The acute effects of active recovery during high-intensity interval training on lactate clearance and sprint performance in college-aged students

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ABSTRACT

THE ACUTE EFFECTS OF ACTIVE RECOVERY DURING HIGH-INTENSITY INTERVAL TRAINING ON LACTATE CLEARANCE AND SPRINT PERFORMANCE IN COLLEGE-AGED STUDENTS

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Northern Illinois University, 2017
Peter J. Chomentowski III, Thesis Director

High-intensity interval training (HIIT) is a form of exercise used to counter the effects of obesity. HIIT consists of low volume but increased intensity in a short period of time followed by a relative recovery period, which can be active or passive. PURPOSE: The purpose of this study is to determine the effects of different recovery modalities and durations between high-intensity interval training on lactate clearance, sprint performance, heart rate, and the rating of perceived exertion. METHODS: Forty students participated in the study. [(Age: 21.9 ± 0.3 years; Height: 172.6 ± 1.6 cm; Weight: 79.4 ± 2.4 kg; Body Fat %: 18.1 ± 1.3 (BodPod)]. Subjects were randomly assigned into recovery conditions (modality x duration) which was one of four groups: active recovery for 10 minutes (AR10), active recovery for 5 minutes (AR5), passive recovery for 10 minutes (PR10), or passive recovery for 5 minutes (PR5). The exercise protocol consisted of three total maximal-effort sprints each followed by the assigned group recovery phase. Each sprint trial covered a 75-foot distance between a starting line and wall, in which each subject sprinted down to the wall and back to the starting line a total of three times, for a total of 450 feet per sprint trial. Following each sprint trial, sprint time, blood lactate concentration, heart
rate, and the rating of perceived exertion were recorded. RESULTS: There was significant main effect on blood lactate concentrations seen from recovery modality across all the trials ($p = .038, \eta^2 = .088$). The mean difference across the trials for blood lactate concentration when comparing the active recovery modality to the passive recovery modality was -1.51 mmol/l ($p = .038, 95\% \text{ CI } [-2.92, -0.86]$). There was only a significant interaction effect between the trials and recovery duration on blood lactate concentration ($p = .002, \eta^2 = .118$). Only an interaction effect between the trials and recovery duration on the rating of perceived exertion was found ($p = .034, \eta^2 = .065$). No main or interaction effects were found for either sprint times or heart rate. CONCLUSION: Active recovery is more beneficial for lactate clearance when compared to passive recovery during high-intensity interval training. The effect of recovery duration on lactate clearance and sprint performance must be further investigated.

*Keywords*: recovery, lactate clearance, high-intensity interval training, performance
THE ACUTE EFFECTS OF ACTIVE RECOVERY DURING HIGH-INTENSITY INTERVAL TRAINING ON LACTATE CLEARANCE AND SPRINT PERFORMANCE IN COLLEGE-AGED STUDENTS

BY

MARK FLURY
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A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE MASTER OF SCIENCE IN EDUCATION

DEPARTMENT OF KINESIOLOGY AND PHYSICAL EDUCATION

Thesis Director:
Dr. Peter J. Chomentowski III
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DEDICATION

I would like to dedicate my thesis to my grandpa, Sim Palisbo, who was unable to be with me upon my completion of both my collegiate degrees, and my grandma, Petronila Palisbo, who has persevered by her strength.
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INTRODUCTION

Obesity in adults has been considered common, serious, and very costly in the United States of America. Obesity is related to life-threatening conditions such as heart disease, stroke, type 2 diabetes, and some forms of cancer which all are preventable through a complete and balanced diet along with sufficient exercise (Eyre et al., 2004). The obese population of all adults living in the U.S. has grown over one-third (36.5%) during 2011-2014 of which the prevalence in younger adults (20-39 years of age) was 32.3% obese and prevalence in middle-aged adults (40-59 years of age) was 40.2% obese (Ogden, Carroll, Fryar, & Flegal, 2015). Medical costs of obesity have continued to rise over every year, estimated at $147 billion U.S. dollars in 2008; additionally, an individual who is obese has an average of $1,429, or 42%, higher medical cost than an individual of normal weight (normal body composition) (Finkelstein, Trogdon, Cohen, & Dietz, 2009). Exercise can help counter the rise in the obese population, reduce the annual medical costs, and decrease risk of all-cause mortality by improving physical fitness (Trilk, Singhal, Bigelman, & Cureton, 2011).

High-intensity interval training (HIIT) is a type of physical exercise which can be utilized to prevent obesity. HIIT consists of low volume but increased intensity in a short period of time with minimal rest, usually performed for cardiovascular training. It has been determined as an acceptable alternative to longer, endurance training with the same health benefits such as an improved cardiovascular system, body composition, and the reduced risk of developing disease
as well as managing a current disease (Kenney, Wilmore, & Costill, 2008). Specifically, chronic diseases such as coronary artery disease, diabetes mellitus, hypertension, and obesity have been seen to improve through high-intensity interval training (Gibala, Little, MacDonald, & Hawley, 2012).

High-intensity interval training (HIIT) is utilized to improve performance for athletic competition. Studies have shown that a structured HIIT program can increase VO$_{2\text{max}}$, resting glycogen content, reduced rate of glycogen diminishment, increased muscle lipid oxidation, improved vascular structure and function, reduced lactate accumulation, and improved time-to-exhaustion similar to adaptations during continuous, aerobic training (Gibala et al., 2012). Considering highly trained athletes are subjected to these adaptations through sport-specific training, HIIT has been proposed to further central and peripheral adaptations such as a greater improvement of VO$_{2\text{max}}$, thermoregulation, ATP production, resynthesis and utilization, peak power, time-to-exhaustion at over maximal power output, myoglobin stores, resynthesis of phosphocreatine, and buffering capacity and clearance of lactate accumulation (Laursen & Jenkins, 2002). During high-intensity exercise, whether in a training session or competition, the most prevalent negative factor to performance is the accumulation of blood lactate within the working muscles leading to overall fatigue.

Lactate accumulation during HIIT has been highly researched for many decades. Specifically, recovery type and duration have been manipulated during HIIT to seek a better understanding of physiological responses and performance benefits. Recovery types used during HIIT can be passive or active. Passive recovery (PR) between high-intensity intervals consists of no aerobic movement, where individuals remain seated or standing in place while waiting for the
next exercise interval. Conversely, active recovery (AR) between intervals consists of various types of low-intensity aerobic exercise such as cycling, swimming, or walking while approaching the next set of intervals. The rationale of performing active recovery between high-intensity exercises is to decrease lactate concentrations, thus aiding in the preservation and restoration of performance capacity of the athlete and ultimately reaping greater physiological benefits.

Statement of the Problem

Literature suggests active recovery may be more effective in the clearance of lactate accumulation when compared to passive recovery alone. However, the effects of recovery duration on lactate clearance have yet to be studied fully. Fitness professionals seek to find additional training methods to increase health of their patients or performance of their athletes; therefore, there is a necessity to better understand the effects of recovery modality and durations during exercise. The purpose of this study is to determine the effects of different recovery modality and durations between high-intensity interval training on lactate clearance and performance.

Research Hypotheses

The researcher hypothesized that the study would yield results of the following:

1. The active recovery (AR) groups will display lower average blood lactate concentrations (BLC) when compared to the passive recovery (PR) groups.
2. The longer duration (R10) recovery groups will display lower average blood lactate concentrations (BLC) when compared to the shorter duration (R5) recovery groups.
3. The active recovery (AR) groups will display lower average sprint times when compared to the passive recovery (PR) groups.

4. The active recovery (AR) groups will display higher average heart rates (HR) when compared to the passive recovery (PR) groups.

5. The active recovery (AR) groups will display lower average rating of perceived exertion (RPE) when compared to the passive recovery (PR) groups.

6. Active recovery (AR) groups will display lower average blood lactate concentrations (BLC), heart rate (HR), and rating of perceived exertion (RPE) from sprint 3 to post measurements when compared to passive recovery (PR) groups.

The rationale for the hypotheses is due to the effects of active recovery on lactate clearance. Performing active recovery instead of passive recovery, increases in blood flow, cardiac output, and oxidative metabolism will occur to facilitate an increase in lactate metabolism. Ultimately, the active recovery group participants will be able to further exert themselves during the high-intensity intervals, thus showing a rise in overall HR, lower RPE and BLC, and faster sprint interval times.

Operational Definitions

Recovery methods were instituted during each interset rest period of exercise as well as following final set of high-intensity sprint interval. Recovery methods consisted of low-intensity walking (2.5 mph) for the active recovery group or sitting/standing for the passive group. The rating of perceived exertion (RPE) was quantified by the Borg scale 6-20, in which 6 represents
minimal effort such as sitting and 20 represents maximal effort in which may possibly result in medical assistance.

Assumptions

The researcher of the study assumed that the college students participating in the study had some prior experience with high-intensity interval training. Also, each participant performed the series of sprints for the high-intensity interval protocol with maximum effort and ability during testing. Additionally, the rating of perceived exertion was given as accurately and truthfully by each participant to assess the condition of fatigue. In regards of technology being used, the experimenter assumed that each device (accelerometer and lactate meter) was worn appropriately and calibrated correctly.

Limitations

Possible limitations may have arisen through the efforts of the participants in which the high-intensity interval sprints may not have been performed at maximum effort. Another limitation which may have influenced performance is dietary and supplementary intake, which was not tracked during the study. In addition, participants may feel unwell to the extent to which they are not able to complete the remainder of the HIIT protocol. All participants had the option of refusing the finger prick for blood lactate analysis at any time during the high-intensity interval sprinting session. The difference in training level between subjects may have impacted the results based on training adaptations such as cardiovascular, muscle fiber type, and glycolytic enzymes which can influence the clearance of lactate.
Delimitations

College students were selected to ensure the probability that the ages of participants were not a confounding factor in the study. The gymnasiums used during the second visit were free from any unnecessary stimulus, such as additional persons within the room, which could influence heart rate for each individual.
REVIEW OF LITERATURE

Anaerobic Metabolism

Aerobic metabolism is primarily used to generate energy for skeletal muscle contraction during most exercise situations, although, due to the latency of adenosine triphosphate (ATP) production by aerobic metabolism, energy is needed for early muscle contraction in the first few minutes of exercise. The energy provided in this initial period of exercise must be provided using other metabolic pathways. Additionally, the intensity of the exercise influences the generation of ATP due to the requirement of energy from the muscles during intense exercise (Hargreaves & Spriet, 2006). Therefore, to supply the necessary energy for working muscles, more rapid metabolic processes must be utilized.

Anaerobic metabolism is defined as the ability of muscle to generate ATP through metabolic pathways with the absence of oxygen (O₂), commonly termed as oxygen deficit (Hargreaves & Spriet, 2006). In both aerobic and anaerobic metabolic pathways, adenosine diphosphate (ADP) and inorganic phosphate (Pᵢ) are converted to ATP which becomes readily available to myosin ATPase enzymes that consume the energy stored within the phosphate bonds (Hargreaves & Spriet, 2006). Aerobic metabolism uses oxygen molecules for these biochemical reactions to produce or resynthesize ATP, but anaerobic metabolism can perform these biochemical reactions without oxygen to yield ATP. The rate of oxygen consumption and utilization for ATP production during aerobic metabolism is lower than the energy demands of high-intensity exercise. In contrast, with anaerobic metabolism, the rate of ATP production is
greater (up to 5-6 times) than oxidative energy systems (Lamb & Murray, 1999). This increase in ATP production complements the energy demand of the intense exercise but becomes limited by a short duration of the high-energy output. The duration is dependent on the depletion of phosphocreatine (PCr) and the accumulation of byproducts of anaerobic metabolism (Lamb & Murray, 1999).

The energy produced in 30 seconds of high-intensity exercise originates from the combination of ATP-PCr and glycolytic systems (Gastin, 2001; Katch, Katch, & McArdle, 2007; Kenney, Wilmore, & Costill, 2008). Approximately 73-80% of energy produced during a 30-second maximal sprint comes primarily from anaerobic processes (Gastin, 2001; Hargreaves & Spriet, 2006). High rates of ATP synthesis have been found to be produced up to 15 seconds in high-intensity exercise using the ATP-PCr metabolic system (Gastin, 2001; Kenney, Wilmore, & Costill, 2008). In the first 2-3 seconds, ATP stores within the muscle cells are utilized immediately but quickly switched to the use of PCr to ensure the conservation of ATP for intracellular processes. The phosphocreatine begins to be degraded through chemical reactions to synthesis ATP during the 3-15 seconds of high-intensity exercise. Once stored PCr reaches the end capacity, about 11.1 total kcal, the anaerobic glycolytic system begins to produce the remainder of the energy needed to sustain the demand of the intense exercise (Brooks, Fahey, & Baldwin, 2004; Katch, Katch, & McArdle, 2007).

**Anaerobic Glycolysis**

The anaerobic glycolysis metabolic pathway becomes the primary source of ATP production following 15 seconds, lasting up to 90 seconds into the high-intensity exercise (Katch, Katch, & McArdle, 2007). Occurring within the cytosol of the skeletal muscle cells, the
glycolysis process breaks down glucose and ultimately yields 36-38 molecules of ATP in a series of 10-12 enzymatically controlled chemical reactions with the assistance of the Krebs cycle, electron transport chain, and depending on the conversion of glycogen to glucose (Katch, Katch, & McArdle, 2007; Kenney, Wilmore, & Costill, 2008). The first enzymatic chemical reaction is the conversion of a glucose molecule to glucose 6-phosphate with the non-equilibrium enzyme, hexokinase, which allows greater glucose utilization when glucose uptake into the cell increases (Lamb & Murray, 1999). Hexokinase assists in the transfer of a phosphoryl group from an ATP molecule used in the reaction to form glucose 6-phosphate (G6P), adenosine diphosphate (ADP), and a hydrogen ion (H+). Once glucose becomes phosphorylated and glucose 6-phosphate in formed, phosphohexose isomerase (PHI) and phosphoglucose isomerase (PGI) initiate and complete, respectively, the conversion of G6P to fructose 6-phosphate (F6P). The enzyme needed to break down F6P is phosphofructokinase (PFK), which utilizes another molecule of ATP through hydrolysis to yield fructose 1, 6-diphosphate (F1, 6DP); adenosine diphosphate (ADP), and a hydrogen ion (H+) (Brooks, Fahey, & Baldwin, 2004; Katch, Katch, & McArdle, 2007).

Once fructose 1,6-diphosphate (F1, 6DP) is created, fructose bisphosphate aldolase splits the glucose derivative into two three-carbon chain molecules, dihydroxyacetone phosphate (DHAP) and glyceraldehyde 3-phosphate (G3P). These carbon chains can be converted by the enzyme triosephosphate isomerase (TIM) to produce two 3-phosphoglyceraldehyde (G3P), in which both undergo a parallel sequence of chemical reactions resulting in the production of energy (Brooks, Fahey, & Baldwin, 2004; Katch, Katch, & McArdle, 2007).
The majority of adenosine triphosphate (ATP) is produced in the remaining parallel processes of glycolysis which is known as the payoff phase. The enzyme glyceraldehyde 3-phosphate dehydrogenase (GAPDH), inorganic phosphate (P_i), and nicotinamide adenine dinucleotide (NAD^+) convert G3P into 1,3-diphosphoglycerate (1,3-DPG), NADH, and H^+. This chemical reaction results in the first “high-energy” intermediate formation of NADH which can be utilized via electron transport chain. The molecule 1,3-DPG is hydrolyzed into a carboxylic acid by the enzyme 3-phosphoglycerate kinase (PGK), along with ADP and H^+, to produce 3-phosphoglycerate (3-PG) and ATP. The 3-PG molecule undergoes additional chemical reactions in which the enzyme phosphoglyceromutase reduces the molecules to 2-phosphoglycerate (2-PG). A single water molecule (H_2O) is produced when 2-PG is catalyzed by enolase, or phosphopyruvate hydratase, to form phosphoenolpyruvate (PEP). In the final processes of glycolysis, PEP is reduced to a single molecule of pyruvate by pyruvate kinase with the creation of another ATP molecule (Brooks, Fahey, & Baldwin, 2004; Katch, Katch, & McArdle, 2007). Lastly through homolactic fermentation, a lactate molecule is formed when NAD^+ separates from a nonoxidized hydrogen ion (H^+) which combines with the pyruvate molecule with the use of lactate dehydrogenase (LDH) (Katch, Katch, & McArdle, 2007).

Fate of Lactate

Fatigue can be identified by factors such as the ability to produce and utilize energy, contractile mechanisms of muscle fibers, or neural control of muscle contraction. More specifically, the factors involved with blood lactate accumulation in skeletal muscle cells are of the following: imbalances between the rate of glycolysis and mitochondrial respiration, decrease in redox potential (increased NADH compared to NAD^+), decrease in blood oxygen content,
and/or decreased blood flow to skeletal muscles (Katch, Katch, & McArdle, 2007). In regards to high-intensity exercise, the greatest factor is rate of accumulation of by-products compared to the rate of clearance.

The lactate produced as a by-product of anaerobic glycolysis is attributed to lactic acidosis during high-intensity exercise. One possible fate of lactate is to be oxidized within the mitochondria of either oxidative muscle cells (type I), the heart, or liver to produce energy when oxidative processes are viable, for example, during a recovery phase. In order for lactate to arrive at these aerobic tissues, it must diffuse into the interstitial space between the tissues and into the blood to be transported (Katch, Katch, & McArdle, 2007). This is where the intercellular (ILS) and extracellular (cell-to-cell) lactate shuttle concepts come into action. The intracellular lactate shuttle (ILS) concept occurs between the cytosol and the mitochondria of the organ, where the lactate-pyruvate (monocarboxylate) transporter (MCT1) assists in shuttling lactate and NADH into the mitochondria from the cytosol (Brooks, Fahey, & Baldwin, 2004).

The formation of lactate occurs when NADH is oxidized and pyruvate is reduced to form lactate within the cytoplasm as a result of “rapid” glycolysis (Brooks, Fahey, & Baldwin, 2004). The remaining NAD+ continues to be reduced by combining with more H+ ions and forming lactate in the cytosol. Once lactate concentrations rise within the cytosol, lactate enters the mitochondria with the help of MCT1, then is oxidized into pyruvate by mitochondrial LDH and with the assistance of the electron transport chain and tricarboxylic acid cycle (TCA) produces energy (Brooks, Fahey, & Baldwin, 2004). Skeletal muscle is the major site for the production of lactate, but it also is the primary tissue involved in the removal of lactate via oxidation. If there is insufficient mitochondrial activity in the muscle fibers, such as in type II, NADH is oxidized and
Lactic acidosis in the cytosol decreases the potential of hydrogen (pH) due to the increased concentrations of unbuffered protons, H⁺, also resulting in lower blood, muscle, and intracellular pH (Brooks, Fahey, & Baldwin, 2004; Kenney, Wilmore, & Costill, 2008). The human body produces bi-carbonate (HCO₃⁻) naturally to help counteract the effects of the acidosis, although, with an increased rate of H⁺ production and insufficient rate of clearance, pH eventually decreases, becoming more acidic. The acidity causes the inhibition of extracellular acid-base changes such as the competition between Ca²⁺ and H⁺ at binding sites during excitation/contraction coupling (Fry & Poole-Wilson, 1981). Normal pH in resting skeletal muscle is approximately 7.1 but can decrease to 6.6-6.4 after maximal exercise even with the use of bi-carbonate buffering. Intracellular pH below 6.9 can affect the ability to produce energy due to the inhibition of the enzymes hexokinase and phosphofructokinase which causes a slower rate of glycolysis, thus lowering the rate of ATP production (Brooks, Fahey, & Baldwin, 2004; Cruz, de Aguiar, Turnes, Penteado Dos Santos, Fernandes Mendes de Oliveira, & Caputo, 2012). If intracellular pH falls below 6.4, glycolytic processes become withheld, leading to a quick reduction in ATP production and the preservation of the cell (Kenney, Wilmore, & Costill, 2008). Blood lactate concentrations during high-intensity exercise lasting 30-120 seconds can reach maximum values of 15-25 mmol/l and peak approximately 3-8 minutes post-exercise (Goodwin, Harris, Hernández, & Gladden, 2007).
Recovery

At the end of high-intensity bouts of exercise, lactate begins to reach peak concentrations in the muscles and blood. Sufficient time is needed in order to promote the clearance of lactate through the use of lactate shuttling, cardiorespiratory system, and oxidative tissues. Excess post-exercise oxygen consumption (EPOC) occurs to support the elimination of lactate by providing muscles with oxygen, which have been depleted during the earlier portion of exercise, to perform oxidation (Kenney, Wilmore, & Costill, 2008). Additionally, lactate in the blood is transported via circulatory system during the resting period.

By performing low-intensity aerobic exercise (known as active recovery) instead of inactive rest (passive recovery), the rate of lactate clearance increases. Active recovery could promote higher metabolic rates and systemic flow, which will accelerate lactate metabolism (Martin, Zoeller, Robertson, & Lephart, 1998). The increased blood flow should promote the rate at which lactate is shuttled to other tissues for metabolism.

Power Output

Power output has been found to have positive attributes through the utilization of active recovery (AR) between high-intensity intervals when compared to passive recovery (PR). Signorile, Tremblay, and Ingalls (1993) found that AR displayed an increase in power when compared to PR in 6-second power tests on a cycle ergometer. The purpose of this study was to determine whether active recovery was superior to passive recovery during short-duration, high-intensity performance. Signorile, Tremblay, and Ingalls (1993) believed that active recovery would produce a positive effect on sprint performance in regards to peak power (PP), fatigue rate (F), and total work (TW).
Six male athletes, ages 18-40 years, who were trained in power-dominant activities such as powerlifting, Olympic lifting, 200-m track and field sprint, and soccer, participated in the study. The testing protocol consisted of eight consecutive 6-second supramaximal (over 100% of VO$_{2\text{max}}$) rides on a modified constant-load cycle ergometer. Recovery conditions for each group were either active or passive amounting to 30 seconds between the high-intensity intervals. Active recovery consisted of pedaling at 60 rpm with a 1kg resistance, resulting in a 360 kgm·min$^{-1}$ workload, while passive recovery involved sitting passively on the cycle ergometer seat until the next interval. The variables PP, F, and TW were collected during each trial within each group and analyzed by an 8x2 (Trial x Condition) mixed multiple analysis of variance (MANOVA) with repeated measures across trials (Signorile et al., 1993).

Signorile, Tremblay, and Ingalls (1993) found the active recovery (AR) group’s peak power (PP; 1192.85 watts, 1134.58 watts; p < 0.0001, respectively) and total work (TW; 6.59 kJ, 6.23 kJ; p < 0.0001, respectively) were significantly higher than the passive recovery (PR) group. There was no significant difference for fatigue rate (F) between the groups. The study promotes the theory that active recovery between high-intensity intervals of short duration increases the rate of lactate removal by oxidative metabolism and the movement of metabolites by the “pumping” action of the active musculature, thus increasing in peak power and, ultimately, linking to an increase in performance (Signorile et al., 1993). Total work increased in the AR group due to the additional work performed during the recovery period. Considering exercise intervals were of short duration (6-second sprints), it is possible that the anaerobic glycolysis metabolic pathway did not produce a significant amount of lactate to be measured through blood
The researchers did not include the collection of blood lactate concentration in this study.

Similarly, a research study by Dupont, Moalla, Guinhouya, Ahmaidi, and Berthoin (2004) found that not only does power increase with active recovery during recovery periods, but also an increase in oxyhemoglobin (HbO₂) within blood. It was hypothesized that there would be a higher reoxygenation of myoglobin and hemoglobin and, additionally, higher resynthesis of phosphorylcreatine (PCr) with passive recovery when compared to active recovery (Dupont et al., 2004). The study was designed to compare time-to-exhaustion (TTE) and HbO₂ variations between active and passive recovery methods. They hypothesized that TTE would be longer in duration and deoxygenation would be slower with passive recovery than active.

The subjects who volunteered to participate were 12 male, soccer-trained and specialized, physical education students. The participants were subjected to three different pre-testing protocols: a maximal graded test, force-velocity test, and a Wingate anaerobic test. Each testing day was separated by at least two days. The pre-testing protocols test was used to determine baseline VO₂max and power output which were used for calculations for the intermittent exercises. During the intermittent exercise testing protocol, each participant performed 15-second high-intensity sprints alternated with 15 seconds of either passive recovery or active recovery, which consisted of light cycling at 40% VO₂max of the individual, with the cycling frequency at 60 rpm. The intermittent exercises were performed until the participant reached exhaustion in which the researchers felt the subject could no longer proceed with additional sprints. Measurements were collected by a near-infrared spectroscopy device to determine the changes in tissue HbO₂, a universally standard metabolic cart to assess respiratory gas exchange,
and blood lactate concentration using a spectrophotometer technique. Statistical analysis performed on data was a Student’s $t$ test to determine differences between the active and passive group (Dupont et al., 2004).

Dupont, Moalla, Guinhouya, Ahmaidi, and Berthoin (2004) found significant results for TTE and HbO$_2$ between the active and passive recovery groups during and following the intermittent exercises. TTE was found to be significantly longer for the passive group than for the active group ($962 \pm 314$s, $427 \pm 118$s; $p < 0.001$, respectively). The mean rate of decrease in HbO$_2$ was significantly lower ($p < 0.001$) in the passive group ($2.9 \pm 2.4\% \cdot s^{-1}$) when compared to the active group ($7.8 \pm 3.4\% \cdot s^{-1}$). The increase of time-to-exhaustion in the passive group when compared to the active group suggests that recovery occurs more quickly when the individual does not perform any work between intervals. The decrease in HbO$_2$ from the passive group may be because active recovery allows a greater reoxygenation of myoglobin within the blood. Additionally, metabolic power during the exercise was stated to decrease with passive recovery than with active recovery ($48.9 \pm 4.9$, $52.6 \pm 4.6$; $p < 0.001$, respectively) (Dupont et al., 2004). The researchers of this study chose to not collect blood lactate concentration from each subject during the intermittent exercises.

Spierer, Goldsmith, Baran, Hryniewicz, and Katz (2004) performed a similar study but with an increased duration of cycle ergometer sprints and recovery time between bouts. This prospective crossover study involved the comparison between the active and sedentary population through mean power, total work, and capillary blood lactate concentrations. The subjects recruited consisted of six sedentary and nine moderately training ice hockey players. The testing protocol for both groups entailed a Wingate anaerobic power test with 30-second
sprints followed by 4 minutes of recovery between the bouts. This study assigned the active recovery group with light-intensity cycling corresponding with 28% VO$_{2_{\text{max}}}$ The Wingate sprints continued for each subject until peak power fell below 70% of the first bout or the subject was unable to continue pedaling during the 30-second period. Workload during the sprints was calculated for each group, sedentary and trained, by using a percentage of body mass as the resistance (body mass [kg] x 0.075, body mass [kg] x 0.098; respectively). Oxygen consumption was measured by a metabolic cart to determine VO$_{2_{\text{max}}}$ which was used for the recovery phase during the sprints. Capillary blood lactate concentrations were determined by the finger-stick method immediately following every sprint bout and again 5 minutes after the last bout completed. Data analysis used involved repeated-measures ANOVA with one between-groups (sedentary vs. ice hockey players) variable, within-group variable ANOVA (recovery mode, time), and a paired $t$-test for power and total work; significance set at $p < 0.05$ (Spierer et al., 2004).

Spierer et al. (2004) found that mean power by active recovery had a significantly higher output when compared to passive recovery in sedentary subjects (388 ± 42 watts, 303 ± 37 watts; respectively), but not in the ice hockey players (589 ± 22 watts, 563 ± 26 watts; respectively). Also, the sedentary group had a significantly lower fatigue index per bout during active recovery (3.1 ± 0.8%) than during passive recovery (8.9 ± 1.7%), but not in the ice hockey players (6.1 ± 1.1% active, 7.3 ± 0.9% passive). Total work increased significantly in both groups under the active recovery method: 34890 ± 3768 joules for the sedentary group and 86763 ± 9151 joules for the ice hockey players. Additional results found that differences in heart rate were not significant in both sedentary (77 ± 4 to 173 ± 5 min$^{-1}$ active, 72 ± 3 to 177 ± 5 min$^{-1}$) and trained
(67 ± 4 to 187 ± 2 min\(^{-1}\) active, 7.3 ± 0.9 min\(^{-1}\) passive) groups for recovery types. Capillary blood lactate concentrations were found to be significantly lower in the active recovery group (data not presented) for the ice hockey players only, 30 minutes following exercise, but not significant within the sedentary group (77 ± 4 to 173 ± 5 min\(^{-1}\) active, 72 ± 3 to 177 ± 5 min\(^{-1}\) passive) or the trained group (67 ± 4 to 187 ± 2 min\(^{-1}\) active, 69 ± 4 to 188 ± 2 min\(^{-1}\) passive) (Spierer et al., 2004).

This study supports the theory that active recovery provides positive effects on power, total work, fatigue, and blood lactate clearance, but only in the sedentary group. They found that 28% \(\text{VO}_{2\text{max}}\) may not have been an appropriate work rate to produce a significant effect on power and blood lactate clearance in moderately training ice hockey players (Spierer et al., 2004). The moderately trained ice hockey players may have needed an increase in workload to stimulate the increase in lactate clearance by active recovery via cycling. The study finds that the training level of an individual may play a role in lactate clearance.

In another study involving the effects of active versus passive recovery on power output and blood lactate clearance, Connolly, Brennan, and Lauzon (2003) found confounding results to the previously mentioned studies. The main purpose of this study was to determine any changes in peak power (PP), average power (AP), and blood lactate during short-duration, high-intensity bouts of cycling with active or passive recovery. The subjects used in the study consisted of seven healthy, male cyclists (age 21.8 ± 3.3 years; mass 73.0 ± 3.8kgs; height 177.3 ± 3.4cm) whom underwent six 15-second, maximal effort sprints on a cycle ergometer with 3 minutes of recovery between sets. The active recovery group performed 3 minutes of light-intensity cycling at 80rpm with 1kg resistance, while the passive recovery group remained passively seated on the
cycle ergometer seat until the next set of sprints. The workload during the sprints for all participants were standardized at 5.5kg in accordance to methods in the study by Ainsworth, Serfass, and Leon (1993, as cited by Connolly et al., 2003).

Peak power (PP), average power (AP), time-to-peak (TPP), and fatigue index were collected with the utilization of power software (Sports Medicine Industries Power software V3.02). Blood lactate concentrations were calculated by a portable lactate analyzer a total of seven times during the session, one following each sprint interval at the 2-minute mark of the recovery phase and another 5 minutes following the last bout. Data was analyzed using a 2x6 repeated-measures ANOVA, p < 0.05.

The data suggests that mean peak power and average power between the active and passive groups were both insignificant. Connolly et al. (2003) found that mean peak power across the trials was 775 ± 11.2 watts for active recovery and 772 ± 33.4 watts for passive recovery, which were not significant findings (p = 0.785, F = 0.08). Average power across the trials was also insignificant with 671 ± 26.4 watts compared to 664 ± 10.0 watts for the active and passive group, respectively. Blood lactate concentrations were also insignificant between the groups, although the active recovery group displayed a lower mean concentration across the trials when compared to the passive recovery group (9.09 ± 2.37 mmol·l$^{-1}$, 10.05 ± 2.84 mmol·l$^{-1}$; p = 0.37, respectively) (Connolly et al., 2003).

The researchers of the study believed that a short recovery period of 3 minutes would have been a sufficient duration to determine the effects of active recovery compared to passive recovery on peak power, average power, and blood lactate clearance. Peak and average power output between the active and passive recovery groups was found to be insignificant. Connolly et
al. (2003) found that after trial one to the end of trial six, the active recovery group had a 2.9% decrease in power output when compared to the passive recovery group at a 10.6% decrease. Although there were no significant findings between the lactate values between the groups, the active recovery was found to be lower on average and had a significant effect on lactate values between the trials (p < 0.001, F 6.4). Connolly et al. (2003) believed that recovery periods extending beyond 3 minutes could have influenced the rate of lactate metabolism through the utilization of active recovery.

The previously mentioned studies have found that active recovery during recovery periods during intermittent high-intensity intervals have positive impacts on power output, which can suggest an increase in overall performance during training and competition.

Lactate Clearance

Different types of recovery modes have been used to interpret the effect of active recovery on blood lactate clearance. For example, massage components have been introduced into methods of recovery for high-intensity interval exercise (Martin, Zoeller, Robertson, & Lephart, 1998). This study sought to compare the effects on lactate clearance of passive, active, and sports massage recovery techniques. They believed that sports massage could be a viable technique for clearing lactate due to the local increases in skeletal muscle blood flow.

Ten male cyclists, ages from 21 to 34, who were closely similar in fitness levels and years of competitive cycling experience, underwent three successive Wingate cycle sprints followed by 20 minutes of assigned recovery type. After determining each subject’s VO\textsubscript{2peak} by a maximal oxygen consumption test on a cycle ergometer, the individual performed three sets of
30-second supramaximal Wingate sprints with 2-minutes of passive rest between the sets. Resistance for the sprints were relative to the subject’s body weight in kilograms. Following the completion of the last sprint, each subject remained seated on the cycle ergometer for 5 minutes to allow blood lactate to accumulate to peak levels post-exercise. After the 5 minutes, subjects began 20 minutes of their assigned recovery method. The passive group consisted of lying down in supine position, while the active group performed low-intensity (40% VO$_{2peak}$) cycling on the ergometer at 80 revolutions per minute. The sports massage included techniques such as effleurage, petrissage, tapotement, and compression to multiple lower body muscle groups.

Blood samples were taken via catheter and collected before exercise, immediately after the last Wingate sprint, 5 minutes after exercise, and at 5-minute intervals throughout the 20-minute recovery period. Data was analyzed using a two-factor repeated-measures ANOVA, followed by a Scheffe post hoc procedure (Martin et al., 1998).

The post hoc analysis specified that the active recovery group had a significant decrease (6.79 mL/L) when compared to both the passive group (4.33 mL/L) and sports massage group (4.39 mL/L) for blood lactate concentrations in absolute terms. In relative terms, the active group displayed a 59.38% decrease in blood lactate concentration while the passive and sport massage groups had a 38.67% and 36.21% decrease, respectively (Martin et al., 1998). This study reinforces the theory that active recovery has a positive effect on lactate clearance compared to passive recovery following high-intensity interval exercise. The researchers believe that 20 minutes of low-intensity (40% VO$_{2peak}$) active recovery produced a significant reduction in blood lactate concentration when compared to passive recovery and sports massage techniques. Data
suggests that after 10 minutes of active recovery, there is also a significant decrease in blood lactate concentration compared to the passive and massage groups (Martin et al., 1998).

Bangsbo, Graham, Johansen, and Saltin (1994) aimed to find the effects of active recovery on lactate metabolism during the first 10 minutes following high-intensity exercise. For this study, the researchers tested each leg separately with active and passive recoveries after an exhaustive single-leg ergometer exercise. Subjects consisted of six healthy, physically active, young-adult males, ages from 22 to 26 years, with an average height of 182 cm and weight of 75 kg.

The protocol consisted of a one-legged exercise with an ergometer which permitted subjects to lie in the supine position while isolating the quadriceps muscles. After a 10-minute warm-up at 10 watts, each subject performed a single-legged exercise on the ergometer with a kick frequency approximately 60 per minute on average (61.0 ± 5.4) to exhaustion. After the first leg exercise, a 10-minute recovery period was instituted, where the active group performed a low-intensity exercise at a work load of 10 watts and passive group at rest. Following the 10-minute recovery period, a 1-hour rest break was given to each participant until the second exercise testing. The same exercise test was performed a second time on the opposite leg following with the alternative recovery type (Bangsbo et al., 1994).

Blood flow was taken via femoral catheter and measured by thermodilution to determine the rate of blood circulating through the quadriceps muscles collected at ~0.5, 1.3, 2.4, 3.2, 5.2, 7.2, and 9.8 minutes of the 10-minute recovery period. Blood was also analyzed for hemoglobin O₂ concentrations measured spectrophotometrically by the cyanmethemoglobin method (Drabkin & Austin, 1935, as cited by Bangsbo et al., 1994). Muscle biopsies were measured by
fluorometric assays to assess lactate, glycogen, and creatine phosphate. Blood samples were taken at ~0.8, 1.8, 2.9, 5.5, 7.8, and 10.2 minutes of the 10-minute recovery period. Lactate and glucose were analyzed from perchloric acid-precipitated extractions using a fluorometric assay (Lowry & Passonneau, 1972, as cited by Bangsbo et al., 1994). Data was analyzed by the Wilcoxon ranking test for paired data at p < 0.05.

The results of the study found that arterial lactate concentrations were significantly higher in passive recovery tests than active (3.0 and 2.6 mmol/l, respectively) 10 minutes following the exercise tests. Venous lactate concentrations were 7.4 mmol/l for passive and 7.0 mmol/l for active after 1.8 minutes into the recovery period, then reduced to 3.5 mmol/l and 2.7 mmol/l, respectively, following the 10-minute recovery period. The muscle biopsies found that muscle lactate concentrations by weight were significantly higher 10.8 minutes of the recovery period in the passive recovery test than active (4.4 mmol/kg wet wt and 3.2 mmol/kg wet wt, respectively). Net lactate concentrations decreased significantly from 3.4 to 10.8 minutes of the recovery period in the active recovery tests (21.5 mmol/kg wet wt) when compared to the passive recovery tests (19.9 mmol/kg wet wt). Muscle glycogen did not significantly change for both groups, yet net glucose uptake was 32% lower during the passive recovery tests than active (Bangsbo et al, 1994).

This study suggests that active recovery results in lower blood and muscle lactate concentrations following high-intensity, exhausted exercise. This study’s importance is highly significant showing that arterial, venous, and muscle lactate concentrations decreased at a quicker rate after a few minutes into recovery and greater total amount following exercise during
active recovery when compared to passive recovery. They believe there is a higher rate of lactate metabolism after 3 minutes of active recovery (Bangsbo et al. 1994).

One study which tested the effects of active recovery in high-intensity bouts of climbing, found supporting results to previously studies on lactate clearance (Draper, Bird, Coleman & Hodgson, 2006). Ten male recreational climbers (age 22 ± 3.6 years; height 1.74 ± 0.06m; mass 70.6 ± 5.3kg) who trained one or two indoor climbing sessions per week volunteered for the study. Climbing procedures consisted of five 2-minute trials where all participants climbed a self-selected route on an indoor wall. The indoor climbing wall was angled at 106° vertically towards the floor to illicit an intensity to increase in blood lactate concentrations. The route started with both hands and feet on the wall, where they climbed to the top of the wall to the finishing hand position located 4.1 meters from the starting hand position. During the 2-minute recovery period, all participants randomly completed both active and passive recovery conditions for the climbing test due to the study’s two-way crossover design. The passive recovery type consisted of resting at a seated position, while active recovery allowed subjects to walk at a moderate to fast pace totaling 182 meters. After the recovery period, a transition period was given before the next trial to allow the subjects to mentally prepare for the next climb, clean boots, and re-chalk their fingers. Blood lactate was taken by finger-stick method post-warm-up, after 2-minute recovery, and 5 minutes after the last trial. The Borg scale was used for the rating of perceived exertion (RPE), which was measured following each climbing trial. Heart rate was recorded every 5 seconds throughout the trials (Draper et al., 2006).

The active recovery conditions displayed a significant difference when compared to the passive recovery conditions ($F_{(1,9)} = 18.79, p = 0.002$). Lactate concentrations increased with an
average of 0.9-1.2 mmol/l in the passive recovery condition when compared to the active recovery condition. There was a significant increase in RPE with the passive recovery protocol, 0.6-1.0 higher on average than the active recovery condition ($t_{(1.9)} = 6.51$, $p < 0.0005$). During the phase of recovery, there was a difference in heart rate at the point of transition ($t_{(9)} = 3.25$, $p = 0.01$). This study displays results which agree with previous research on the effects of active recovery on lactate clearance. The study also provides an insight on central fatigue using RPE, which was found to be lower in the active recovery condition.
METHODOLOGY

This research study was performed on two separate days by each subject. The first visit consisted of screening protocols, an instructional information session, informed consent, and anthropometric measurements. The second visit consisted of the exercise testing portion (high-intensity interval training protocol). The total time for each subject was about 2 hours. Both days occurred at Northern Illinois University’s Kinesiology and Physical Education Department in Anderson Hall, Advanced Testing Laboratory (AN141) and Gym B AN102 or AN135.

Participants

The study included 45 healthy, non-athlete college students with ages ranging from 19-26 years-old. Non-athlete is defined in this study as a person who is not “trained”; past training could alter the results due to their cardiovascular and muscles physiology capacity. Participants of this study were recruited from the general student population at Northern Illinois University using flyers (see Appendix A) posted in Anderson Hall and Gable Hall, as well as verbal announcements in various classes within the Kinesiology and Physical Education Department with the instructor’s permission, accompanied with a sign-up sheet.

All participants underwent a health screening by the completion of a Health History Questionnaire which assisted identifying any risk of coronary artery disease, hypertension, and other cardiopulmonary conditions (see Appendix B). Each participant was considered in good overall health, which in this study includes non-hypertensive to pre-hypertensive, no risk factors
for CAD, no risk factors relating to cardiopulmonary conditions, and no previous skeletal injuries which could affect the outcome of the study. Any participant who was or could be pregnant was immediately excluded from the study. Subjects completed a Blood Health/Finger Prick Blood Analysis Questionnaire (see Appendix B) and any participant who answered “yes” to any exclusion questions was subject to exclusion from the study to prevent the spread of any blood-borne pathogens and conditions and ensure the safety of the subject as well as the researcher.

Recovery protocols were of two conditions: modality (active [AR] or passive [PR]) and duration (5 minutes [R5] or 10 minutes [R10]). In order to determine any differences in recovery protocols, each participant was randomly placed into one of four groups: 5-minute Active Recovery (AR5), 10-minute Active recovery (AR10), 5-minute passive recovery (PR5), or 10-minute passive recovery (PR10). The PR groups consisted of the subject remaining in a seated or standing position, while the AR groups performed a light walking pace (2.5 mph), approximately 40-60% maximum heart rate. The randomization method was conducted following the completion of the first meeting in which each subject was determined eligible and then placed in a group.

Instruments/Apparatus

Body composition was measured by the BOD POD system and InBody 520 Bioimpedance Analysis Scale. The BOD POD (COSMED USA, Inc., Concord, CA) is considered the gold standard for determining body composition (fat mass, fat-free mass, and muscle mass) by using air displacement plethysmography, which is a safe, noninvasive, and reliable method for research participants. A secondary analysis by the InBody 520 Bioimpedance
Analysis Scale (Biospace, Korea) was utilized to ensure the accuracy of the participant’s body composition via different methods. The InBody 520 Bioimpedance Analysis Scale uses electrical currents which travel through the body to determine body composition. Usually, the greater fat within the body, the more resistance there is to the current. Other factors such as hydration can also affect this results. Body fat percentage was taken from the body composition analysis for data collection.

HR throughout the high-intensity interval protocol was measured by a Polar heart rate monitor (Polar Electro Inc., Lake Success, NY). Each participant was fitted to appropriate H7 strap size, sensor located directly below the xiypoid process, and the watch on the participant’s wrist (participant’s choice). The HR monitor was calibrated before the beginning of the warm-up phase and removed following the cool-down phase.

BLC was measured by a Nova Biomedical Lactate Plus Lactate Meter (Nova Biomedical, Waltham, MA). Before every high-intensity interval training session, the blood lactate monitor was calibrated using control solution, either with a 1.0-1.6 mM solution or 4.0-5.4 mM solution, to ensure accurate measurement of the device during the study. The lancet used for the study was the Accu-Chek Safe-T-Pro (Roche Diagnostics, Mannheim, DE). The lactate meter is commonly used in various clinical and medical applications, making it practical for this research study.

Reliability/Validity of Instruments

The BOD POD is considered the gold standard of body composition estimation with a $R^2$ value of 0.93 accuracy when compared to hydrostatic weighing (McCrory, Gomez, Bernauer, &
Molé, 1995). The safety and high accuracy in determining body composition with the BOD POD makes it a useful tool in this research study.

The InBody 520 Bioimpedance Analysis Scale uses the resistance (or impedance) of the body to determine the amount of body fat. When compared to the BOD POD, bioimpedance analysis has been found to have no significant difference in the estimation of body fat percentage (Biaggi et al., 1999).

The Nova Biomedical Lactate Plus Lactate Meter is used in many clinical and medical settings to measure BLC because of the accuracy and ease of use. Tanner, Fuller, & Ross (2010) reported that the correlation $r$ of the Nova Biomedical Lactate Plus Lactate Meter was 0.988 when compared between multiple paired trials. In another study, the lactate meter was found to have a strong correlation ($r = 0.9967$) between multiple paired trials, and when compared to the TSI bench-top lactate analyzer, the lactate meter had an $r$ value of 0.9149 (Hart, Drevets, Alford, Salacinski, & Hunt, 2013).

The Polar FT60 heart rate monitor is a viable tool when assessing an individual’s HR during exercise. Unfortunately, this specific model has not been validated within a study, but similar models have been shown to be highly correlated with HR. Goodie, Larkin, & Schauss (2000) found that between an older model, Polar Vantage XL, and electrocardiography, the correlation was high ($r = 0.98, p < 0.001$) at rest. Another model (Polar S810) was found to have high correlation ($r = 0.85-0.99$) with electrocardiography (Nunan et al., 2009).

**Preliminary Procedures (Session 1)**

After contact was made with the willing individual, a set date and time were given to
meet for a first visit, which was a health screening to determine eligibility. The meeting occurred in the Advanced Testing Laboratory room in Northern Illinois University’s Anderson Hall. The health screening consisted of Informed Consent, Inclusion Form, Health History Questionnaire, Blood Health/Finger Prick Blood Analysis Questionnaire, and health measures (see Appendix B). The health screening included determining the subject’s blood pressure and body composition. Blood pressure was taken in a seated position in a low-noise environment with a standard stethoscope and sphygmomanometer. If the blood pressure of the subject was read above 140 systolic and/or 90 diastolic, a second measurement was taken again with at least 5 minutes after to identify hypertension and ensure accuracy. If the blood pressure is hypertension stage 1 or higher, over 140 systolic and/or 90 diastolic, the subject was excluded from the study.

Additionally, the participants will underwent body composition analysis via BOD POD and InBody 520. Participants followed the body composition protocol outlined in Appendix C. After the anthropometric testing, each participant was advised to remain performing normal daily tasks but to refrain from organized physical activity (recreational fitness, strength & conditioning workouts, etc.) on the night before the high-intensity interval training session. They were also asked to refrain from eating 2-3 hours prior to testing and remain properly hydrated for the upcoming activity.

HIIT Session (Session 2)

The second visit consisted of the high-intensity interval training session. The participants were advised to arrive on time to their scheduled session at AN102 gym or AN135 stage in Anderson Hall, which both contain a solid hardwood floor. Once the subject arrived, the
subject’s ethnicity, physical activity level, blood pressure, resting BLC, HR, and RPE were taken prior to the exercise session (see Appendix D). Each subject was fitted with the Polar HR watch and monitor with an appropriate strap size. Resting HR that was accepted for participation during the session was <50% on the subject’s predicted max heart rate. Instructions on the exercise protocol were explained to the participant and that any time they feel unwell they may cease the exercise. Once preparatory and baseline measurements were completed, the subject will performed the warm-up, which consisted of walking for 1-2 minutes, followed by a 1-2 minutes of light jogging (>50% maximum heart rate), then 1-2 minutes of dynamic stretches. The dynamic stretches were selected by each participant to ensure the intensity of the exercises did not cause a rise in blood lactate or fatigue for individuals who were not accustomed to this type of warm-up exercises before the beginning of the trials.

For this study, each participant will underwent three sets of sprints to elicit an increase in BLC, HR, RPE, and incur sprint times. Resting measurements were taken before the warm-up portion of the session described above. Following each of the three sprint sets, data was collected and a recovery phase took place (a total of three recovery phases).

The floor was marked with duct tape from the start/finish line to wall, 75 feet (19.81m) apart. Once warmed up, the subject lined up at the start/finish line. On the researcher’s command, the subject sprinted down to the other line and back a total of three times at maximum effort for a total of 450 feet (137.16m) for the single-sprint set. Time was recorded from the beginning of the set until the point the subject crossed the start/finish line. Time was hand-timed by standard stop-watch. Each subject was encouraged to give maximal effort by verbal phrases during the sprint sets. After the subject crossed the start/finish line, he/she safely slowed, and
immediately walked to the blood collection station, approximately 10-15 feet from where the participant stopped the sprint. Once the participant was seated, data was collected in the respective order: sprint time, HR, RPE, and BLC. BLC was taken on the right hand for each subject. Directly following the collection of data, recovery time began. Depending on which group the participant was assigned to, the subject performed either the passive/active recovery for 5 or 10 minutes. At the end of the specified recovery time, the subject lined up back on the start/finish line to begin the next set of sprints/recovery until the last set was completed. The total volume of distance covered during the sprints was 1,350 feet or 450 yards (411.18m).

The cool-down consisted of 5-10 minutes of escorted walking (speed chosen by subject) until the subject’s HR fell below 50% of predicted max HR, then 3-5 minutes of optional static stretching (hamstring, quadriceps, glutes). Once all data had been collected and subject was well enough to continue with daily activities, the data was entered into an Excel spreadsheet on the researcher’s personal computer. The hardcopy from the second visit was stored in the subject’s personal folder which was locked in a drawer with corresponding identification number. Subjects were advised to contact the researcher if any issues should arise following the testing session.

Statistical Analysis

Demographic, anthropometric, independent variables, and dependent variables were recorded in Excel (Microsoft Corporation, Redmond, WA), then transferred and analyzed using SPSS Statistics 23 (SPSS, Inc., Chicago, IL). All data was checked for normality and equality of variance among groups via Shapiro-Wilks test of normality and Levene’s test of equality of variance, respectively. Differences in group means across the trials (S1, S2, S3, and Post) were calculated by mixed-factorial analysis of covariance (MANCOVA) (2 x 2 x 4 design, modality x
duration x trial) to compare BLC, RPE, and HR. Sprint times (S1, S2, and S3) were analyzed by a mixed-factorial analysis of covariance ANCOVA (2 x 2 x 3 design). In order to analyze differences in post-exercise responses (S3 to Post) to recovery group, a mixed-factorial ANOVA (2 x 2 x 2 design) was utilized to analyze blood lactate concentrations. The alpha level for significance was set at p < 0.05 for all tests.
RESULTS

Subject Characteristics

Forty-five students from Northern Illinois University’s Kinesiology and Physical Education Department volunteered to participate in the study; only 40 students completed the study. Descriptive characteristics for all groups of subjects are provided in Table 1. No significant differences were detected in age, weight, height, and body fat percentage between groups. Two of the 45 subjects were unable to complete the entire testing protocol due to feeling unwell after the second sprint trial, in which variables following the third sprint trial were not obtained, therefore both subjects were excluded from data analysis. The remaining three students were unable to attend the second session.

Table 1
Descriptive Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Body Fat % (BP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
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<td>172.6 ± 1.6</td>
<td>79.4 ± 2.4</td>
<td>18.1 ± 1.3</td>
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<td>Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AR10</td>
<td>22.3 ± 1.4</td>
<td>170.7 ± 9.6</td>
<td>78.6 ± 17.2</td>
<td>16.2 ± 5.8</td>
</tr>
<tr>
<td>AR5</td>
<td>21.8 ± 2.0</td>
<td>171.8 ± 10.7</td>
<td>78.7 ± 15.7</td>
<td>17.2 ± 6.7</td>
</tr>
<tr>
<td>PR10</td>
<td>22.6 ± 1.5</td>
<td>177.3 ± 11.6</td>
<td>82.2 ± 15.2</td>
<td>16.8 ± 9.4</td>
</tr>
<tr>
<td>PR5</td>
<td>21.0 ± 0.8</td>
<td>170.1 ± 9.3</td>
<td>76.5 ± 15.1</td>
<td>20.6 ± 10.6</td>
</tr>
</tbody>
</table>
Covariates

The only covariate which was found to have a significant effect on the mixed-factorial MANCOVA model for BLC, HR, and RPE was gender. The mixed-factorial ANCOVA model to analyze sprint performance times used body fat percentage and gender as covariates.

Blood Lactate Concentration

The mixed-factorial MANCOVA revealed no significant interactions found between the trials and recovery modality; trials, recovery modality, and recovery duration; or between groups for recovery modality and recovery duration ($p > .05$). However, there was a significant interaction effect between the trials and recovery duration ($p = .002$, $\eta^2 = .118$) (see Figure 1).

![Figure 1: Estimated marginal means for blood lactate concentration between recovery duration across trials.](image-url)
BLCs were significantly different across the trials \((p < .001)\), which was to be expected as sprint trials progressed. A significant main effect on BLC was seen from recovery modality across all the trials \((p = .038, \eta^2 = .088)\). The AR group had a significantly lower average BLC when compared to the PR group as trials progressed (see Figure 2). The mean difference across the trials for BLC when comparing the AR group to the PR group was \(-1.51 \text{ mmol/l} (p = .038, 95\% \text{ CI } [-2.92, -0.86])\). However, there were no main effects from recovery duration on BLC between the groups \((p > .05)\).

Figure 2: Estimated marginal means for blood lactate concentration between recovery modalities across trials.
Using a mixed-factorial ANOVA to analyze the differences in group means for BLC from the end of trial 3 to post-exercise measurements, no significant effects were found for either recovery modality or recovery duration ($p < .05$).

**Sprint Times**

The mixed-factorial ANCOVA revealed no significant differences in sprint times for all groups across the trials ($p > .05$). No significant interaction effects were found between trials and recovery modality, trials and recovery duration, as well as between trials and recovery modality and recovery duration on sprint times ($p > .05$). There were no significant interactions between the groups from recovery modality and recovery duration on sprint times ($p > .05$). No significant main effects were found for sprint times from either recovery modality or recovery duration ($p > .05$). The PR group displayed an increase in estimated marginal means (EMM) from the end of sprint trial 2 (29.41s) to sprint trial 3 (30.17s), while the AR group displayed a consistent (29.37s to 29.35s) EMM for sprint time across the last sprint trials (see Figure 3). Similarly, the R5 group displayed an increase in EMM from the end of sprint trial 2 (29.42s) to sprint trial 3 (30.04s), while the R10 group displayed a slight increase (29.36s to 29.48s) EMM for sprint time across the last sprint trials (see Figure 4).
Figure 3: Estimated marginal means for sprint times between recovery modalities across trials.

Figure 4: Estimated marginal means for sprint times between recovery durations across trials.
Heart Rate

The mixed-factorial MANCOVA revealed no significant differences in HR for all groups across the trials ($p > .05$). No significant interaction effects were found between trials and recovery modality, trials and recovery duration, as well as between trials and recovery modality and recovery duration on HR ($p > .05$). There were no significant interactions between the groups from recovery modality and recovery duration ($p > .05$). No significant main effects were found for HR from either recovery modality or recovery duration ($p > .05$).

Using a mixed-factorial ANOVA to analyze the differences in group means for HR from the end of trial 3 to post-exercise measurements, no significant effects were found for either recovery modality or recovery duration ($p < .05$).

Rating of Perceived Exertion

The MANCOVA found significant differences across the trials for RPE ($p < .01$). However, there were no significant interaction effects between recovery modality and duration ($p < .05$). On the other hand, there was an interaction effect between the trials and recovery duration on RPE ($p = .034$, $\eta^2 = .065$; see Figure 5). The R5 group had lower average RPE following the first sprint trial, although, after the second sprint the R5 group’s mean RPE appears to become higher, especially following the third sprint trial and post-measurements. No significant main effects on RPE were found between the groups from recovery modality or recovery duration ($p > .05$).
Figure 5: Estimated marginal means for the rating of perceived exertion between recovery durations across trials.

Using a mixed-factorial ANOVA to analyze the differences in group means for RPE from the end of trial 3 to post-exercise measurements, no significant effects were found for either recovery modality or recovery duration ($p < .05$).
DISCUSSION

The purpose of this study was to determine the effects of recovery modality (either active or passive recovery) and recovery duration (10 or 5 minute periods) on lactate clearance and sprint performance. The assumption was that AR can positively influence lactate clearance in the blood when compared to PR due to the increase in blood flow throughout the body during recovery periods which allows for further transport and metabolism of lactate by increased metabolic rates and systemic flow, thus decreasing BLC (Kenney, Wilmore, & Costill, 2008; Martin, Zoeller, Robertson, & Lephart, 1998).

Subject Characteristics

The groups did not differ in regards to age, height, weight, or body fat percentage. However, the PR10 group was taller and weighed more on average than the other groups, which could have potentially affected lactate accumulation and sprint times. In addition, the two subjects who were unable to complete the entire protocol due to feeling unwell could have potentially increased the average BLCs for PR since BLCs ranged between 16-17.8 mmol/l following the second sprint trial, and while accounting for the trend in BLCs over consecutive trials, both subjects’ BLCs could have potentially resulted in even higher BLCs, thus further supporting AR as an important factor in lactate clearance.

Blood Lactate Concentration

In regards to lactate clearance, the study design produced significant results which were
comparable to the findings in the literature. The main effect found from recovery modality across the trials on lactate clearance suggests that AR had a lower average BLC across multiple sprint trials and post-exercise when compared to PR (see Figure 2). The AR modality was seen to promote the clearance of lactate by an increased blood flow (cardiac output) while walking, which assists in the removal of lactate from the working muscles and shuttles the by-product to other sites in the body for further metabolism (Bogdanis, Nevill, Lakomy, Graham, & Louis, 1996).

Across all the trials, the difference in BLC means for AR was approximately 1.5 mmol/l when compared to PR. The difference across the trials could potentially influence whether additional high-intensity intervals could be performed, thus leading to an increase in physical fitness. In comparison, Draper, Bird, Coleman, and Hodgson (2006) used indoor rock climbers who each completed five 2-minute climbing trials followed by either active or passive recovery, then another five 2-minute climbing trials. They found that mean BLCs during the AR phase were between 0.9 and 1.2 mmol/l lower when compared to the PR phase.

In this study, with 95% confidence, the difference in mean blood lactate concentration for the AR modality was 0.8 to 3.0 mmol/l lower when compared to the PR modality. A 3.0 mmol/l difference in BLCs across multiple sprint intervals could have high potential to affect an individual’s ability to perform additional sprints or even suppress feeling unwell following sprints.

The intensity for the AR groups may have been adequate to elicit a decrease in BLCs during repeated sprint trials. The maximum oxygen uptake suggested by previous studies was
28% VO$_{2\text{max}}$, which corresponds with 40-60% HR$_{\text{max}}$ from the light walking pace (2.5 mph) used for the AR phase. Spierer et al. (2004) performed the same AR intensity during repeated Wingate cycle ergometer sprints and found positive effects on BLCs for the moderately training hockey players.

The interaction between recovery duration and trials on BLC suggests that the duration of recovery may affect BLCs depending on which sprint interval completes. Displayed in Figure 1, the longer recovery duration (R10) has higher average BLCs following sprint trial 1 when compared to the shorter duration (R5). After sprint trial 2, the interaction shows R5 mean BLCs are higher than R10, then by the end of sprint trial 3, R5 have noticeably higher mean BLCs, as well as during the post-exercise measurements. This interaction suggests that the recovery duration could potentially play a role in lactate clearance as additional, consecutive sprint intervals are performed. When only comparing recovery duration groups from sprint trial 2 to post-exercise measurements, a potential main effect could be found if additional sprint trials are completed and each group’s BLC taken following their specific recovery duration period. Recovery duration should hypothetically be a large factor in the clearance of lactate due to the additional time blood lactate can be transported out of the muscle cell to other parts of the body for metabolism. Total blood flow for a 10-minute interval will be much greater than a 5-minute interval with the same cardiac output for an individual, therefore total lactate clearance should be greater during 10 minutes of recovery than 5 minutes. Glaister, Stone, Stewart, Hughes, and Moir (2005) found that when comparing short-duration recovery periods (10 or 30 seconds) for multiple sprints on a cycle ergometer, the 30-second recovery periods had significantly lower
BLCs compared to the 10-second recovery periods. However, further investigation is needed to fully understand the effect of recovery durations on lactate clearance.

Sprint Times

No significant main or interaction effects from recovery modality were found on sprint times. However, following sprint trial 2, EMM of sprint times were approximately similar for both recovery modality groups, but after sprint trial 3, EMM of sprint time for PR was noticeably slower when compared to AR (see Figure 3). If additional sprint trials are preformed, there could be a main effect for recovery modality. Additional sprint trials may display a progressive increase in sprint times for PR while AR stay relatively consistent. In relation, Lopez, Smoliga, and Zavorsky (2014) concluded that PR is beneficial in earlier sprint trials when compared to AR on average power output during 30-second Wingate sprints. However, average power output was better maintained across consecutive sprint trials using AR. The impact from recovery modality in later sprint trials could be attributed to the accelerated transport of lactate out of the highly acidic muscle cells which, in turn, reduces muscle fatigue preceding the following sprint trial. The reduction in muscular fatigue allows for a greater ability to produce and utilize energy, improved contractile mechanisms within muscle fibers, and neural stimulation for muscle contraction, ultimately leading to better sprint performance (Katch, Katch, & McArdle, 2007).

No significant main or interaction effects were found for recovery duration on sprint times. However, similarly to recovery modality, recovery duration was seen to follow a trend to influence sprint times. Following sprint trial 2, EMM of sprint times were approximately similar for both recovery duration groups, but after sprint trial 3, EMM of sprint time for R5 was noticeably slower when compared to R10 (see Figure 4). There could potentially be an effect
from the amount of time within a recovery period on sprint time as repeated sprint trials occur. As stated earlier, recovery duration should hypothetically be a large factor in the clearance of lactate due to the additional time blood lactate can be transported out of the muscle cell to other parts of the body for metabolism. Therefore, the by-products attributing to muscular fatigue within the muscle cells decrease, and the potential for muscle contraction is increased, thus leading to an increase in performance.

Rating of Perceived Exertion

The interaction from recovery duration and trials on RPE suggest that the shorter recovery durations may not influence RPE in earlier trials but as repeated sprint trials occur may have an effect. The shorter recovery duration may influence the overall fatigue of the participant because of the insufficient time needed to recover.

Heart Rate

The results found in this study were insignificant, which were consistent with results from the literature. Draper, Bird, Coleman, and Hodgson (2006) found that HR was not effected by recovery modality. The crossover design did not find any significant differences in the recovery groups across the trials.

Conclusion

Active recovery is beneficial for lactate clearance during high-intensity interval training such as repeated sprints when compared to passive recovery. When blood lactate concentration is a limiting factor in progressing physical fitness, utilizing active recovery is a method to increase lactate clearance, ultimately preforming additional high-intensity intervals and further reaping
the benefit associated with the exercise. A light walk (2.5 mph) between sprint intervals is a viable activity for active recovery to benefit a decrease in blood lactate concentrations. The amount of time for recovery needs to be investigated further.
REFERENCES


Are you interested in participating in a KNPE research study?
Are you a NIU college student?
Are you aged 18-28?
Are you healthy?
Are you a non-athlete?

The Effects of Active Recovery during High Intensity Training

Studying the Effects of Anaerobic Activity on:
* Lactic Acid production during Physical Activity*
* Fatigue during high intensity workouts*

Stop in Anderson 123 - Mark Flury (Graduate Student)
Advised under Dr. Peter Chomentowski III
Or Email below – subject “Research Study”

This study has been approved by the Northern Illinois University Institutional Review Board, study #HS15-0024.
APPENDIX B

PRESCREENING FORMS
Health/Blood Questionnaire

Name: ___________________________ Date: ______________________

Please answer the following by checking **YES** or **NO**

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you ever had a bleeding condition or a blood disease?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have Sickle Cell Anemia, or any other blood conditions?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you ever had liver disease, viral hepatitis, or a positive test for hepatitis?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you ever had malaria?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you ever had, or come into contact with persons possessing a sexually-transmitted disease?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In the past 12 months have you had a tattoo applied, ear or skin piercing, accidental needlestick, or come into contact with anyone else's blood?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you ever used needles to take drugs, steroids, or anything else not prescribed by your doctor?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In the past 12 months, have you had sexual intercourse with anyone who has ever used needles to take drugs, steroids, or anything else not prescribed by their doctor?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you ever had a positive test for the HIV/AIDS virus?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In the past 12 months, have you had sexual intercourse with anyone who has HIV/AIDS or has had a positive test for the HIV/AIDS virus?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*All subjects have the right to not complete the form if they chose but they will be excluded for safety reasons.

*If a subject answers YES but chooses not to disclose more information they will be excluded for safety reasons.

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

Name(Print)- ___________________________

Signature- ___________________________ Date- ______________________
N-HIIT2 2017 – Inclusion Form

“The Effects of Active Recovery during High-intensity Interval Training on Lactate Clearance and Sprint Performance in College-Aged Students”

Screening Protocol:
Date: ________________ ID: ______________________

Inclusion Criteria:
Are you a healthy male or female between the ages of 18-30? Yes
No
Are you currently an NIU student? Yes
No

Exclusion Criteria:
Any past lower extremity muscle injuries that would affect results?* Yes
No
Any past lower extremity skeletal injuries that would affect the results?* Yes
No
Are you currently an NIU college athlete? Yes
No
Are you pregnant or could you be pregnant? Yes
No
Any history of illness or disease that would affect study outcomes?* Yes
No

Explain:  * if answered YES, the decision to exclude will be made by the PI after a full disclosure by the subject.

________________________ ____/____/_____
Name of person completing form Month     Day       Year

________________________
Initials of person completing the screening

Consent to Participate in a Research Study
The Effects of Active Recovery during High-intensity Interval Training on Lactate Clearance and Sprint Performance in College-Aged Students

Why am I being asked to participate in this research?

You are being invited to take part in a research study about the effects of active recovery during the rest periods of high-intensity interval training. You are being invited to participate in this research study because you are a Northern Illinois University student that will give us a great insight as to how different recovery methods increase overall sprint performance, and well-being. If you take part in this study, you will be one of about 40 people to do so. We are looking into this study to determine if the presence of active recovery will increase rates of lactate clearance during physical activity and improve overall sprint performance. If active recovery does have an effect on an individual’s ability to increase performance, it will allow us to link this to training performance to become a viable training element of basic fitness programs.

Who is doing the study?

The person in charge of this study is Mark Flury a graduate student in the Kinesiology and Physical Education department. And other graduate students from the Kinesiology and Physical Education department will be assisting with data collection and screening.

What is the purpose of the study?

By doing this study, we hope to learn if active recovery will have an effect on lactate clearance and overall sprint performance.

Where is the study going to take place and how long will it last?

The research procedures will be conducted at Anderson Hall on the campus of Northern Illinois University. You will need to physically come 2 times to Anderson hall. Each of those visits will take about 45 minutes to 1 hour. The total amount of time you will be asked to volunteer for this study is about 120 minutes over two days.

What will I be asked to do?

When you arrive, the first meeting will occur at the Exercise Physiology Lab in Anderson Hall. You will be required to sign this statement of informed consent, in addition, each you will complete a medical questionnaire known as the “Health History Questionnaire” to assess if you are cleared for vigorous physical activity. You will also complete a Blood Health Questionnaire for Finger Prick Blood Analysis. You will also have some general health measures such as blood pressure and heart rate. If you display any medical problems or concerns, you will be unable to participate within the research study. If at any time you uncomfortable about the screening questions you may opt to not complete the forms but this will lead to your exclusion from the study for safety precautions.
After completion of the consent, anthropometric data including height & weight will be collected, in addition to blood pressure utilizing a standard blood pressure cuff and sphygmomanometer. Subjects will also be randomized into one of four groups: Active-5 (active recovery 5 minutes), Active-10 (active recovery 10 minutes), Passive-5 (passive recovery 5 minutes), and Passive-10 (passive recovery 10 minutes). You will also be tested for body composition using an official BOD Pod system and the InBody body impedance analysis. In order to receive an accurate measurement, you will be instructed to not consume a meal at least 2 hours prior to arriving for preliminary testing and to be hydrated.

On completion of the anthropometric tests, the participant will be informed of the protocol of the remainder of the day before the interval training session. The participant will be instructed to carry out their normal daily activities, but must refrain from organized physical activity (recreational fitness, strength & conditioning workout, etc.) on the night of the first day prior to the interval training session. The participants will be allowed to consume a normal diet, however, they will be asked to refrain from usage of alcohol to prevent decline in performance during the interval training testing session on Day 2.

The second stage of the research will continue on the 2nd day with the interval training session facilitation. You will be instructed to arrive on time to your scheduled session at the exercise lab in Anderson Hall and then you will be escorted to the testing gymnasium. All measurements during the study will be recorded using standard data tables using paper and pencil materials. The interval training session will be conducted by the exercise physiology researchers. The testing will include a high-intensity interval training session which will determine the effect of the inclusion or absence of active recovery during the resting periods of the training session. Prior to the sprinting session, you will be taken through a brief light aerobic warm-up consisting of a light jog (50% Max Heart Rate) around the gymnasium for 5 minutes followed by 5 minutes of dynamic stretching exercises to increase blood flow to your muscles. The interval training protocol consists of 3 sets of sprints, known as gassers, which are standard protocols, not only used in various studies, but in athletic settings, and public aerobic conditioning training environments. Gassers consist of performing 3 - 25 yard (75 feet) sprints at an individual’s highest output/speed (90% of maximal heart rate). Each set of gassers will be timed using standard stopwatches in order to compare the duration of sprints over time. The Gasser will be followed by a recovery period that will correspond with the subjects randomized grouping; Active-5 (active recovery 5 minutes), Active-10 (active recovery 10 minutes), Passive-5 (passive recovery 5 minutes), and Passive-10 (passive recovery 10 minutes).
recovery 10 minutes). During each rest period, you will be tested for blood lactate levels utilizing an approved method for finger prick blood lactate analysis using a Nova Biomedical Lactate Plus Lactate Meter. Finger prick blood analysis will be done in a safe area of the gymnasium room. Each blood sample and materials used to clean the subjects fingers will be disposed of using Bio-Safe containers.

After the finger prick blood analysis is complete, the participants in the experimental group will perform the active recovery protocol by walking at a low intensity pace of 50% maximum heart rate. After the finger prick analysis, the control group will remain seated until the start of the next gasser circuit. Finger prick analysis will occur at rest before the start of the session, and at the beginning of each rest period for a total of 5 finger prick blood tests per participant. The third analyzed variable during the resistance training session will be the rate of perceived exertion using the Borg scale. You will shown the BORG scale on a chart at the start of the training session, before the beginning of each gasser, and during the rest period. The fourth variable of measure will be heart rate using Polar Heart Rate monitors used in standard medical offices, hospitals, and research environments. The Polar heart rate monitor includes a chest strap sensory, and a watch receiver. The comfortable chest strap will be secured around the top of your torso underneath your clothing. The watch reciever will then be synced to the chest strap, reading the electrical impulses from your heart, and displaying your heart rate on the watch face. Heart rate will be recorded at rest at the beginning of the training session, and before and after each gasser circuit. Before releasing you at the conclusion of the interval training session, the you will be instructed to complete the energy survey to assess the fatigue and overall physical condition on the following 3 days at your home. Upon the completion of the survey on the fifth day, you will be required to return the completed surveys to the Moberly Building, where you will be debriefed on the study, and provided a completion notice by which then your participation in the research study will be complete.

Are there reasons why I could not qualify for this study?

You may be excluded from this if you do not meet the inclusion criteria. The researchers will discern if you do not qualify. Participants will be excluded from participation if they do not meet the age requirements for the study and/or if they answer "Yes" to any of the questions in the HHQ Questionnaire and do not provide physical activity clearance from a doctor if contraindications are present. Some questions from the HHQ questionnaire and inclusion form include:

- Have you ever had a heart attack or stroke?
- Do you have a history of diabetes?
- Do you lose your balance because of dizziness or do you ever loss consciousness?
- Do you have cardiovascular disease or pulmonary disease?
- Is your doctor currently prescribing drugs for your blood pressure or heart condition?
- Could you be pregnant?
- Do you know of any other reason why you should not do physical activity?

The participants will also be screened using a Health/Blood Questionnaire for clearance for the finger prick blood analysis procedure. Participants will be immediately excluded if they answer "Yes" to any of the questions listed in the Health/Blood Questionnaire for Finger Prick Blood Analysis. The questions include:

- Have you ever had a bleeding condition or a blood disease?
- Do you have Sickle Cell Anemia, or any other blood conditions?
- Have you ever had liver disease, viral hepatitis, or a positive test for hepatitis?
- Have you ever had malaria?
- Have you ever had, or come into contact with persons possessing a sexually-transmitted disease?
- In the past 12 months have you had a tattoo applied, ear or skin piercing, accidental needlestick, or come into contact with anyone else's blood?
- Have you ever used needles to take drugs, steroids, or anything else not prescribed by your doctor?
- In the past 12 months, have you had sex with anyone who has ever used needles to take drugs, steroids, or anything else not prescribed by their doctor?
- Have you ever had a positive test for the HIV/AIDS virus?
- In the past 12 months, have you had sex with anyone who has HIV/AIDS or has had a positive test for the HIV/AIDS virus?

*If a participant answers "Yes" to any of these questions, the participant will be excluded from the study and its testing procedures.

In addition, you will be excluded from this study if you are pregnant or have a good reason to believe you are pregnant. All other predetermined factors will be taken into account that may exclude you from this study.
What are the possible risks and discomforts?

The things you will be doing have no more risk of harm than you would experience in everyday life as an individual engaging in physical activity. You must be aware that by participating in this study, you may sustain common musculoskeletal injuries that are associated with physical activity and interval training. Subjects may also experience delayed onset muscle soreness as a result of the training protocol, which is a normal and natural process of the human body as a result of physical activity. You may also develop a feeling of a light “burning” sensation in your legs during the testing due to an increased level of blood lactate in your muscles. This is normal and is usually dissipated within a few minutes.

In addition, during the lactate testing protocol, risk of contact with blood from person to person will be minimized due to explicit procedures carried out by principal investigator utilizing proper equipment such as gloves, alcohol wipes, and bio-hazard bins.

There are no other known potential risks associated with this study. You may, however, experience a previously unknown risk or side effect.

Will I benefit from taking part in this study?

Benefits from the study include knowledge of high-intensity interval training, and body composition measurement. In addition, you will discover your physical capabilities through your performance in the interval training session.

Do I have to take part in this study?

If you decide to take part in the study, it should be because you want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering.

If I don’t take part in this study, are there other choices?

If you do not want to be in the study, there are no other choices except to not take part in the study.

What will it cost me to participate?

There are no costs associated with taking part in this study.

Will I receive any payment or rewards for taking part in the study?

You will not receive any payment or reward for taking part in this study.

Who will see the information I give?

Your information will be combined with information from other people taking part in the study. When we write up the study to share it with other researchers, we will write about this combined information. You will not be identified in these written materials. Only the study
testing facilitators will have access to your information but all information will be coded with an ID number so your personal name will not be available.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from the information you give, and these two things will be stored in different places under lock and key.

Can my taking part in the study end early?
If you decide to take part in the study, you still have the right to decide at any time that you no longer want to participate. You will not be treated differently if you decide to stop taking part in the study.

The individuals conducting the study may need to end your participation in the study. They may do this if you are not able to follow the directions they give you, if they find that your being in the study is more risk than benefit to you, or if the agency funding the study decides to stop the study early for a variety of scientific reasons.

What happens if I get hurt or sick during the study?
If you believe you are hurt or if you get sick because of something that is done during the study, you should call Mark Flury at (740)466-6094 immediately. It is important for you to understand that Northern Illinois University will not pay for the cost of any care or treatment that might be necessary because you get hurt or sick while taking part in this study. That cost will be your responsibility. Also, Northern Illinois University will not pay for any wages you may lose if you are harmed by this study.

Usually, medical costs that result from research-related harm cannot be included as regular medical costs. You should ask your insurer if you have any questions about your insurer’s willingness to pay under these circumstances.

What if I have questions?
Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, Mark Flury at (740)466-6094.

What else do I need to know?
You will be told if any new information is learned which may affect your condition or influence your willingness to continue taking part in this study.

I have thoroughly read this document, understand its contents, have been given an opportunity to have my questions answered, and agree to participate in this research project.
Signature of person agreeing to take part in the study __________________________

Date

Printed name of person taking part in the study __________________________

Name of person providing information to subject __________________________
APPENDIX C

BODY COMPOSITION/BLOOD LACTATE PROTOCOL
BODPOD:

1. Subjects will be asked to have on the proper clothing
2. They will be asked to sit inside the equipment for three runs that take about 60 seconds each
3. They will be asked to sit still and refrain from laughing or speaking
4. The door will also be opened after every run to ensure subject safety
5. If there is an issue, there is an automatic shut off button in the equipment for emergency
6. If a subject feels uncomfortable anytime during the test, we will discontinue this portion and they will be able to finish the other portions of testing

InBody:

1. Subjects will be asked to remove their socks and shoes
2. They will stand still on the scale hold the arms handles for about 2 minutes
3. Test will finish with subjects stepping off the equipment
4. If a subject feels uncomfortable anytime during the test, we will discontinue this portion and they will be able to finish the other portions of testing
Finger Prick Procedure:

1. Clean the area of the fingertip with an alcohol prep pad (1st – 3rd digit from the thumb).
2. This can be completed on the right or left appendage (on average 1-2 fingers will be pricked more than twice – 5 total).
3. Dry with gauze completely.
4. Prick the finger with a lancet (one time use, self-contained, disposal).
5. Wipe the first blood produced with a new dry gauze pad.
6. Squeeze the finger to produce a blood droplet and measure using the lactate plus.
7. Blood is collected on a test strip, which the device uses to measure blood lactate.
8. Place a dry gauze pad on the area and the finger prick will close in roughly about 1-2 minutes.
9. The lancet, gauze, and test strips that all had contact with blood are disposed of in a biomedical container.
10. The dry clean gauze will be disposed of in a biohazard trash receptacle.
11. If a subject feels uncomfortable anytime during the test, we will discontinue this portion and they will be able to finish the other portions of testing.
APPENDIX D

DATA SHEETS
Active recover study  Visit 1  2017

Visit One:

Name: ___________________________ Id Number: __________________

Group: P5
P10  A5  A10

Date: ___________________________ Time: ___________________ Age: _________
Gender:  M  F

Included  or  Excluded  (Please circle)

If Excluded, Why?

Checklist (forms):  (Please circle)

Consent: Yes No  Inclusion/Exclusion: Yes No  HHQ: Yes No
Blood Questions: Yes No

Baseline Measurements:

1. Blood Pressure: _______________ mmHg  Resting HR: ______

2. Blood Pressure: _______________ mmHg  (If needed)

Issues:

Body Composition:  (Copy must be attached)  Height: ___________ in

BODPOD  Yes No  InBody Yes No  Weight: ___________ lb.

Issues:
Active recover study  Visit 2  2017

Visit Two:

Id Number: __________________ Date: __________________________ Age: __________

Race:  Caucasian  □  Gender:  M  F
African American  □
Hispanic  □
Asian  □
American Indian  □
Pacific Islander  □
Other  □

Physical Activity Level:

___ Sedentary (less than 2 days a week, or less than 40 minutes)

___ Active (More than 2 days a week, but less than 5 or 60-150 minutes per week)

___ Very active (More than 5 days a week of < than 150 minutes per week)

Notes:

Resting Measures:

Blood Pressure: ____________ mmHg  Resting HR: _____  RPE: ________

Issues:

Warm Up:

Maximal age HR (Predicted): ______  50% HR: ________  65% HR: ________

Light jog (65% max):  Yes  No  Dynamic exercise:  Yes  No
<table>
<thead>
<tr>
<th>Training Session:</th>
<th>Group (circle):</th>
<th>P5</th>
<th>P10</th>
<th>A5</th>
<th>A10</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>PRE-Resting</th>
<th>Time</th>
<th>Blood Lactate</th>
<th>Heart rate</th>
<th>RPE</th>
</tr>
</thead>
</table>

**SET 1**
Completion

Pre measures

**NOTES:**

**SET 2**
Completion

Pre measures

**NOTES:**

**SET 3**
Completion

Pre measures

**NOTES:**

**POST**
Completion

POST measures

**NOTES:**

**Post Notes/Issues:**
APPENDIX E

EXPERIMENTAL DESIGN LAYOUT
Resting measures → Warm-up → Sprint 1 → Recovery 1

Sprint 2 → Recovery 2 → Sprint 3 → Recovery 3

Post-exercise measures → Cool Down

★ = Sprint time (if applicable), blood lactate, HR, & RPE recorded

75 Feet

x 6 = 450 feet