strip into the sharps container (Figure 4F).

It should be noted that blood lactate measurements were taken immediately post arm ergometry testing, and 5 minutes post arm ergometry testing, to facilitate the diffusion of intramuscular lactate into the blood stream for a more accurate estimation of blood lactate concentration (Cheetham et al., 1986; MacRae et al., 1992; Plowman & Smith, 2014). Each lactate measurement was drawn from alternate earlobes to increase participant comfort.

Following blood lactate collection, a standardized dynamic warm-up took place consisting of 10 jumping jacks, 10 backward and forward arm circles, and 10 alternating lunges. This ensured that participants were prepared for movements associated with the baseline testing session. Following the warm-up, a 3 minute rest break was taken prior to the initiation of the muscular strength, endurance, and power tests to allow adequate recovery.

The first test was the shoulder flexion maximum voluntary isometric contraction (MVIC) (Figure 5A). The subject was seated with their hips and torso secured using a padded belt (EL881, Kuny's™ Leather Manufacturing Company, Leduc, AB, CA) to ensure no movement of the lower body and trunk during the test. During the initial testing procedure, the notch that the belt was tightened to was recorded to maintain consistency with the other testing dates. Participants were instructed to keep their back flat against the back of the chair to isolate shoulder joint movement. The flexion MVIC set up (Figure 5A) used a rope handle attached to a cable, which was attached to a load cell (Interface, AZ, USA) anchored to an overhead steal beam. The load cell recorded the force generated during shoulder flexion (pulling downward) or shoulder extension (pulling upward). Note: During the extension MVIC test the participant's positioning was the same, however positioning of the load cell was changed to be anchored to the floor (Figure 5B). Participants held the rope handles parallel to the ground (90 degrees of shoulder flexion) for both flexion and extension MVIC (Figure 5A & 5B).

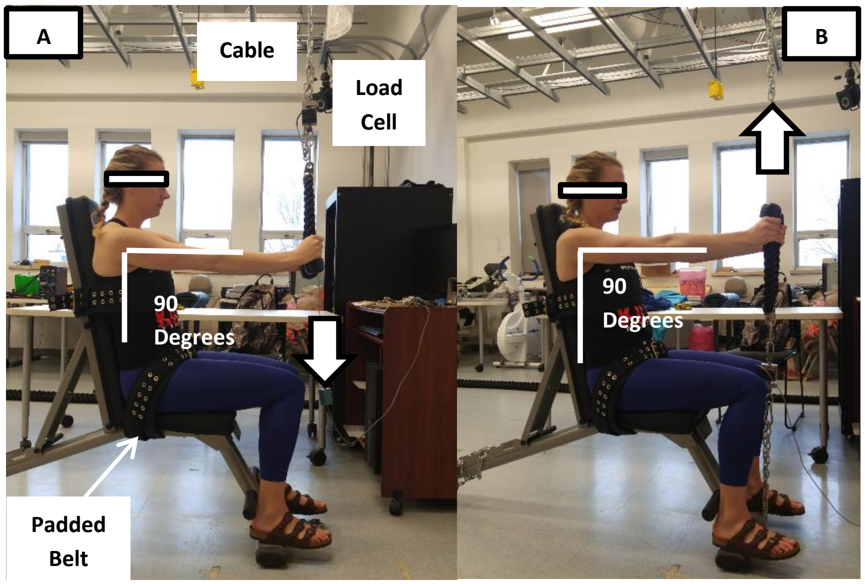

Figure 5: *A shows shoulder positioning at 90 degrees for the shoulder flexion maximum voluntary isometric contraction (MVIC) test, with each participant pulling downward 3 separate times, for 3 secs, with 30 secs of rest in between each attempt B depicts the same shoulder positioning but for the extension MVIC test with participants pulling upward 3 separate times, for 3 secs, with 30 secs of rest in between each attempt. As seen above, participants maintained a flat back throughout both testing procedures, with a padded belt across their hips and torso to prevent lower body and trunk muscle activity.*

Each of the MVIC tests was held for 3 secs, and done 3 separate times (REB #16-031, 16-239). Participants were given 30 secs of rest between each of the MVIC's to allow for muscle recovery. The average of the forces was calculated and recorded as the baseline value for each participant. Performing maximum voluntary flexion and extension isometric contractions were measurements of isometric strength (Figure 5A and 5B), focusing on muscle activation of the deltoids, biceps, triceps, and forearms used during BR activity (Calatayud et al., 2015). This baseline MVIC value was then be compared to the post 3 weeks of BR HIIT values before the rope weight is increased, and the post 6 week BR HIIT values.

The next participants completed the medicine ball slam test (Figure 6A/B), which assessed muscular power changes due to BR HIIT.

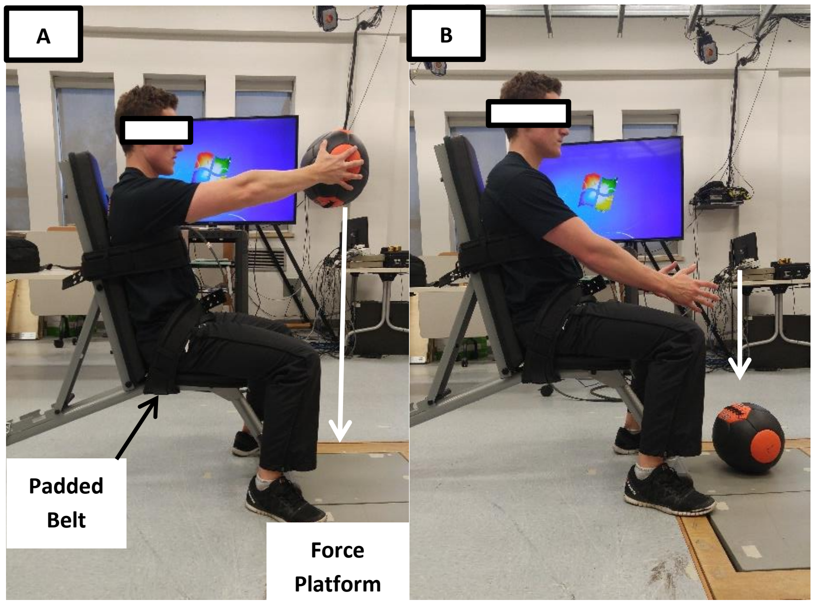

Figure 6: *A was the starting position for the medicine ball slam test with the medicine ball (6 lbs for males and females) at head level, with arms fully extended. B was the final position after the participant has slammed the medicine ball into the force platform. There were 3-5 practice slams allotted, followed by 3 recorded slams.*

Participants were given 1-2 mins of rest to recover from the shoulder MVIC tests, but remained seated in the testing chair. The investigator will demonstrate the medicine ball slam test holding the ball with arms extended between 110-120 degrees of shoulder flexion at eye level. The participant then threw the medicine ball into the force plate (Figure 6B), and the data was recorded. Participants performed 3-5 practice slams followed by 3 recorded slams, which were averaged providing a baseline value to be compared to the post 3 week BR HIIT values, and post 6 week BR HIIT values, to demonstrate power improvements. Male and female subjects used a 6 lb medicine ball (UltraFit^{TM} Evolution^{TM}, Gopher®, Owatonna, MN, USA), to accommodate strength and hand size differences between the sexes. Participants were given 30 secs of rest between each of the recorded ball slams.

After completion of the medicine ball slam test participants were given 2-3 minutes to recover, this was followed by a test of each participants upper-body strength/endurance using the American College of Sports Medicine (ACSM) push-up test (Figure 7).

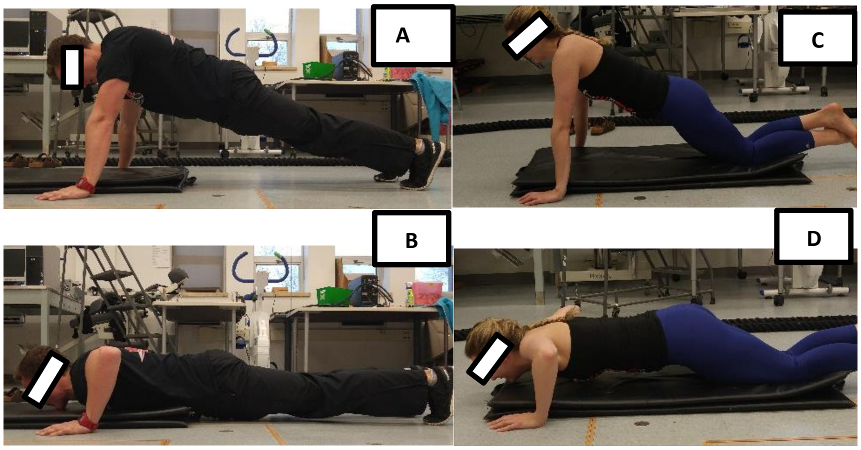

Figure 7: *A was the male starting (upward) position from the toes for the ACSM Push-up Test while B was the male lower finishing position for the ACSM Push-up Test. C was the female starting (upward) position from the knees for the ASCM Push-up Test. D was the female lower finishing position for the female ACSM Push-up Test.*

Subjects were told to place their hands on the floor shoulder width apart (Figure 7A & 7C), with females performing push-ups being supported from their knees (Figure 7C) and males performing this push-up test were supported by their toes (Figure 7A). During each push-up, the chin must touch the mat to count as a successful attempt. Once they could no longer maintain proper form on two consecutive push-ups, the test was terminated. This test was designed to measure the maximum number of push-ups that a participant can do until volitional fatigue, and represented a measure of skeletal muscle strength/endurance. This allowed the investigator to determine the effect of BR HIIT on push-up endurance, comparing the baseline values, to the post 3 weeks of BR HIIT values, and the post 6 week BR HIIT values.

After testing upper body muscular endurance, the subjects were given another 2-3 min rest and then completed the YMCA Bent-Knee Sit-up test to establish trunk muscular endurance (Figure 8).

Figure 8: *A was the starting positioning for the YMCA Bent-Knee Sit-Up Test. B was the end positioning for the YMCA Bent-Knee Sit-Up Test. Once the elbows touch the knees, the participant returned to the starting position (the shoulder blades return to the mat) to complete one full repetition.*

All participants laid on their back, knees bent with their feet off the mat and hands behind their head, with their elbows forward. The investigator held their feet still while the participants lifts themselves off the floor until their elbows touched their knees, indicating a successful repetition. The participant then lowered themselves to the floor until the upper portion of their back touches the mat. The investigator recorded how many repetitions are completed until failure at a cadence of 30 sit-ups per minute, or one every 2 seconds. When the participant could no longer touch their elbows to their knees for two consecutive repetitions, the test was terminated. The scores achieved by each participant in the baseline testing session provided a score which was compared to the post 3 weeks of BR HIIT values, and the post 6 weeks of BR HIIT scores.

After the tests of muscular strength, power, and endurance, participants were seated for 10 minutes to recover prior to doing the arm ergometer aerobic capacity (maximal oxygen consumption, VO_2 max) test. The maximal oxygen consumption test for upper body (arm) determined the participant’s ability to take in and utilize oxygen, the standard measure of aerobic capacity. To determine the upper body VO_2 max, participants pedalled with their arms on a Monark Arm Ergometer (Model 881) (Figure 9), designed specifically for upper body aerobic testing, while completing the progressive Astrand (1965) VO_2 maximum protocol (Appendix I).

Prior to the arm ergometer test, the investigator began by recording HR data with the previously fitted Polar HR monitor (Figure 3), which displayed the exercising HR of the participants at each stage of the Astrand VO_2 max test. Each subject was shown a Borg Ratings of Perceived Exertion (RPE) 6-20 point scale which quantified the degree of difficulty felt by each participant throughout different stages of testing and training sessions (Appendix J). During the arm ergometer test, the investigator held up the RPE chart at the end of each 2 minute period, and pointed to the scale, while having the subject indicate (nod) to the effort they perceived. The participant was fitted with a Hans Rudolph facemask (Model V2) (Figure 9) which was attached to the VO_2 testing apparatus (Cosmed FitMate PRO) for minute to minute gas collection and analysis.

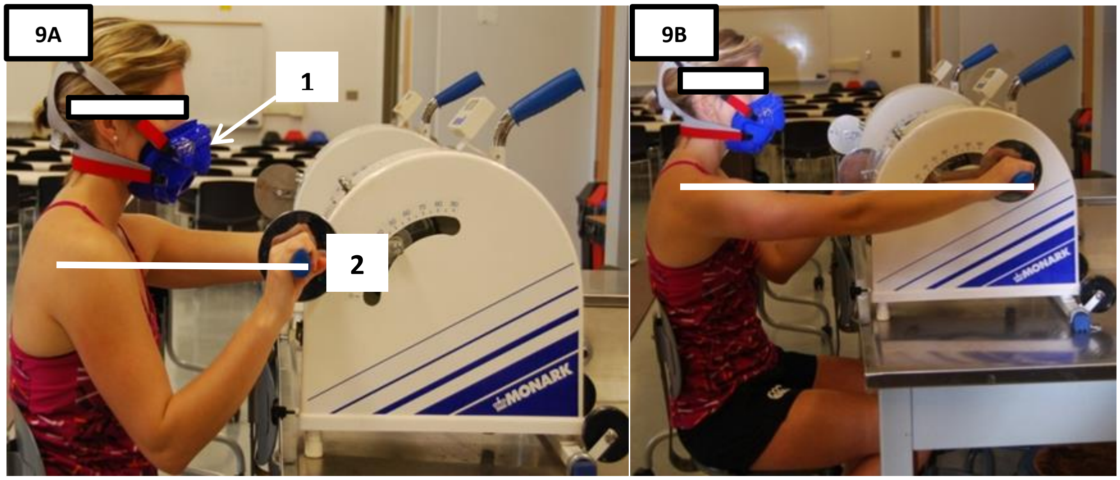

Figure 9: *A illustrates the starting position of the Astrand Arm Ergometer Protocol (Appendix F). The head of the humerus was set parallel to the axis of the arm ergometer pedal axis. B displays the second half of a full rotation of the Arm Ergometer. The seat was set to allow adequate arm extension during the pedalling motion. 1 is the Hans Rudolph VO2 max mask with head straps for positioning and 2 is the Monark Arm Ergometer set shoulder height.*

Participants were seated with their seat/body position set so that the head of the humerus was parallel to the axis of the arm ergometer pedals and at a distance allowing adequate extension of the arm during pedalling (Figure 9A and 9B).

The subject pedaled for a few minutes to familiarize themselves with the arm ergometer motion. The participant began by arm pedalling at 60 rpm, which was set using a digital visual display located on top the ergometer. The initial workload (resistance) was set at a workload of 10 Watts and then the workload was increased by 10 Watts every two minutes until the maximal workload of 100 Watts was reached (Appendix I). If the participants were still pedalling at 100 Watts, participants then were instructed to increase the revolutions per minute by 10 every 2 minutes until volitional fatigue was achieved. RPE values recorded through each stage. During the arm ergometer workloads, gas collection was monitored via the Cosmed FitMate PRO equipment, continuously until volitional fatigue, along with HR via the polar heart rate monitors and RPE via the Borg scale. As mentioned previously, immediately after completion of the

Astrand arm ergometer protocol an earlobe blood lactate measurement was determined, as well as a 5 minutes' post exercise blood lactate concentration. The Hans Rudolph facemask was then sterilized in-between each participant in an autoclave located in the Kinesiology laboratory (Room 241).

After all tests were completed, participants were again given the opportunity to practice the BR alternating and double whip HIIT intervals to familiarize themselves prior to the training sessions. The investigator provided feedback to the participants about the proper form while completing BR exercise so that participants gained an understanding of how the BR exercises should be performed, when they arrived for the first training session.

Battling Ropes HIIT Sessions

When participants arrived at the first training session they were fitted with a Polar HR monitor (Figure 3), shown a copy of the Borg RPE 6-20 scale (Appendix J), instructed how to count their cadence for each BR exercise, and given an explanation of the BR HIIT protocol. To measure cadence during each interval, participants self-reported to the number of complete BR cycles they performed (the number of times they returned to the start/finish position; double whip= rope hitting the ground; alternating whip= right hand returning to elevated starting position), to keep track of potential differences from interval to interval as fatigue sets in. The standardized dynamic warm-up then took place consisting of 10 jumping jacks, 10 forward and backward arm circles, and 10 alternating lunges. This is to ensure that participants were prepared for movements associated with the training session. Following the warm-up, a 3 minute rest break was taken prior to the initiation of the BR HIIT training to allow adequate recovery from the warm-up. Participants were reminded about the work to rest interval ratio to which they would be performing throughout the BR HIIT sessions. For the purposes of this study participants performed ten, 30 sec bouts of all-out exercise separated by 60 secs of rest, therefore completing a 1:2 work to rest ratio (McAuslan, 2013; Ratamess et al., 2015b). This ratio was chosen because it had been previously noted in an acute BR study to elicit greater VO_2 response compared to other less intense work to rest ratios. Total training session time was approximately 30 minutes including warm up, BR HIIT, and cool down.

Participants completed the two most common BR motions; the double whip (Figure 1) which saw both arms moving together, and the alternating whip (Figure 2) which saw arms moving opposite of each other in the sagittal plane. The 10 different rounds completed were comprised of 5 alternating rope whip, and 5 double rope whip, interchanging each set (Table 2) to prevent specific muscular fatigue and reduce deterioration of BR form between workout sets. For both exercises, the rope was bolted to the floor using steel anchors, and participants were coached on maintaining a head up, tight core, with knees and trunk in a slightly bent position. As fatigue began to set in, the knees and trunk of participants may not remain completely stationary, and it was the job of the investigator to constantly monitor participant technique and provide feedback.

Table 2: The exercise protocol throughout each HIIT session which saw the double whip and alternating whip interchanged each interval to minimize specific muscular fatigue, and reduce breakdown of form during each successive workout set.

Workout Set	Rope Exercise
1	Double whip
2	Alternating whip
3	Double whip
4	Alternating whip
5	Double whip
6	Alternating whip
7	Double whip
8	Alternating whip
9	Double whip
10	Alternating whip

HIIT Protocol:

30:60 (sec:sec)

Participants began their "all out" exercising work interval completing double whip exercise using a 50 ft 25 lb BR for males, and a 40 ft 20 lb BR for females, at 1.5 inches in diameter (Figure 1), for 30 secs. A Gymboss Interval Timer (Figure 10) was used to track time of the intervals using a "beep" to begin the work and rest periods.

Figure 10: *Gymboss Interval Timer was pre-set to indicate the beginning and end of every work and rest period with a "beep".*

At the end of each work interval, participants self-reported their HR, RPE, and cadence during all 18 BR HIIT sessions (Table 3). After 60 secs of recovery, participants then were asked to complete a maximum "all out" effort of an alternating whip exercise for 30 secs (Figure 2), and then the same length of recovery time was allotted, with the participants seated between rounds.

Table 3: *The investigator recorded each participants HR, RPE and cadence during each session to determine physiological responses throughout the BR HIIT study.*

Round	Battling Rope Variation (30 Secs)	Rest Break (Secs)	Heart Rate (BPM)	RPE (6-20)	Cadence
1	Double Whip	60			
2	Alternating Whip	60			
3	Double Whip	60			
4	Alternating Whip	60			
5	Double Whip	60			
6	Alternating Whip	60			
7	Double Whip	60			
8	Alternating Whip	60			
9	Double Whip	60			
10	Alternating Whip	60			

Throughout the first 3 weeks, males utilized a 50 ft, 1.5 inch diameter, 25 lb BR, which was increased to a 50 ft, 2 inch diameter, 35 lb BR for the last 3 weeks of training (as seen in Table 1). Females began with a 40 ft, 1.5 inch diameter, 20 lb BR for the first 3 weeks, and was increased to a 40 ft, 2 inch diameter, 30 lb BR for the last 3 weeks. Female rope size was shortened, reducing the weight of the rope, due to the difficulty shown with the full-length rope in a pilot study by McAuslan (2013).

At the end of each testing and BR HIIT session participants completed a stretching routine, where each stretch is held for a minimum of 20 secs. Sit and reach (hamstrings), seated twist (low back and gluteal), arm across chest (chest), cobra (back and abdominal), and wrist flexion and extension (forearm muscles) stretches are to be performed. A foam roller and lacrosse ball were provided as well to aid in participant recovery post exercise. After each training session, all equipment used (ropes, ergometer, seat, polar HR monitor, medicine ball) was sterilized with disposable alcohol wipes.

Participant Confidentiality

Participant's personal information and testing results was stored confidentially. All digital data was stored on a password protected computer with hard copies being locked in the investigators office locked away. All Cosmed VO_2 data was stored on a password protected computer in the Multipurpose Laboratory. All personal data was stored as a unique identification number, instead of a participant name to further keep the data anonymous. Participants were notified that if they felt uncomfortable, or would like to no longer participate in the research study, they could withdraw from the investigation at any point in time.

Sample Size

The purpose of this study was to examine if there were any physiological adaptations in shoulder maximum voluntary isometric flexion and extension contraction, shoulder medicine ball slam power, push-up endurance, sit-up endurance, arm ergometer VO_2 max, heart rate, and metabolic adaptations in exercising lactate concentration with BR HIIT and increases in BR weight after the first 3 weeks of the study. With an alpha level of 0.05, an effect size of 0.8, and a power of 0.8, the sample size necessary to detect significant changes was 12 participants of each sex. For this study, the aim was to recruit 18 of each sex to prepare against potential dropouts negatively affecting the statistics.

Statistics

Statistical analyses were performed using IBM SPSS24. All data including descriptive statistics were presented as means and standard deviations (SD). Discriminative analyses using univariate ANOVAs were conducted on skeletal muscle performance data (Shoulder flexion MVIC, shoulder extension MVIC, medicine ball slams, push-ups, and sit-ups), and physiological data (VO_2 max, average peak HR, and average peak RPE) to investigate and identify relationships throughout the training protocol. All ANOVA's required repeated measures on the factor of time (baseline, post 3 weeks of BR HIIT, and post 6 weeks of BR HIIT). Direct comparison of the two sexes were avoided due to the different lengths of BR that were used throughout the testing and training period. For the analysis of lactate values a 3 (resting, immediately after, and 5 minutes post exercise) x 3 (baseline, post 3 weeks of BR HIIT, and post 6 weeks of BR HIIT) repeated measures factorial ANOVA was used, with one for each sex. Mean differences were considered statistically significant when $p < 0.05$.

RESULTS

Descriptive Statistics

Participant characteristics are outlined in Table 4. Three females dropped out due to injuries obtained outside of the study, and the inability to adhere to the time commitment of the training protocol.

Table 4: *Participant characteristics.*

Sex	Age (years)	Weight (kg)	Height (m)
Males (n=18)	22.61 ± 2.09	82.99 ± 10.92	1.77 ± 0.07
Females (n=15)	23.13 ± 1.44	64.36 ± 7.13	1.66 ± 0.07
Values are means ± SD.			

Battling Rope Specific Physiological Performance

Battling Rope HIIT RPE Response

Univariate analyses for males determined there was no significant differences in their ratings of perceived exertion (RPE) responses with BR weight increases for both double whip $F_{(1,17)} = 2.942$, $p=0.125$, and alternating whip $F_{(1,17)}$. Females however, demonstrated significant differences in RPE response with an increase in BR weight for the double whip intervals $F_{(1,14)} = 19.240$, $p<0.01$ (Table 5). Similarly, significant differences in heart rate response were produced for alternating whip $F_{(1,14)} = 23.474$, $p<0.01$, with an increase in BR weight.

For males, comparing difference in double whip, and alternating whip with the light ropes, there was a significant difference in RPE response $F_{(1,17)} = 235.501$, $p<0.001$, as well as a significant difference with the heavier BR $F_{(1,17)} = 45.720$, $p<0.001$ (Table 5). Females demonstrated significant differences similar to males comparing double whip and alternating whip intervals for the light BR F (1,14) = 85.235, p<0.001 (Table 5). With heavier BR females produced significant differences when comparing double and alternating whip intervals, as alternating whip had a greater RPE response F (1,14) = 49.720, p<0.001.

Table 5: *Double whip vs. alternating whip mean peak RPE and mean peak heart rate (HR) responses during the first and last 3 weeks of battling rope HIIT.*

Sex		Peak RPE Double Whip	Peak RPE Alternating Whip	Peak HR Double Whip (bpm)	Peak HR Alternating Whip (bpm)
Males (n=18)	First 3 Wks (25lb Rope)	17.78 ± 0.17	18.27 ± 0.23[b]	178.42 ± 1.17	178.86 ± 1.15
	Last 3 Wks (35lb Rope)	17.91 ± 0.30	18.26 ± 0.26[b]	178.52 ± 1.67	177.24 ± 1.2[ab]
Females (n=15)	First 3 Wks (20lb Rope)	17.66 ± 0.26	18.16 ± 0.30[b]	178.7 ± 1.28	179.35 ± 1.55
	Last 3 Wks (30lb Rope)	17.13 ± 0.22[a]	17.63 ± 0.23[ab]	176.35 ± 1.39[a]	176.19 ± 1.31[a]

Values are means ± SD. beats per minute – (bpm).
[a] p<0.05 First 3 wks vs Last 3 Wks. [b] p<0.05 Double whip vs Alternating Whip.

Battling Rope HIIT Heart Rate Responses

Univariate analyses for males produced no significant differences in average peak heart rate (HR) between the double whip exercises with the increase in BR weight from 25 lb to 35 lb F (1,17) = 0.018, p=0.897, however there was significant increase in average peak HR during the alternating whip exercise after an increase in BR weight F (1,17) = 13.708, p<0.01. For females, there was a significant increase in average peak HR when increasing the BR from 20 lb to 30 lb for the double whip interval F (1,14) = 14.322, p<0.01, as well as during the alternating whip interval F (1,14) = 28.283, p<0.01 (Table 5).

When comparing differences between the two styles of BR whips at the same rope weight, there was no significant difference between the double and alternating whip HR response with the 25 lb BR weight $F(1,17) = 3.189$, $p=0.112$, however there was a significant difference with the increase in BR weight to 35 lbs when comparing the two styles of BR whip $F(1,17) = 8.438$, $p<0.05$ (Table 5). In females, no significant changes in HR response were demonstrated between the two styles of BR whip with both the 20 lb light rope $F(1,14) = 2.425$, $p=0.158$, and with the 30 lb heavier rope $F(1,14) = 0.192$, $p=0.673$.

Battling Rope HIIT Blood Lactate Response

For males, the univariate analyses determined that the [BLa] during the 9th BR session rose significant immediately post exercise from resting levels $F(1,17) = 194.890$, $p<0.001$. There was no significant difference between the immediately post exercise [BLa] and 5 minutes post exercise $F(1,17) = 4.540$, $p<0.05$. When comparing resting values to that 5 minutes after BR intervals, [BLa] remained significantly different $F(1,17) = 125.416$, $p<0.001$. For females, there was also a significant rise in [BLa] during the 9th BR session from resting levels immediately post exercise $F(1,14) = 76.599$, $p<0.001$. Similar to males, there was not a significant decrease in [BLa] from the immediately post exercise to the 5 minutes post exercise sample times $F(1,14) = 3.346$, $p=0.089$ (Table 6). Females also displayed significant differences between resting values and 5 minutes post BR intervals $F(1,14) = 72.849$, $p<0.001$.

Table 6: *Summary of 9th and 18th battling rope HIIT session blood lactate values for male and female participants.*

Sex		Resting Blood Lactate (mmol/L)	Immediately Post Exercise (mmol/L)	5 Minutes Post Exercise (mmol/L)
Male (n=18)	9th Session	1.65 ± .0.44	10.56 ± 1.98[a]	9.71 ± 2.47[bc]
	18th Session	1.46 ± 0.24	10.79 ± 2.19[a]	10.29 ± 3.19[bc]
Female (n=15)	9th Session	1.61 ± 0.54	8.33 ± 2.71[a]	7.70 ± 2.57[c]
	18th Session	1.79 ± 0.58	8.21 ± 2.27 [a]	7.01 ± 2.15[bc]

Values are means ± SD.
[a] $p<0.05$ Resting vs Immediately Post. [b] $p<0.05$ Immediately Post vs 5 Minutes Post.
[c] $p<0.05$ Resting vs 5 Minutes Post.

Based on univariate analyses of [BLa] during the 18th BR session, for males, concentrations rose significantly immediately post exercise $F(1,17) = 188.869$, $p<0.001$, and decreased significantly 5 mins after the BR session $F(1,17) = 7.020$, $p<0.05$ (Table 6). For males, [BLa] were also significantly different when comparing resting values to 5 minutes after heavy BR intervals F (1,17) = 100.150, p<0.001. For females, during the 18th session [BLa] rose significantly from resting levels immediately post exercise F (1,14) = 102.830, and then similarly to males decreased significantly 5 minutes post exercise F (1,14) = 15.882, p<0.01. When comparing resting values to 5 minutes after exercise, females produced a significant difference as well, F (1,14) = 75.460, p<0.001.

A comparison of resting [BLa] for males between the 9th and 18th BR sessions did not display significant changes F (1,17) = 2.283, p=0.149, along with no significant changes immediately post exercise F (1,17) = 0.263, p=0.614, and 5 minutes post exercise F (1,17) = 0.043, p=0.838. Similar results were produced for females as differences between resting [BLa] did not reach significance F (1,14) = 0.847, p=0.373, as well as no significant change immediately post exercise F (1,14) = 0.082, p=0.778, and 5 minutes post exercise F (1,14) = 2.267, p=0.154 (Table 6).

Skeletal Muscle Endurance

Push-ups

For males, univariate analysis showed significant improvements were produced after 3 weeks of BR HIIT F (1,17) = 21.60, p<0.001, with further significant improvements after the second 3 week BR HIIT phase F (1,17) = 9.831, p<0.01 (Figure 11). Males also produced significant increases between baseline (0 weeks) and post 6 week BR HIIT values F (1,17) = 30.866, p<0.001.

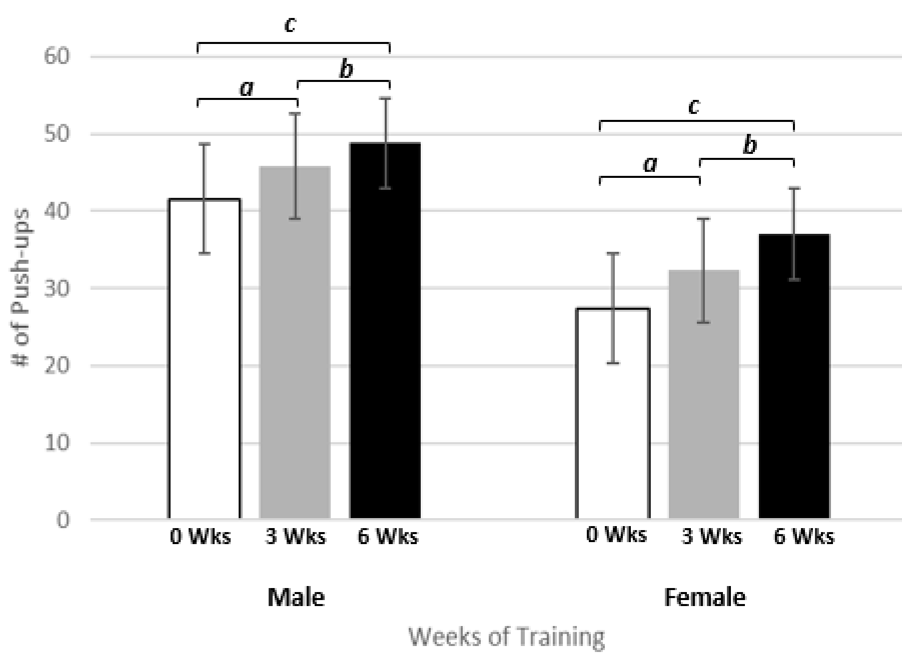

Figure 11: *Number of push-ups to volitional fatigue completed by males and females following 3 and 6 weeks of BR HIIT. Males n=18, Females n=15. Values are means ± SD, [a] p<0.05, 0 vs 3 wks; [b] p<0.05, 3 vs 6 wks; [c] p<0.05, 0 vs 6 wks.*

Females sit up scores also improved significantly after the first 3 weeks of BR HIIT F (1,14) = 17.908, p<0.01. Significant improvements were also produced after the second 3 week training period F (1,14) = 56.732, p<0.001. It is also important to note that females saw significant differences when comparing post 6 week BR HIIT push scores, to that of baseline (0 weeks) values F (1,14) = 37.391, p<0.001.

Sit-ups

Based on the univariate analyses, for males there was a significant improvement in consecutive sit-ups after the first 3 weeks of BR HIIT $F(1,17) = 16.112$, $p<0.01$, and further significant improvement after the last 3 weeks of BR HIIT $F(1,17) = 32.327$, $p<0.001$ (Figure 12). For males, sit-up scores also increased significantly between baseline (0 weeks) and post 6 wks BR HIIT values $F(1,17) = 40.876$, $p<0.001$.

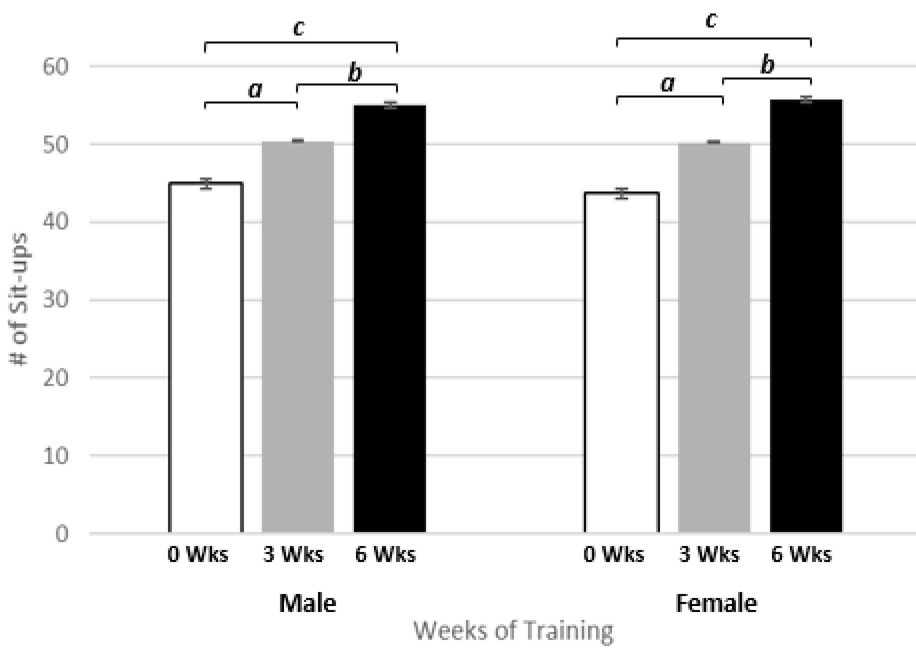

Figure 12: *Number of sit-ups to volitional fatigue completed by males and females following 3 and 6 weeks of BR HIIT. Males n=18, Females n=15. Values are means ± SD,* ^{a} *p<0.05, 0 vs 3 wks;* ^{b} *p<0.05, 3 vs 6 wks;* ^{c} *p<0.05, 0 vs 6 wks.*

Females also produced significant sit-up endurance improvements from the first phase of BR HIIT $F(1,14) = 37.246$, $p<0.001$, and significant improvements from the second 3 week BR phase $F(1,14) = 9.571$, $p<0.01$. Compared to baseline values (0 weeks), significant improvements were also noted after 6 week of BR HIIT $F(1,14) = 23.983$, $p<0.001$.

Skeletal Muscle Strength

Shoulder Flexion MVIC

Univariate analyses revealed that for males, after the first 3 weeks of BR HIIT significant shoulder flexion improvement was demonstrated F (1,17) = 14.825, p<0.01, with further improvement also reaching significant levels after an additional 3 weeks of BR HIIT F (1,17) = 4.656, p<0.05, when compared to the first 3 weeks' scores (Figure 13). Significant improvements were also reported after the 6 weeks of BR training when compared to baseline values (0 weeks) F (1,17) = 25.914, p<0.001.

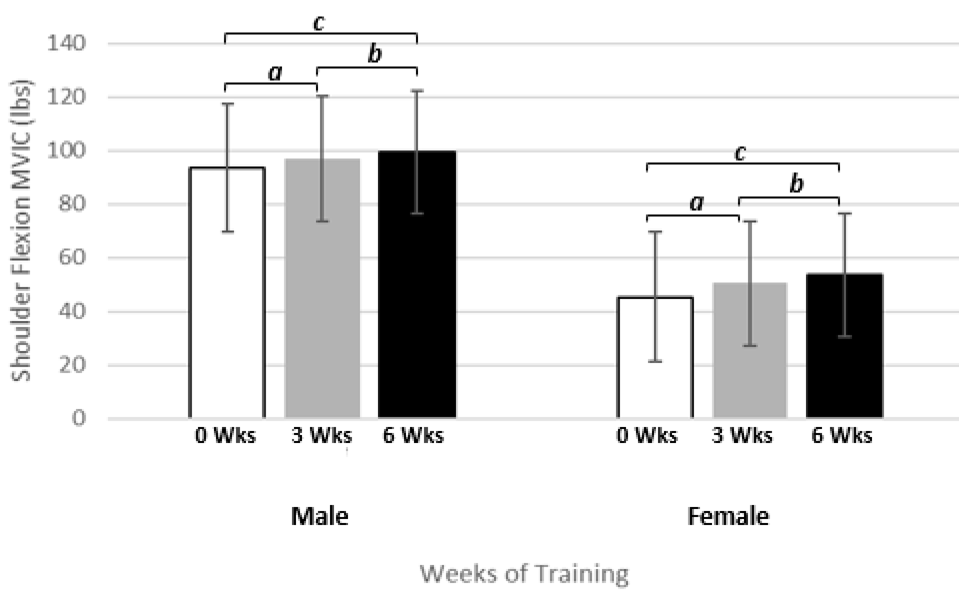

Figure 13: *Shoulder flexion maximum voluntary isometric contraction (MVIC) for males and females following 3 and 6 weeks of BR HIIT. Males n=18, Females n=15. Values are means ± SD, [a] p<0.05, 0 vs 3 wks; [b] p<0.05, 3 vs 6 wks; [c] p<0.05, 0 vs 6 wks.*

Females generated significant improvements after both 3 week BR HIIT phases, F (1,14) = 52.118, p<0.001, F (1,14) = 11.839, p<0.01, respectively. These increases lead to further significant improvements when comparing baseline levels (0 weeks) to post 6 weeks of BR HIIT F (1,14) = 139.665, p<0.001.

Shoulder Extension MVIC

Using univariate analyses to determine shoulder extension improvements, males did not improve significantly after the first 3 week period F (1,17) = 3.817, p= 0.067. When comparing the first 3 weeks scores and post 6 weeks BR HIIT scores, males also did not improve significantly F (1,17) = 0.076, p= 0.787, however comparing baseline scores (0 weeks) to post 6 week BR HIIT protocol score, males did produce significant improvements F (1,17) = 4.706, p<0.05 (Figure 14).

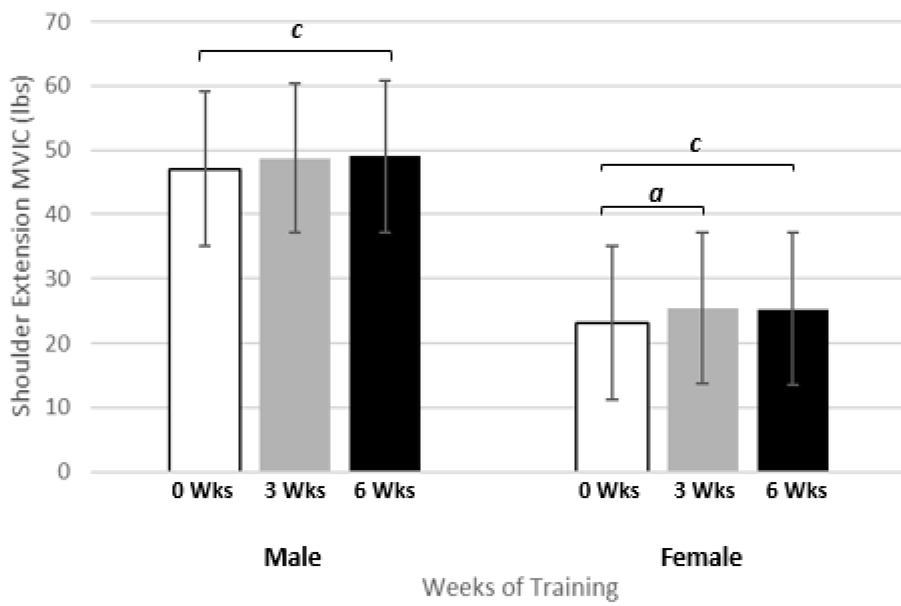

Figure 14: *Shoulder extension maximum voluntary isometric contraction (MVIC) for males and females following 3 and 6 weeks of BR HIIT. Males n=18, Females n=15. Values are means ± SD, [a] p<0.05, 0 vs 3 wks; [c] p<0.05, 0 vs 6 wks.*

Females demonstrated significant shoulder extension improvement after the first 3 weeks of BR HIIT F (1,14) = 13.708, p<0.01, but similar to the males, the improvement after the first 3 weeks did not reach significant levels F (1,14) = 0.071, p=0.793. Also, it is important to note that significant improvements were found between the baseline testing session, and in the final testing session, after completion of the 6 week BR HIIT protocol F (1,15) = 28.571, p<0.001.

Skeletal Muscle Power

Medicine Ball Slam Peak Force

Based on the univariate analyses, for males, there was a significant improvement in skeletal muscle power production during the ball slam test after the first 3 weeks of BR HIIT $F(1,17) = 17.645$, $p<0.01$, as well as further significant improvements after the last 3 weeks $F(1,17) = 12.205$, $p<0.01$ (Figure 15). Comparing baseline values (0 weeks) to that of post 6 weeks of HIIT, significant increases were produced after completion of the 6 week BR protocol as well $F(1,17) = 29.210$, $p<0.001$.

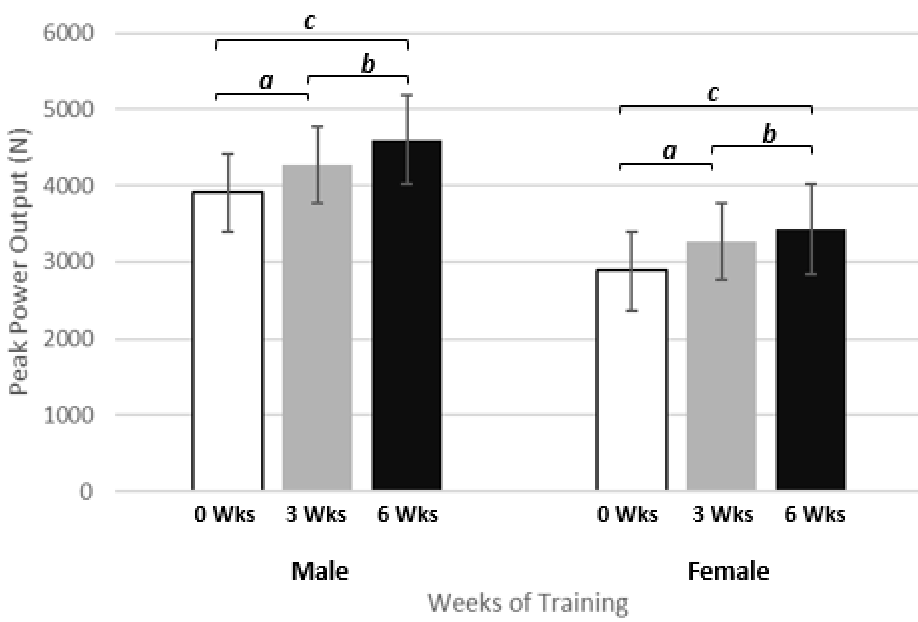

Figure 15: *Male and female medicine ball slam peak power output following 3 and 6 weeks of BR HIIT. Males n=18, Females n=15. Values are means ± SD, [a] p<0.05, 0 vs 3 wks; [b] p<0.05, 3 vs 6 wks; [c] p<0.05, 0 vs 6 wks.*

Females produced similar significant improvements after both 3 week BR HIIT periods, $F(1,14) = 17.316$, $p<0.01$; and $F(1,14) = 28.379$, $p<0.001$, respectively. This also resulted in a significant increase from baseline levels after the end of the 6 week training period $F(1,14) = 32.802$, $p<0.05$.

Blood Lactate Concentrations

For males, the resting blood lactate concentrations ([BLa]) rose significantly immediately after the arm ergometer Astrand protocol for the baseline (0 weeks) testing session (Pre) $F (1,17) = 139.439$, $p<0.001$, after 3 weeks of BR HIIT testing session $F (1,17) = 141.582$, $p<0.001$, and the post testing session $F (1,17) = 198.645$, $p<0.001$, after all 6 weeks of the BR HIIT protocol had been completed. Females produced similar results demonstrating that resting [BLa] also rose significantly immediately after the arm ergometer exercise in the baseline testing session (Pre) $F (1,14) = 113.318$, $p<0.001$, after the 3 weeks of BR HIIT testing session $F (1,14) = 100.226$, $p <0.001$, and post 6 weeks of BR training $F (1,14) = 85.548$, $p<0.001$ (Table 7).

Table 7: *Summary of BR HIIT blood lactate values pre and post Astrand arm ergometer VO_2 max protocol for male and female participants.*

Sex		Resting Blood Lactate (mmol/L)	Immediately Post Exercise (mmol/L)	5 Min Post Exercise(mmol/L)
Male (n=18)	0 Wks	1.44 ± 0.23	7.45 ± 2.1^{d}	6.82 ± 2.14^{ef}
	3 Wks	1.54 ± 0.29	7.83 ± 2.14^{d}	6.64 ± 2.15^{ef}
	6 Wks	1.47 ± 0.21	9.15 ± 1.94^{bcd}	8.21 ± 2.16^{bcef}
Female (n=15)	0 Wks	1.57 ± 0.54	6.19 ± 1.76^{d}	5.89 ± 1.90^{f}
	3 Wks	1.77 ± 0.38	7.53 ± 2.24^{ad}	6.47 ± 1.91^{ef}
	6 Wks	1.43 ± 0.45	8.3 ± 2.77^{cd}	7.39 ± 2.06^{bcef}

Values are means ± SD.
[a] $p<0.05$ 0 vs 3 wks. [b] $p<0.05$ 3 vs 6 wks. [c] $p<0.05$ 0 vs 6 wks.
[d] $p<0.05$ Resting vs Immediately Post. [e] $p<0.05$ Immediately Post vs 5 Min Post.
[f] $p<0.05$ Resting vs 5 Min Post.

Blood lactate concentrations 5 minutes post exercise were taken to determine any patterns of intramuscular lactate diffusion. When [BLa] compared to the immediately post exercise lactate values, males found that there was a significant decrease during all three testing sessions;

baseline (0 weeks) $F(1,17) = 10.628$, $p<0.01$, post 3 weeks of BR HIIT $F(1,17) = 30.771$, $p<0.001$, and post 6 weeks of BR HIIT protocol $F(1,17) = 11.913$, $p<0.01$ (Table 7). Female [BLa] did not see a significant decrease during the baseline (0 weeks) testing period $F(1,14) = 2.143$, $p=1.65$, however significant reductions in [BLa] were reported after the 3 weeks of BR HIIT testing session $F(1,14)$ 12.157, $p<0.01$, and during the final testing session post 6 weeks of BR HIIT $F(1,14) = 6.013$, $p<0.05$.

Comparisons of [BLa] were also done between resting levels and 5 minutes post arm ergometer exercise, to which males still had significantly increased [BLa] in the baseline (0 weeks) $F(1,17) = 107.118$, $p<0.001$, post 3 weeks BR HIIT $F(1,17) = 94.186$, $p<0.001$, and post 6 weeks BR HIIT $F(1,17) = 137.863$ (Table 7). Females produced similar significant results when comparing resting [BLa] to that 5 minutes after exercise in the baseline (0 weeks) $F(1,14) = 79.307$, $p<0.001$, after 3 weeks of BR HIIT $F(1,14) = 89.250$, $p<0.001$, and post 6 weeks BR HIIT $F(1,14) = 112.267$, $p<0.001$, testing sessions (Table 7).

Comparing differences between resting [BLa] values over the three testing periods (Baseline [0 weeks], post 3 weeks BR HIIT, post 6 weeks BR HIIT), in males, no significant differences were produced between baseline (0 weeks) and after 3 weeks of HIIT $F(1,17) = 0.364$, $p=0.559$, along with no significant differences between the baseline and post 6 weeks BR HIIT $F(1,17) = 0.00$, $p=1.000$, and comparing 3 weeks of BR HIIT and post 6 weeks BR HIIT testing sessions $F(1,15) = 0.218$, $p=0.647$. Females also did not demonstrate significant changes in resting [BLa] when comparing baseline testing concentrations to that of the 3 weeks post BR HIIT testing session $F(1,14) = 1.850$, $p=0.195$, between baseline and post 6 weeks BR HIIT concentrations $F(1,14) = 3.957$, $p=0.067$, and between the post 3 weeks BR HIIT testing values and post 6 week BR HIIT values $F(1,14) = 0.497$, $p=0.492$ (Table 7).

Analyzing differences between immediately post exercise [BLa] over the three testing periods (Baseline [0 weeks], post 3 weeks of BR HIIT, post 6 weeks of BR HIIT), for males no significant differences were reported between baseline and post 3 week BR HIIT $F(1,17) = 1.848$, $p=0.192$, however there was significant differences in [BLa] between baseline and post 6 weeks of BR HIIT testing sessions $F(1,17) = 17.184$, $p=<0.01$, and between the post 3 week BR HIIT and the post 6 week BR HIIT testing sessions $F(1,17) = 16.206$, $p<0.01$ (Table 7). Females produced significant [BLa] changes between baseline and the post 3 weeks of BR HIIT testing sessions $F(1,14) = 6.660$, $p<0.05$, and baseline and the post 6 week BR HIIT testing sessions $F(1,14) = 19.708$, $p<0.05$, however there were not significant differences between the post 3 week BR HIIT values and post 6 week BR HIIT testing session [BLa] immediately after exercise $F(1,14) = 2.061$, $p=0.173$.

Based on the univariate analysis of testing session (Baseline (0 weeks), Post 3 weeks, Post 6 weeks) [BLa] 5 minutes post exercise, for males, produced significant differences between the post 3 week BR HIIT and post 6 week HIIT testing sessions $F(1,17) = 34.138$, $p<0.001$, and significant differences between baseline and post 6 week BR HIIT testing session [BLa] $F(1,17) = 14.772$, $p<0.01$, however there were no significant changes between baseline and post 3 weeks of BR HIIT testing [BLa] $F(1,17) = 0.143$, $p<0.710$. Females similarly did not produce significant changes in [BLa] 5 minutes after exercise when comparing baseline and 3 weeks post BR HIIT testing concentrations $F(1,14) = 1.537$, $p=0.235$. When comparing post 3 weeks and post 6 weeks of BR HIIT [BLa] significant differences were reported $F(1,14) = 5.238$, $p<0.05$, and significant differences were found between baseline and post 6 weeks BR HIIT [BLa] $F(1,14) = 9.852$, $p<0.01$ (Table 7).

Oxygen Consumption

VO_2 Maximum

For males, completion of univariate analyses determined there was a significant improvement in VO_2 maximum after the first 3 weeks of BR HIIT period $F(1,17) = 34.286$, $p<0.001$, as well further improvements reached significant levels after second 3 week BR HIIT period $F(1,17) = 15.911$, $p<0.01$ (Figure 16). Significant improvements were also noted when comparing baseline values, to that of the final testing session after completion of the 6 week BR HIIT protocol $F(1,17) = 48.750$, $p<0.001$.

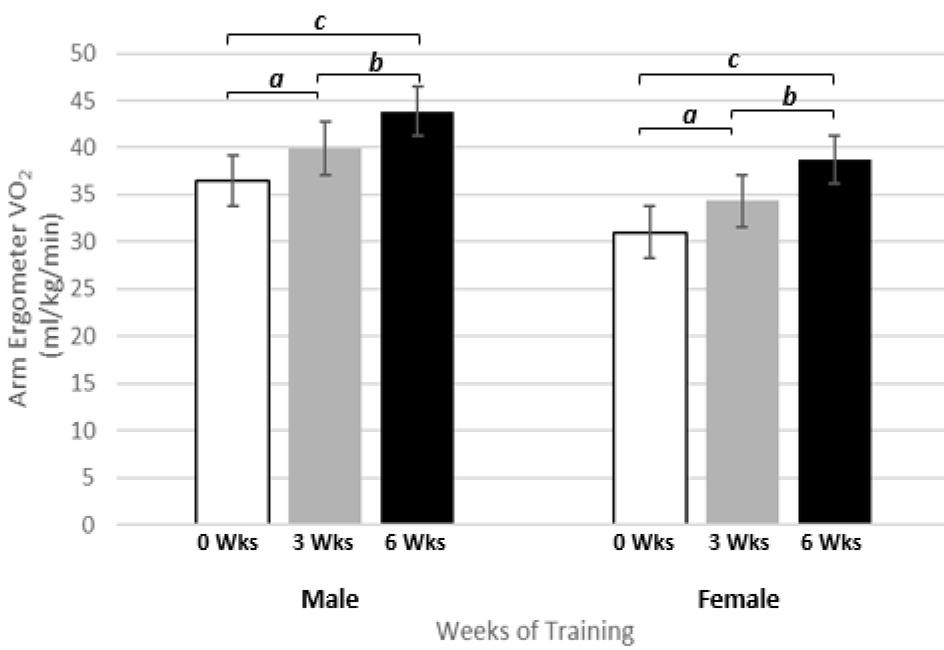

Figure 16: *VO_2 maximum for males and females during the Astrand arm ergometer protocol following 3 and 6 weeks of BR HIIT. Males n=18, Females n=15. [a] $p<0.05$, 0 vs 3 wks; [b] $p<0.05$, 3 vs 6 wks; [c] $p<0.05$, 0 vs 6 wks.*

Females demonstrated similar improvements after the first 3 weeks of BR HIIT $F(1,14) = 11.485$, $p<0.01$, and further significant improvement after the increase in BR weight $F(1,14) = 26.560$, $p<0.001$. Females produced significant improvements as well when comparing baseline values to post 6 week BR HIIT values $F(1,14) = 47.425$, $p<0.001$.

DISCUSSION

Treadmill and cycle ergometer high intensity interval training (HIIT) studies have reported significant acute and chronic improvements in VO_2 and anaerobic capacity, along with muscular strength, power, and endurance (Astorino et al., 2012; Hood, Little, Tarnopolsky, Myslik, & Gibala, 2011; Laursen et al., 2005). Similarly, acute BR HIIT exposure significantly increases upper body male and female peak VO_2 (Fountaine & Schmidt, 2015) and increases in BR weight or intensity also elevated peak VO_2 (Fountaine & Schmidt, 2015; Ratamess et al., 2015a). Research by McAuslan (2013) also reported a 7% improvement in female VO_2 and increases in skeletal muscle performance, while males only saw improvements in push-ups, but no significant VO_2 and sit-up improvements after 4 weeks of BR HIIT. This lack of significant sit-up, and VO_2 improvement in males was attributed to the weight of the BR being an insufficient stimulus, leading to the idea of progressively increasing BR weight during the training period to potentially induce physiological improvements. McAuslan (2013) also determined that for the females to complete the 10 sets of 30 sec work: 60 sec recovery during BR HIIT, the BR weight had to be reduced to accommodate the majority of female participants.

The purpose of the current study was to implement 6 weeks of BR HIIT, but increase the BR weight after 3 weeks for both males and females, with the intention of evoking additional improvements in VO_2 and skeletal muscle performance. Our study found that with BR HIIT there were dramatic increases in exercising HR (Table 5), but no significant differences in HR responses when performing either alternating or double whip BR HIIT, for both males and females during the first 3 weeks of training. However, RPE were 2-3% higher for both males and females while performing the alternating whip due to the single arm motion. When the BR weight was increased by 10 lb for the final 3 weeks both males and females reported a slight initial drop (10 reps) in average BR cadence, and no physiologically significant decrease in HR indicating the subjects were still giving their maximal effort during HIIT. Further, after switching to the heavier BR, there was a small decrease in RPE for females while performing the alternate whip protocol, attributed to the reduction in cadence with the heavier ropes.

During BR HIIT, anaerobic glycolysis is activated due to high ATP demand leading to the accumulation of blood lactate during and post HIIT exercise (Cheetham et al., 1986; Ozturk, Ozer, & Gokce, 1998). Blood lactate concentrations ([BLa]) were measured at rest, immediately post HIIT and 5 minutes post HIIT after the 9^{th} and 18^{th} BR HIIT training sessions to quantify the anaerobic glycolytic activity during the BR HIIT protocol (Korhonen, Suominen, & Mero, 2005; Lacour, Bouvat, & Barthélémy, 1990). Immediately post BR HIIT male and female [BLa] were significantly elevated by 6 and 4 fold respectively (Table 6), however increases in BR weight during the first 3 weeks of training did not result in further significant increases in [BLa], indicating an in improvement skeletal muscle oxygen consumption due to BR HIIT.

To assess the benefits of BR HIIT on upper body muscular endurance we conducted a push-ups test until volitional fatigue (Figure 11). After the first 3 weeks of BR HIIT, males improved by 10%, and females improved by 15%, from their baseline levels. The results were comparable to that of McAuslan (2013), who employed the same BR HIIT protocol and reported male push-up scores increased by 11%, and in females by 26%. Increasing BR weight for the final 3 weeks resulted in an additional significant increase in both males and females of 6% and 12% respectively, from the values post 3 weeks BR HIIT, suggesting based on our subject pool that an increase in BR weight can evoke additional improvements in upper body muscular endurance.

To assess if BR HIIT enhanced core muscle performance we conducted a sit-up cadence test until volitional failure, and reported that 3 weeks of BR HIIT improved female sit-up performance by 13% (Figure 12), similar to the 10% increase previously reported by McAuslan using a 1 minute timed sit-up test. We also report an 11% increase in male sit-ups until volitional fatigue, in contrast to no changes reported by McAuslan (2013) who used the 1 minute sit-up test. This discrepancy in male data may simply illustrate a limitation in using the 1 minute timed sit-up test to assess muscular strength/endurance versus our cadence test until fatigue. With a 10 lb increase in BR weight for the last 3 weeks, both males and females improved by an additional 8% and 10% in sit-up scores respectively, demonstrating the efficacy of increasing BR weight to further improve abdominal muscular strength/endurance.

Given the repetitive shoulder flexion and extension associated with BR HIIT, we found that after 3 weeks of BR HIIT males showed a significant 4% improvement in shoulder flexion MVIC strength, while females showed a 9-10% for both shoulder extension and shoulder flexion MVIC (Figures 13, and 14). An increase in BR weight for the last 3 weeks increased shoulder flexion MVIC by an additional 5% in females and 3% in male subjects. The larger increases in both female shoulder extension and flexion MVIC versus their male counterparts may be explained by their inexperience with BR workouts and that typical female resistance training workouts do not stress upper body exercises as much as male workouts (Esbjörnsson-Liljedahl, Holm, Sylven, & Jansson, 1996).

Individual exercises that increase strength, but more importantly translate into muscular power or quickness in sporting events are gaining recognition as a key component in individual and team strength and conditioning programs (Baker, 2001; Newton et al., 1997). Previously using BR, Kramer et al. (2015) had participants perform 5 different BR exercises for 4 weeks, 3x/wk for 10 sets at a 15:45 sec work to rest ratio and reported a 12.5% increase in Wingate upper body power output. Given the repetitive downward BR motion during both the alternating and double whip exercises we decided to assess shoulder power output changes by having our participants throw a medicine ball into a force plate (Figure 15) simulating the BR motion. After the first 3 weeks of BR HIIT males improved their shoulder peak power by 8%, and females improved by 12%. With an increase in BR weight, and an additional 3 weeks of BR training, males and females increased shoulder peak power an additional 7% and 5% respectively**.** This indicated that 3 and/or 6 weeks of BR HIIT could significantly improve upper body power production through the shoulder joint**,** providing further evidence that implementing BR HIIT into a strength and conditioning program can significantly increase upper body strength, endurance and power output.

In previous HIIT studies, researchers have assessed improvements in VO_2 by using treadmill and cycle ergometer tests, but for VO_2 adaptations associated with BR HIIT our lab utilized the arm ergometer VO_2 test to more specifically assess upper body VO_2 adaptations (McAuslan, 2013). In a 4 week BR HIIT study, McAuslan (2013) reported females significantly improved arm ergometer VO_2 max by 7%, however males did not improve, which he attributed to the weight of the BR not providing an adequate stimulus to elicit VO_2 changes. The importance of BR weight on training was indirectly supported by examining two separate studies using BR with a 10 lb difference, where the heavier BR produced a 4% greater peak VO_2 response during BR HIIT (Fountaine & Schmidt, 2015; Ratamess, et al. 2015a). Their data suggested that an increase in BR weight during BR HIIT may provide an essential stimulus to evoking additional gains in VO_2.

Given the specificity of BR HIIT we chose to assess VO_2 improvements using the Astrand arm ergometer VO_2 test where male and female participants were arm pedaling until they reached their maximal VO_2, indicated by volitional fatigue, or a plateau in VO_2. During these VO_2 max tests peak HR averages were greater than 170 bpm for both baseline and after 3 weeks of BR HIIT, and above 180 bpm after 6 weeks of BR HIIT, indicating high exercising intensities at the end of the VO_2 test throughout the 3 testing sessions. Additionally, we assessed [BLa] immediately after the arm ergometer VO_2 max test as another marker of exercise intensity and anaerobic glycolysis energy contribution. As expected [BLa] following arm ergometry significantly increased indicating an elevated contribution of skeletal muscle anaerobic glycolysis to energy demands during the arm ergometer VO_2 test. It should be noted that females demonstrated a significant increase in [BLa] immediately post exercise after 3 wks of BR HIIT when compared to baseline immediate post exercise BLa values. This data suggests that in females there was a greater initial contribution of skeletal muscle glycolysis due to the novel upper body energy demand associated with BR HIIT. Males however did not show a similar significant increase in [BLa] immediately post exercise until after 6 wks of BR HIIT suggesting that the increase in BR weight was the key stimulus to further activate skeletal muscle glycolysis. Comparing differences in [BLa] immediately post and 5 minutes post arm ergometer VO_2 tests, we found both males and females [BLa] decreased significantly following 3 and 6 weeks BR HIIT testing sessions. These decreases in [BLa] 5 min post exercise coincide with Juel et al., (2004) who reported decreases in lactate 3 minutes post exercise, potentially indicating an enhanced ability of smaller cross-sectional area muscles (upper body) in diffusing skeletal muscle lactate during arm ergometry due to BR HIIT.

As in previous HIIT treadmill, a cycle ergometry, or stair climbing protocols (Allison et al., 2017; Astorino et al., 2012; Bayati et al., 2011; Ziemann et al., 2011) and 4 weeks of BR HIIT (McAuslan, 2013), our first 3 weeks of BR HIIT 3x/week using a 30:60 sec work to rest ratio resulted in a significant 10% increase in female arm ergometer VO_2 using a 20 lb BR (Figure 16). The female arm ergometer VO_2 improvements after 3 weeks are similar to the 7% reported by McAuslan (2013) also using a 20 lb BR following for 4 weeks of BR HIIT. In contrast to McAuslan's (2013) lack of significant male VO_2 changes, we reported a 9% increase in male arm ergometer VO_2 and currently have no explanation for this difference as baseline male VO_2 scores were similar and all subjects were university aged and recreationally active. After the 10 lb BR weight increase for the last 3 weeks both males and females increased arm ergometer VO_2 max scores by an additional 9% and 11%, respectively. Overall these improvements in arm ergometer VO_2 max are similar to the 5-10% improvements in leg VO_2 seen following treadmill, cycle ergometer, and stair climbing HIIT (Allison et al., 2017; Astorino et al., 2012; Bayati et al., 2011; Driller et al., 2009; Laursen et al., 2005; Ziemann et al., 2011). Our BR arm ergometer VO_2 changes primarily reflect a specific and significant increase in arm or upper body VO_2, matching arm ergometer results found in trained swimmers and gymnasts (Seals & Mullin, 1982).

In summary, 3 weeks of BR HIIT can lead to significant increases in male and female arm ergometer VO_2 and skeletal muscle performance and increasing in BR weight for an additional 3 weeks can further enhance these improvements. These data suggest that strength and conditioning coaches should implement BR into their training programs using progressive increases in BR weight to stimulate additional physiological changes beneficial to the performance of recreationally active individuals and varsity/professional athletes.

LIMITATIONS AND IMPLICATIONS

The current study is not without its limitations as the protocol prescribes all-out activity, however each participant determined their own all-out effort level, and we are only able to encourage maximum effort and cannot force this upon them. It should also be noted that we did not have a recreationally active control group, who were not participating in BR HIIT. Also, we prescribed a set BR weight based on previous data by McAuslan (2013), and therefore did not take into account each participants' initial body weight, skeletal muscle strength, endurance, and/or power. Lastly, our sample population were all students from the Kinesiology program, which could have influenced our results as they were already an active population, so future studies should also look at a more sedentary group and/or highly trained varsity athletes to see if similar results can be elicited.

The improvements in the skeletal muscle and arm ergometer VO_2 through both 3 week BR HIIT phases also provides evidence that progressive resistance training principles can be applied to BR training. Additionally, with the availability of varying BR weights they are suitable for the young, elderly, those with limited or restricted lower body functioning, and for rehabilitative training to maintain or improve muscle performance and aerobic fitness based on their physical abilities.

REFERENCES

Allison, M. K., Baglole, J. H., Martin, B. J., MacInnis, M. J., Gurd, B. J., & Gibala, M. J. (2017). Brief Intense Stair Climbing Improves Cardiorespiratory Fitness. *Medicine and Science in Sports and Exercise*, *49*(2), 298–307.

Astorino, T., Allen, R., Robertson, D., & Jurancich, M. (2012). Effect of High-Intensity Interval Training on Cardiovascular Function, VO2max, and Muscular Force. *Journal of Strength and Conditioning Research*, *26*(1), 138–145.

Baker, D. (2001). Comparison of Upper-Body Strength and Power Between Professional and College-Aged Rugby League Players. *The Journal of Strength and Conditioning Research*, *15*(1), 30.

Bayati, M., Farzad, B., Gharakhanlou, R., & Agha-Alinejad, H. (2011). A practical model of low-volume high-intensity interval training induces performance and metabolic adaptations that resemble "all-out" interval training. *Journal of Sports Science and Medicine*, *10*, 571–576.

Burgomaster, K. A., Howarth, K. R., Phillips, S. M., Rakobowchuk, M., Macdonald, M. J., Mcgee, S. L., & Gibala, M. J. (2008). Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans. *Journal of Physiology*, *586*(1), 151–160.

Burgomaster, K. A., Hughes, S. C., Heigenhauser, G. J. F., Bradwell, S. N., Gibala, M. J., Kirsten, A., … Gibala, M. J. (2005). Six sessions of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans. *Journal of Applied Physiology*, *98*, 1985–1990.

Calatayud, J., Martin, F., Colado, J., Benitez, J., Jakobsen, M., & Andersen, L. (2015). Muscle Activity During Unilateral vs. Bilateral Battle Rope Exercises. *Journal of Strength and Conditioning Research*, *29*(10), 2854–2859.

Cheetham, M. E., Boobis, L. H., Brooks, S., & Williams, C. (1986). Human muscle metabolism during sprint running. *Journal of Applied Physiology*, *61*(1), 54–60.

Driller, M. W., Fell, J. W., Gregory, J. R., Shing, C. M., & Williams, A. D. (2009). The Effects of High-Intensity Interval Training in Well-Trained Rowers. *International Journal of Sports Physiology and Performance*, 110–121.

Esbjörnsson-Liljedahl, M., Holm, I., Sylven, C., & Jansson, E. (1996). Different responses of skeletal muscle following sprint training in men and women. *European Journal of Applied Physiology and Occupational Physiology*, *74*(4), 375–383.

Fountaine, C. J., & Schmidt, B. J. (2015). Metabolic Cost of Rope Training. *Journal of Strength and Conditioning Research*, *29*(4), 889–893.

Gibala, M. J., Little, J. P., Essen, M. Van, Wilkin, G. P., Burgomaster, K. A., Safdar, A., … Tarnopolsky, M. A. (2006). Short-term sprint interval versus traditional endurance training : similar initial adaptations in human skeletal muscle and exercise performance. *Journal of Physiology*, *575*(3), 901–911.

Gibala, M., Little, J., Macdonald, M., & Hawley, J. (2012). Physiological adaptations to low-volume, high-intensity interval training in health and disease. *The Journal of Physiology*, *590*(5), 1077–1084.

Gibala, M., & McGee, S. (2008). Metabolic Adaptations to Short-term High-Intensity Interval

Training: A Little Pain for a Lot of Gain? *Exercise and Sport Sciences Reviews*, *36*(2), 58–63.

Gosselin, L., Kozlowiski, K., DeVenney-Boymel, L., & Hambridge, C. (2012). Metabolic Response of Different High-Intensity Aerobic Interval Exercise Protocols. *Journal of Strength and Conditioning Research*, *26*(10), 2866–2871.

Green, H., Tupling, R., Roy, B., Toole, D. O., Burnett, M., & Grant, S. (2000). Adaptations in skeletal muscle exercise metabolism to a sustained session of heavy intermittent exercise. *American Journal of Physiology Endocrinology and Metaobolism*, *278*, 118–126.

Hood, M. S., Little, J. P., Tarnopolsky, M. A., Myslik, F., & Gibala, M. J. (2011). Low-volume interval training improves muscle oxidative capacity in sedentary adults. *Medicine and Science in Sports and Exercise*, *43*(10), 1849–1856.

Jacobs, R. A., Flück, D., Bonne, T. C., Bürgi, S., Christensen, P. M., Toigo, M., & Lundby, C. (2013). Improvements in exercise performance with high-intensity interval training coincide with an increase in skeletal muscle mitochondrial content and function. *Journal of Applied Physiology*, *115*, 785–793.

Juel, C., Klarskov, C., Jung Nielsen, J., Krustrup, P., Mohr, M., & Bangsbo, J. (2004). Effect of high-intensity intermittent training on lactate and H + release from human skeletal muscle. *American Journal of Physiology Endocrinology and Metaobolism*, *286*, 245–251.

Korhonen, M. T., Suominen, H., & Mero, A. (2005). Age and sex differences in blood lactate response to sprint running in elite master athletes. *Can J Appl Physiol*, *30*(6), 647–665.

Kramer, K., Kruchten, B., Hahn, C., Janot, J., Fleck, S., & Braun, S. (2015). The Effects of

Kettlebells Versus Battle Ropes on Upper and Lower Body Anaerobic Power in Recreationally Active College Students. *Journal of Undergraduate Kinesiology Research*, *10*(2), 31–41.

Lacour, J. R., Bouvat, E., & Barthélémy, J. C. (1990). Post-competition blood lactate concentrations as indicators of anaerobic energy expenditure during 400-m and 800-m races. *European Journal of Applied Physiology and Occupational Physiology*, *61*(3–4), 172–176.

Laursen, P. B., & Jenkins, D. G. (2002). The scientific basis for high-intensity interval training: optimising training programmes and maximising performance in highly trained endurance athletes. *Sports Medicine*, *32*(1), 53–73.

Laursen, P. B., Shing, C. M., Peake, J. M., Coombes, J. S., & Jenkins, D. G. (2005). Influence Of High - Intensity Interval Training On Adaptations In Well - Trained Cyclists. *Journal of Strength and Conditioning Research*, *19*(3), 527–533.

Le Foll-de Moro, D., Tordi, N., & Lonsdorfer, E. (2005). Ventilation Efficiency and Pulmonary Function After a Wheelchair Interval-Training Program in Subjects With. *Archives of Physical Medicine Rehabilitation*, *86*, 1582–1586.

Little, J., Gillen, J., Percival, M., Safdar, A., Tarnopolsky, M., Punthakee, Z., … Gibala, M. (2011). Low-volume high-intensity interval training reduces hyperglycemia and increases muscle mitochondrial capacity in patients with type 2 diabetes. *Journal of Applied Physiology*, *111*, 1554–1560.

MacRae, H., Dennis, S., Bosch, A., & Noakes, T. (1992). Effects of Training on Lactate

Production and Removal during Progressive Exercise in Humans. *Journal of Applied Physiology*, *72*(5), 1649–1656.

McAuslan, C. (2013) *Physiological Responses to a Battling Rope High Intensity Interval Training Protocol*. Unpublished Masters Thesis Manuscript, Department of Kinesiology, Human Kinetics, University of Windsor, Windsor, Canada.

Mckay, B. R., Paterson, D. H., & Kowalchuk, J. M. (2009). Effect of short-term high-intensity interval training vs. continuous training on O 2 uptake kinetics, muscle deoxygenation, and exercise performance. *Journal of Applied Physiology*, *107*, 128–138.

Meier, J., Quednow, J., & Sedlak, T. (2015). The Effects of High Intensity Interval-Based Kettlebells and Battle Rope Training on Grip Strength and Body Composition in College-Aged Adults. *International Journal of Exercise Science*, *8*(2), 124–133.

Newton, R. U., Murphy, A. J., Humphries, B. J., Wilson, G. J., Kraemer, W. J., & Hakkinen, K. (1997). Influence of load and stretch shortening cycle on the kinematics, kinetics and muscle activation that occurs during explosive upper-body movements. *European Journal of Applied Physiology and Occupational Physiology*, *75*(4), 333–342.

Osawa, Y., Azuma, K., Tabata, S., Katsukawa, F., Ishida, H., Oguma, Y., … Matsumoto, H. (2014). Effects of 16-week high-intensity interval training using upper and lower body ergometers on aerobic fitness and morphological changes in healthy men : a preliminary study. *Open Access Journal of Sports Medicine*, *5*, 257–265.

Ozturk, M., Ozer, K., & Gokce, E. (1998). Evaluation of blood lactate in young men after wingate anaerobic power test. *Eastern Journal of Medicine*, *3*(1), 13–16.

Pilegaard, H., Domino, K., Noland, T., Juel, C., Hellsten, Y., Halestrap, A. P., & Bangsbo, J. (1999). Effect of high-intensity exercise training on lactate/H+ transport capacity in human skeletal muscle. *Journal of Applied Physiology*, *276*, 255–261.

Plowman, S. A., & Smith, D. L. (2014). *Exercise Physiology for Health Fitness*. (E. Lupash, Ed.) (4th ed.). Baltimore, MD: Lippincott Williams & Wilkins, a Wolters Kluwer business.

Ratamess, N., Rosenberg, J., Klei, S., Dougherty, B., Kang, J., Smith, C., … Faigenbaum, A. (2015). Comparision of the Acute Metabolic Responses to Traditional Resistance, Body-Weight, and Battling Rope Exercises. *Journal of Strength and Conditioning Research*, *29*(1), 47–57.

Ratamess, N., Smith, C., Beller, N., Kang, J., Faigenbaum, A. D., & Bush, J. A. (2015). Effects of Rest Interval Length on Acute Battling Rope Exercise Metabolism. *Journal of Strength and Conditioning Research*, *29*(9), 2375–2387.

Rodas, G., Ventura, J., Cadefau, J., Cusso, R., & Parra, J. (2000). A short training programme for the rapid improvement of both aerobic and anaerobic metabolism of both aerobic and anaerobic metabolism. *European Journal of Applied Physiology, 82,* 480–486.

Seals, D. R., & Mullin, J. P. (1982). [Vdot]O $_2$ Max in Variable Type Exercise Among Well-Trained Upper Body Athletes. *Research Quarterly for Exercise and Sport*, *53*(1), 58–63.

Simoneau, J., Lortie, G., Boulay, M., Marcotte, M., Thibault, M., & Bonchard, C. (1985). Human skeletal muscle fiber type alteration with high-intensity intermittent training. *European Journal of Applied Physiology, 54,* 250–253.

Simoneau, J., Lortie, G., Boulay, M. R., Marcotte, M., Thibault, M., & Bouchard, C. (1987).

Effects of two high-intensity intermittent training programs interspaced by detraining on human skeletal muscle and performance. *European Journal of Applied Physiology*, *56*, 516–521.

Ziemann, E., Grzywacz, T., Łuszczyk, M., Laskowski, R., Olek, R. A., & Gibson, A. L. (2011). Aerobic and anaerobic changes with high-intensity interval training in active college-aged men. *Journal of Strength and Conditioning Research*, *25*(4), 1104–1112.

APPENDIX A

Volunteers Needed

Interested in 6 weeks of battling rope training?
Want to improve aerobic capacity and skeletal muscle performance while learning a new, innovative exercise protocol?

Sign up for a University of Windsor Kinesiology Graduate Thesis Study: Physiological Response to Increasing Battling Rope Weight during two 3 week High Intensity Interval Training (HIIT) Programs

- **Female and male participants are needed (17-30 years of age)**
- **With no known cardiovascular disease or major injury (shoulders, low back, hips, knees, ankles)**
- **Recreationally active at least twice a week for the last 3 months**

You will receive a kinesiology research t-shirt and entered into a draw for 2- $50 Sport Chek gift card for participating!

<u>For more information, please contact:</u>

Derek Bornath: bornath@uwindsor.ca

APPENDIX B

To: Human Kinetics- Kinesiology University of Windsor Student Body

From: Lead Graduate Researcher- Derek Bornath and Advisor- Kenji Kenno

Subject: Volunteer for a Battling Rope High Intensity Interval Training (HIIT) Study

I am currently recruiting participants for my graduate master's thesis project entitled a "Physiological Responses to Increasing Battling Rope Weight during two 3 week HIIT Programs". This study will look to determine if there are significant improvements in strength, endurance, and power, along with aerobic capacity (oxygen consumption) after 6 weeks of battling rope HIIT. There will be 3 testing sessions, at the start, middle, and after the final training session, scheduled around your availability. This study will involve 18 sessions (approximately 6 weeks) of battling rope high intensity interval training, with a 10 lb increase in battling rope weight after the first 3 weeks of training. The training will take place approximately three times per week for six weeks, with each training session lasting approximately 30 minutes, and each testing session lasting approximately 80 minutes.

This would be a great opportunity for you to learn about some of the applied research that takes place here in Kinesiology, as well as exercise with a unique training apparatus that is not offered in other training facilities. We are looking for recreationally active males and females who exercise at least 2 times a week for the past 3 months, between the ages of 17-30 years old that will be able to schedule these training sessions over approximately 7 weeks. These sessions will consist of exercise performance testing as well as interval training progressive overload protocols with battling ropes.

The study has been approved by the University of Windsor Research Ethics Board (REB# 16-239)

If interested, or for more information contact:

Derek Bornath at bornath@uwindsor.ca

Kenji Kenno at kenno@uwindsor.ca

APPENDIX C

LETTER OF INFORMATION FOR CONSENT TO PARTICIPATE IN RESEARCH LETTER

Title of Study: Physiological Responses to Increasing Battling Rope Weight during two 3 week High Intensity Interval Training (HIIT) Programs

You are asked to participate in a research study conducted by Derek Bornath and Dr. Kenji Kenno from the Department of Kinesiology at the University of Windsor. The results will contribute to a graduate master's thesis study.

If you have any concerns or questions about the research, please feel free to contact Derek Bornath and/or Dr. Kenji Kenno (519 250 3000 ext. 2444) at any time.

PURPOSE OF THE STUDY

The primary objective of this investigation is to determine the upper body cardiovascular and skeletal muscle responses to increasing battling rope (BR) weight 10 lbs during two 3 week upper body high intensity interval training (HIIT) programs. In a previous study from our lab, 4 weeks of arm BR HIIT led to significant improvements in upper body oxygen consumption in female subjects but did not increase upper body oxygen consumption in males. Additionally, skeletal muscle performance increases in female participant sit-up performance and increases in push-up performance in both males and female subjects were reported. It was speculated that increasing the weeks of BR HIIT training and/or increasing BR weight may be the critical stimulus required to increase upper body male aerobic performance and further increase upper body aerobic and skeletal muscle improvements in both male and female subjects. This was indirectly supported by two separate BR studies with a 10 lb difference in rope weight, yielding a 4% higher peak upper body oxygen consumption, suggesting that increasing the BR weight similar to traditional progressive resistance training may provide the adequate stimulus to elicit increases in both male and female upper body oxygen consumption and skeletal muscle performance. Therefore, with 18 sessions (approximately 6 weeks) of interval training with battling ropes, the aim is for participants to gain an understanding of proper form, along with cardiovascular, strength, and endurance benefits from the application of this unique training apparatus.

PROCEDURES

If you volunteer in this study, you will be asked to:

Come to the Multipurpose Laboratory (Room 202) in the Human Kinetics Building at the University of Windsor where you will be asked to complete the Physical Activity Readiness Questionnaire Plus (PAR-Q+) and participant information questionnaire that determine whether you have any known risks that would prevent you from participating in physical activity. These forms include information such as the month and year of birth, sex, medications you might currently be taking and any known history of cardiovascular disease. Participants will then be asked to schedule a date for their initial testing session following a 24 hour exercise and alcohol hiatus and must fast for 4 hours pre-test to prevent interaction of the thermal effect of food. The first session (80 minutes) will involve:

- The participant will then rest seated for 10 minutes. After which, a single use Medlance blood drop lancet will be used to prick the earlobe and draw a single droplet of blood. This blood will then be analyzed for its lactate concentrations with a Lactate Scout, giving a resting baseline value.
- A maximum voluntary isometric shoulder flexion and extension contraction (MVIC) test will be completed. Participants will pull upward for 3 seconds (secs), 3 separate times with arms extended 90 degrees from the shoulder for the flexion test. For the extension test participants will pull downward for 3 secs, 3 separate times at the same shoulder angle.
- A ball slam test into a force platform will be completed. Participants will throw a slam ball into a force platform to measure forces at which the ball was driven into the plate, and will then be converted into a measure of power.
- ACSM Push-up test, and YMCA Sit-up test will be completed until volitional fatigue.
- A graded Astrand VO_2 max protocol with an arm ergometer will be completed. This is designed to measure your aerobic capacity while wearing a Hans Rudolph VO_2 mask and a Polar Heart Rate Monitor.
- This arm ergometer protocol is completed in two minute stages until volitional fatigue. At the end of each two minute stage you will be asked to rate your exertion using the Borg 6-20 Rating of Perceived Exertion Scale.
- Immediately after the VO_2 test is completed another earlobe blood lactate concentration measurement will be taken, and 5 minutes later the last blood lactate concentration measurement will be taken.
- This protocol will also be completed after the 3 weeks and 6 weeks of battling rope HIIT sessions (approximately 9 and 18 training sessions) to test training adaptations.

After a minimum of 24 hours rest, the first training (30 minute) session will consist of:

- A proper active warmup will take place with simple exercises to make sure that your body is prepared for physical exercise
- Begin the interval training protocol with the battling rope. You will wear the Polar Heart Rate Monitor. You will complete 10 workout sets of 30 secs of battling rope exercises, matched by 60 secs of rest. During each workout set you will be asked your heart rate, cadence and exertion level using the Borg 6-20 point Rating of Perceived Exertion Scale.
- After this, a stretching routine will occur in order to cool down and stretch out the muscle tissue used
- For the first 3 weeks (9 sessions) of battling rope sessions you will be using the standard 1.5 inch diameter rope, with the length and weight of the rope being 50 feet at 25 lbs for males, and 40 feet at 20 lbs for females.

- After the first 3 weeks (9 sessions) the weight of the ropes will be increased 10 lbs. For the last 3 weeks (9 sessions) of the battling rope HIIT sessions male rope size will 2.5 inch diameter, 50 feet long, and 35 pounds; and female rope will be 2 inch diameter, 40 feet long, and 30 pounds.

This study will take approximately 7-8 weeks to be completed.

POTENTIAL RISKS AND DISCOMFORTS

Delayed onset muscle soreness may occur between 24 to 72 hours after your training session. With proper rest and avoidance of extra training, recovery will occur. Proper stretching protocols will be administered post training session in order to assist in muscle flexibility post workout

If an unusual or unexpected discomfort is felt throughout the investigation, the protocol can be stopped. Water will be made available to you.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

Participants can expect to gain knowledge of a unique training apparatus, while improving their fitness. This research can lead to improvements in strength and conditioning programs in the fitness community. Battling ropes are currently being used in this field, however this investigation will provide further information as to their appropriate application, and implementation.

COMPENSATION FOR PARTICIPATION

The participants will not receive any financial compensation.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The confidentiality of participant information will be ensured as each participant will be given a unique cod that can only identify them by name if associated with an initial file. This file will be digitally secured via password on a personal computer, and a hard copy will be kept in an office in a locked cabinet.

PARTICIPATION AND WITHDRAWAL

The investigator may withdraw you from this research if circumstances arise which warrant doing so. Also, the subject may withdraw at any time. If you have a longer than 5 day interval between sessions, you will be asked to withdraw from the study. It is imperative that you are aware of this and can plan accordingly whether you can participate in the study.

FEED BACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

The final transcript will be emailed to you upon request, which will contain the research findings.

Your email address: ____

Data when results are available: ____

SUBSEQUENT USE OF DATA

This data may be used in subsequent studies in publications and in presentations.

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

____ _______________

Signature of Investigator Date

APPENDIX D

CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: Physiological Responses to Increasing Battling Rope Weight during two 3 Week High Intensity Interval Training (HIIT) Programs

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FEED BACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

The final transcript will be emailed to you upon request, which will contain the research findings.

Your email address: ____

Data when results are available: ____________________________________

SUBSEQUENT USE OF DATA

This data may be used in subsequent studies in publications and in presentations.

RIGHTS OF RESEARCH PARTICIPANTS

If you have any questions regarding your rights as a research participant, contact Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone 519-253-3000 ex. 3948; email: ethics@uwindsor.ca

SIGNATUE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE

I understand the information provided for the study “Physiological Responses to Increasing Battling Rope Weight during two 3 Week HIIT Programs” as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____

Name of Participant

______________________________________ ______________

Signature of Participant Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research

____ _______________

Signature of Investigator Date

APPENDIX E

2015 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ________	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ________	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it ***does not limit your current ability*** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ________	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

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01-01-2015

2015 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1.	**Do you have Arthritis, Osteoporosis, or Back Problems?** If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2	
1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	**YES** ☐ **NO** ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	**YES** ☐ **NO** ☐
2.	**Do you have Cancer of any kind?** If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3	
2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?	**YES** ☐ **NO** ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	**YES** ☐ **NO** ☐
3.	**Do you have a Heart or Cardiovascular Condition?** *This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm* If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4	
3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	**YES** ☐ **NO** ☐
3c.	Do you have chronic heart failure?	**YES** ☐ **NO** ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	**YES** ☐ **NO** ☐
4.	**Do you have High Blood Pressure?** If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5	
4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	**YES** ☐ **NO** ☐
5.	**Do you have any Metabolic Conditions?** *This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes* If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6	
5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	**YES** ☐ **NO** ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	**YES** ☐ **NO** ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	**YES** ☐ **NO** ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	**YES** ☐ **NO** ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	**YES** ☐ **NO** ☐

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2015 PAR-Q+

6. **Do you have any Mental Health Problems or Learning Difficulties?** *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome*

If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you **ALSO** have back problems affecting nerves or muscles?	YES ☐ NO ☐

7. **Do you have a Respiratory Disease?** *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*

If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. **Do you have a Spinal Cord Injury?** *This includes Tetraplegia and Paraplegia*

If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. **Have you had a Stroke?** *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*

If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. **Do you have any other medical condition not listed above or do you have two or more medical conditions?**

If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ______________________

____

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

2015 PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that the Trustee maintains the privacy of the information and does not misuse or wrongfully disclose such information.

NAME ______________________________ DATE ______________________________

SIGNATURE ______________________________ WITNESS ______________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________________

For more information, please contact

www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References

1. Jamnik VK, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.

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APPENDIX F

Name: ________________________________

D.O.B. (mm/yy): ____/____

Height (meters): ______ Weight (kg): ______ BMI: _______

Sex: M or F

Participant I.D. # ______

Contact Information:

Phone (cell) # (_____) _____-________

Phone (home)#: (_____) ______-________

E-mail: ____

Emergency Contact (Optional)

Name: ____

Phone#: (_____) ______-________

Physical Activity Background:

How many months have you been regularly exercising?

1 2 3+ 6+ 12+

How many times do you exercise per week?

1 2-3 3-4 4+

Have you ever used a battling rope before (circle) ? Yes No

Recent or past injuries that should be known:

APPENDIX G

Laboratory Emergency Action Plan (EAP)

for <u>Medical Emergencies</u> during Exercise Testing

STEP 1: **REMAIN CALM.**
CONTROL and ASSESS the situation.
DESIGNATE a person to CALL and meet EMERGENCY PERSONNEL:

911 OR Campus Police EXT. 4444
(they will dispatch required authorities)

<u>OUR ADDRESS/DIRECTIONS:</u>

The University of Windsor
Human Kinetics Building
2555 College Ave.
Main Entrance off College Ave.
Room# 202 (uppermost floor)

<u>Directions:</u> Enter the HK building at the North entrance and head up the staircase on the left. Take your first right and Room 202 is on your right.

<u>OUR PHONE#:</u>

519-253-3000 ext 2444

STEP 2: **PERFORM all measures (CPR/First Aid) to ensure safety of subject.**

ATTEND to subject until replaced by emergency personnel.

STEP 3: **CREATE a Department of Kinesiology Incident Report.**

APPENDIX H

Arm Ergometer Test

Testing Protocol

-Set seat height so shoulders are parallel to axel of ergometer

-Arm pedal at 60 rpm

-Monitor HR using the Polar HR monitor

-Workload= kg setting/watts (ie. 0.5/10)

-**Data Collection Format:**

Time	Wkld	HR	RPE	Time	Wkld	HR	RPE	Time	Wkld	HR	RPE	Time	Wkld	HR	RPE
1	.5/10			7	2/40			13	3.5/70			19	5/100		
2	.5/10			8	2/40			14	3.5/70			20	5/100		
3	1/20			9	2.5/50			15	4/80			21	70rpm		
4	1/20			10	2.5/50			16	4/80			22	70rpm		
5	1.5/30			11	3/60			17	4.5/90			23	80rpm		
6	1.5/30			12	3/60			18	4.5/90			24	80rpm		

BW (kg): _____ ; WR (kg m min^{-1})= kg setting x rpm x 2.4m= ______x________ x 2.4=________

-Test should last at least 8-12 minutes for best results

APPENDIX I

Borg rating of perceived exertion

6 No exertion at all

7

Extremely light

8

9 Very light

10

11 Light

12

13 Somewhat hard

14

15 Hard (heavy)

16

17 Very hard

18

19 Extremely hard

20 Maximal exertion

VITA AUCTORIS

NAME:	Derek Bornath
PLACE OF BIRTH:	London, ON
YEAR OF BIRTH:	1993
EDUCATION:	Medway High School, Arva, ON, 2011
	University of Windsor, BHK, Windsor, ON, 2015
	University of Windsor, MHK, Windsor, ON, 2017