EFFECTS OF ACTIVE VERSUS PASSIVE RECOVERY ON BLOOD LACTATE AND PERFORMANCE IN REPEATED WINGATE TESTS

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ABSTRACT

EFFECTS OF ACTIVE VERSUS PASSIVE RECOVERY ON BLOOD LACTATE AND PERFORMANCE IN REPEATED WINGATE TESTS

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The purpose of this study is to determine if an active recovery of a long duration at a moderate intensity or a passive recovery is more beneficial for subsequent anaerobic performance by tracking blood lactate and comparing anaerobic performance variables across Wingate tests. Currently, there is a lack of research on the effect of a longer duration active recovery protocol on blood lactate levels and power output in repeated Wingate tests as compared to passive recovery. A significant interaction was found between recovery and time for blood lactate ($F = 6.935$; $p = 0.000$). Blood Lactate levels were significantly lower for the active recovery condition as compared to the passive recovery condition at time point two, time point three, time point four, and time point five. The active recovery condition resulted in significantly lower lactate levels at the four time points during recovery, but no significant difference in performance was observed. Based on previous research, the lower lactate values and performance might not be as connected as previously thought. However, the lower lactate levels can still be beneficial to recovery after intense exercise and repeated attempts, but there could be no effect of blood lactate clearance on performance. Future research should focus on anaerobically trained athletes, such as sprinters and power lifters, as those types of athletes train with the ATP-PC and anaerobic glycolysis energy systems.

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To all the brave, trailblazing women fighting for equality, those who have come before me and those that will come after me, you are magnificent queens. Yes we can! Nevertheless she persisted.

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INTRODUCTION

The study of the optimal type of recovery to maximize performance and exercise recovery after supramaximal exercise in sport and clinical settings has divided results. While there are researchers that suggest a passive recovery is more effective in optimizing subsequent supramaximal exercise performance (Dupont, Moalla, Matran, & Berthoin, 2007; Lopez, Smoliga, & Zavorsky, 2014; Ouergui, Hammouda, Chtourou, Gmada, & Franchini, 2015), there are also researchers that suggests an active recovery is the superior recovery type (Ahmaidi et al., 1996; J. Bangsbo, Graham, Johansen, & Saltin, 1994; Miladi, Temfemo, Mandengué, & Ahmaidi, 2011; Spierer, Goldsmith, Baran, Hryniewicz, & Katz, 2004; Thiriet et al., 1993). Optimizing performance, in regard to repeated supramaximal exercise, is typically indicated by lower blood lactate levels and being able to produce a peak power output value that is close to the initial exercise's peak and mean power outputs (Ahmaidi et al., 1996; Bonen & Belcastro, 1976; L. Hermansen & Stensvold, 1972). Recovery increases the rate of regeneration of energy, stabilizes the acid-base balance, and decreases fatigue, and thus is crucial in maintaining performance (Bogdanis, Nevill, Lakomy, Graham, & Louis, 1996; Coffey, Leveritt, & Gill, 2004). Therefore, a recovery that allows for faster decline of blood lactate values and a comparable power output after repeated exercise sessions would be classified as a better recovery than a recovery that only produces one of the two desired outcomes. Active recovery is classified as a submaximal recovery that involves some form of physical activity that keeps the heart rate and respiration rates above resting, such as

walking, jogging, running, or cycling (L. Hermansen & Stensvold, 1972; Katch, Gilliam, & Weltman, 1978; Larson, Smeltzer, Petrella, & Jung, 2013). Passive recovery is a resting recovery where the participant is not being physically active, such as sitting quietly in a chair (Lopez et al., 2014). A supramaximal exercise, for the purposes of the studies reviewed, is an exercise that is done at an intensity above the VO_{2max} value (Lima-Silva et al., 2013). Exercises such as sprinting or a Wingate test would be classified as a supramaximal exercise (Katch et al., 1978).

WINGATE TEST

A Wingate test is a supramaximal exercise test that takes place on a mechanically or electronically braked cycle ergometer (Jacob et al., 2002). The Wingate test has been previously validated as an accurate test of anaerobic fitness that involves pedaling on a cycle ergometer at a maximal speed against a constant force for 30 seconds (Inbar, Bar-Or, & Skinner, 1996). The force used during the test is predetermined relative to the body weight and fitness level of the individual completing the test (Spierer et al., 2004). The purpose of the Wingate test is to assess anaerobic power and anaerobic fatigue by measuring the highest power output achieved and indirectly assessing the capacity of an individual's metabolic energy generating system and its fatigability as indicated by percent decline in power, or fatigue index (Lopez et al., 2014).

The Wingate test measures a variety of outcomes, including anaerobic power, anaerobic capacity, peak power, mean power, and fatigue index (Beneke, Pollmann, Bleif, Leithäuser, & Hütler, 2002). Peak power is measured as the maximum power achieved during the 30 second sprint (Lopez et al., 2014). Mean power is the average power output for the 30 second sprint (Lopez et al., 2014). For the purposes of this study, anaerobic power is defined as peak power divided by and individual's body weight, while anaerobic capacity is defined as mean power divided by body weight. Fatigue index is measured as the amount of decline in power during the test expressed as a percentage of peak power by subtracting peak watts from minimum watts divided by test duration (Inbar et al., 1996).

Passive recovery, where the participant rests by sitting still for a length of time, has also been shown to be effective in blood lactate clearance and maintaining a high mean and peak power output on repeated tests (Dupont et al., 2007; Ouergui et al., 2015). Positive physiological benefits of passive recovery on performance can be tied to a slower decline in the oxyhemoglobin, a factor that indicates a passive recovery allows a higher muscular regeneration than active recovery, providing a higher phosphocreatine resynthesis rate (Dupont, Moalla, Guinhouya, Ahmaidi, & Berthoin, 2004; Dupont et al., 2007). A slower decline in oxyhemoglobin allows a higher reoxygenation rate of the myoglobin, which in turn allows for oxygen to be delivered to the working muscles faster (Dupont et al., 2004). Similarly, phosphocreatine resynthesis is dependent upon oxygen availability, with a greater availability of oxygen there would be a greater resynthesis of phosphocreatine (Dupont et al., 2004). Lopez et al. (2014) reported that a passive recovery of four minutes was more beneficial than low intensity active recovery for higher peak power values after one 30 second Wingate. However, in the same study, passive recovery was not beneficial for any of the other components measured such as mean power output, and was less effective than active recovery when it came to mean and peak power in the subsequent Wingate trials, after the first Wingate test, of which there were a total of six trials (Lopez et al., 2014). Connolly, Brennan, and Lauzon (2003) found significant differences within Wingate trials for both peak and mean power with

both values decreasing over time with a greater decrease observed in the passive recovery protocol.

Researchers have shown that active recovery increases exercise performance and decreases blood lactate levels during repeated bouts of moderate to high intensity exercise when compared to passive recovery (Ahmaidi et al., 1996; Spierer et al., 2004). A decrease in blood lactate levels causes an increased time to exhaustion during anaerobic exercise, allowing for more exercise to be performed before the individual fatigues (Dupont et al., 2004). The reason why an active recovery is thought to be more beneficial for blood lactate removal is linked with maintaining blood flow to active muscles and promoting removal of metabolic byproducts, like inorganic phosphate, which impair muscle contractility (Beckett & Steigbigel, 1993; Lopez et al., 2014; Stamford, Moffatt, Weltman, Maldonado, & Curtis, 1978). Blood lactate removal is facilitated by lactate being shuttled to the liver via the bloodstream (Beckett & Steigbigel, 1993). Once the lactate reaches the liver, it becomes part of the Cori Cycle which converts the lactate to glucose by lactate dehydrogenase via gluconeogenesis. The glucose formed by the Cori Cycle is then shuttled back to the active muscles via the bloodstream to be used for ATP production. Inorganic phosphate is shuttled into the mitochondria of the active muscles to allow for ATP resynthesis by binding to adenosine diphosphate (ADP) to form ATP via the Krebs Cycle. Hydrogen ions are shuttled into the mitochondria and into the Electron Transport System to convert NADH to NAD+. The NAD+ ions are shuttled to the cytosol where they then go through anaerobic glycolysis in order to continue to produce ATP. Active recovery facilitates an increase in blood flow to

active muscles, through which there is an increase in oxygen delivery (Bogdanis et al., 1996). An increase in blood flow also allows lactate and hydrogen ions to be removed faster due to the greater lactate and hydrogen ion gradients between the muscle and blood (Gladden, 1989; Sjogaard, 1987). An increase in blood lactate also causes an increase in hydrogen ions which can lead to a state of acidosis via declining pH. Acidosis may alter the ability of the muscles to produce force during contraction by interfering with the binding of calcium and troponin (L. Hermansen & Osnes, 1972; Lopez et al., 2014). Active recovery at intensities between 15-65% of VO_{2max} have been shown to be the optimal intensity range for blood lactate disappearance and power output recovery (Bogdanis, Nevill, Lakomy, Boobis, & Nevill, 1998; Connolly et al., 2003; L. Hermansen & Stensvold, 1972; Losnegard, Andersen, Spencer, & Hallén, 2015; McLellan & Skinner, 1982; Signorile, Ingalls, & Tremblay, 1993; Spencer, Bishop, Dawson, Goodman, & Duffield, 2006). However, Menzies et al. (2010) demonstrated that an active recovery at intensities between 80-100% of the lactate threshold were more beneficial at lactate clearance than active recovery at lower intensity as well as passive recovery. The suggestion that passive recovery is more beneficial than active recovery may be explained by certain studies where researchers used an active recovery of short duration and the intensity of the active recovery chosen for the research being of a high intensity, 60% and up (Smilios, Bogdanis, Mavridis, Tokmakidis, & Toubekis, 2006).

Active Recovery Duration

Longer duration recovery periods, like short duration recovery periods, tend to be tied to a specific sport recovery time. Losnegard et al. (2015) used an active recovery duration of 21 minutes to simulate the time between semifinal and final races in sprint cross-country skiing. Thiriet et al. (1993) used a recovery duration of 20 minutes to simulate athletic field training and competition schedules and avoid inducing fatigue with short duration recovery. Ohya, Aramaki, and Kitagawa (2013) investigated recovery durations of 25 secs, 50 secs, and 100 secs to imitate the ratio of maximal to rest or low intensity activities during field-based sports games. Similarly, Smilios et al. (2006) and Toubekis et al. (2011) both chose short duration recovery periods of 45 and 120 seconds, respectively, to simulate sprint swimming training.

A short recovery period may not be sufficient for removal of metabolic byproducts such as inorganic phosphate and hydrogen ions which are produced in high levels along with lactate following intense exercise (Bogdanis, Nevill, Boobis, Lakomy, & Nevill, 1995). A short recovery period, between 15 secs and 4 min, may also not be adequate for resynthesis of phosphocreatine and adenosine triphosphate (ATP) at levels that would allow for subsequent optimal recovery (Bogdanis et al., 1995; Ohya et al., 2013). Ohya et al. (2013) noted that a passive recovery improved performance on subsequent exercise with peak power values being significantly higher and percent decrease in peak power being lower compared to the short duration recoveries of 25 sec and 50 sec active recovery period, but not for the 100 sec duration active recovery period.

Menzies et al. (2010) demonstrated that a high intensity exercise bout of running on a treadmill at 90% of VO_{2max} with 2-4 minutes of active recovery in between bouts may not be a sufficient amount of time to clear lactate and reduce fatigue to enable more exercise bouts. Smilios et al. (2006) selected a 45 second recovery period between swimming sprints and discovered that the short duration of the recovery caused a negative effect on performance shown by a significant decrease in swimming speed from sprint 1 to sprint 2. However, the researchers also stated that an active recovery carried out at a longer duration, 6 minutes in the respected study, can be used without any impact on performance, shown by swimming time of a 50m sprint test performed after 6 minutes of rest not being different between trials (Smilios et al., 2006).

A long duration active recovery, one that is a duration of 5 minutes and longer, is thought to be more advantageous for lowering blood lactate levels, regeneration of ATP and phosphocreatine, and clearance of hydrogen ions to reverse acidosis than a short duration active recovery (Bogdanis et al., 1996; Harris et al., 1976; Lopez et al., 2014; Sahlin, Harris, Nylind, & Hultman, 1976). Bogdanis et al. (1996) also reported that a long duration active recovery had a positive effect on repeated anaerobic performance. Furthermore, an active recovery duration of 10-20 minutes allowed for full phosphocreatine resynthesis and significant recovery of muscle pH and muscle lactate (Harris et al., 1976; Sahlin et al., 1976). Phosphocreatine levels are nearly completely replenished in both Type I and Type II fibers after 5 minutes of active recovery (Lopez et al., 2014). Additionally, after 15 minutes of recovery, ATP is resynthesized to 95% and

76% of baseline in Type I and Type II fibers, respectively (Soderlund & Hultman, 1991). Inability to replenish phosphocreatine and ATP between exercise bouts or to reduce the buildup of inorganic phosphate that occurs after high-intensity exercise can culminate in decreased performance following the recovery period (Dahlstedt, Katz, & Westerblad, 2001).

Active Recovery Intensity

The intensity of recovery exercise has been shown to affect blood lactate disappearance (Stamford et al., 1978). Active recovery produces lower maximal blood lactate concentrations, lower time to maximal blood lactate values and lower half recovery times following recovery of supramaximal exercise (Ahmaidi et al., 1996; Bond, Adams, Tearney, Gresham, & Ruff, 1991; Cristi-Montero et al., 2015; Menzies et al., 2010; Reaburn & Mackinnon, 1990; Signorile et al., 1993). The intensity at which an active recovery should be completed for optimal performance is a highly debated topic. The baseline level of blood lactate seems to have an effect on whether a high, moderate, or low intensity active recovery is more beneficial for an individual in removing blood lactate (Stamford, Weltman, Moffatt, & Sady, 1981). It is possible that there is not one optimal recovery intensity to be found, but potentially a combination of different intensities over the course of a recovery that could be the most effective at decreasing blood lactate (Menzies et al., 2010; Stamford et al., 1981). However, there is very limited support for that suggestion (Stamford et al., 1981).

A recovery completed at an intensity between 1% and 49% of a measured value such as VO_{2max}, peak power, mean power, lactate threshold, or ventilatory threshold, would be classified as a low intensity active recovery (Ahmaidi et al., 1996; Dupont et al., 2007; Lopez et al., 2014; Spierer et al., 2004; Stamford et al., 1978; Stamford et al., 1981; A. Weltman, Stamford, & Fulco, 1979). In regards to phosphocreatine availability, a lower intensity active recovery, has a lower energetic cost than a moderate to high intensity recovery and therefore could allow for more oxygen to be available for phosphocreatine resynthesis (Smilios et al., 2006). In addition to active recoveries at lower intensities being more effective than passive recovery in the removal of lactate following intense exercise (Ahmaidi et al., 1996; Stamford et al., 1978; Stamford et al., 1981; A. Weltman et al., 1979), there is no noteworthy effect on maximal strength, total work output, fatigue in the quadricep muscles in a subsequent supramaximal test (Bond et al., 1991). Spierer et al. (2004) used an active recovery at an intensity of 28% of the subjects' VO_{2max} which produced an increase in lactate removal rates and higher pedal revolutions in repeated bouts thereby translating into increased peak power and total work achieved when compared with passive recovery.

While there are ample indications of a lower intensity active recovery being more beneficial for lactate removal and increased peak power and mean power output values when compared to passive recovery, there is also a considerable amount of evidence to suggest that a moderate to high intensity active recovery is more advantageous than lower intensity active recovery (Cristi-Montero et al., 2015; L. Hermansen & Stensvold, 1972;

Losnegard et al., 2015; Neric, Beam, Brown, & Wiersma, 2009). Researchers that conducted a study on swimmers discovered that an active recovery at a speed equal to 60-70% of each individual swimmer's best 100m time for 20 minutes allowed their lactate levels to return to resting values (Cazorla, Dufort, Cervetti, & Montpetit, 1983). Menzies et al. (2010) concluded that active recoveries at intensities of 80-100% of lactate threshold were more efficient at clearing lactate than active recoveries at intensities of 60% of lactate threshold or below following repeated 5 minute running bouts at 90% of VO_{2max}. Smilios et al. (2006) used an active recovery at an intensity of 60% of each individual subject's 100m velocity based on the efficiency of lactate removal and also selected an intensity of 50% of each individual subject's 100m velocity for the lower energetic cost to compare in the study. Researchers from that study indicate that both the recovery intensities resulted in lower blood lactate levels compared to passive rest in repeated sprint swimming bouts (Smilios et al., 2006). One aspect of a moderate to high intensity active recovery is that it could have detrimental effects on performance after the recovery, but a study by Losnegard et al. (2015) investigated an active recovery at ~58% of VO_{2max} for 21 minutes and discovered no negative effect on performance of sprint cross country skiing bouts or significant differences in performance as compared to passive recovery.

BLOOD LACTATE

Lactate is produced by a reduction of pyruvate in the cytosol of cells as a result of anaerobic glycolysis whereby electrons added on NADH to pyruvate form lactate (Houston, 2006). During exercise, glucose is broken down and oxidized to pyruvate due to NADH being oxidized to NAD+. The breakdown of glucose produces two pyruvate molecules, and those pyruvate molecules bind with the hydrogen ions that came from ATP splitting. Two molecules of pyruvate absorb two hydrogen ions and convert to lactate.

Blood lactate may inhibit enzymes, such as phosphorylase and phosphofructokinase, which are responsible for ATP resynthesis in the glycolytic pathway (Bangsbo, Krustrup, González-Alonso, & Saltin, 2001). High blood lactate prior to performance might also alter hydrogen stabilization systems which in turn decreases the affinity between hemoglobin and oxygen (Bangsbo et al., 2001). The reduction in affinity between hemoglobin and oxygen leads to a reduction in hydrogen capture and calcium reabsorption into the sarcoplasmic reticulum and causes an overall decrease in muscle power (Cristi-Montero et al., 2015; Neric et al., 2009). Bogdanis et al. (1998) cited incomplete resynthesis of phosphocreatine and a possible reduction of glycolysis due to an increased hydrogen ion concentration, causing a reduced anaerobic ATP regeneration.

The benefit to removing lactate from the blood at a quicker rate is directly tied to the ability of the body to use lactate as an energy source through anaerobic glycolysis.

Anaerobic glycolysis is the main energy system that provides energy to the working muscles during maximal exercise lasting 10-120 seconds (Neric et al., 2009). Phosphocreatine is the most important source for ATP resynthesis during repeated bouts of sprint exercise and early during intense exercise bouts (Bogdanis et al., 1998). Energy from anaerobic metabolism contributes to power output within the Wingate test (Beneke et al., 2002).

Blood lactate elimination is mainly facilitated by oxidation in the tricarboxylic acid cycle to convert lactate into pyruvate with end products carbon dioxide and H_2O, a metabolic action that predominately occurs in active skeletal muscle (Coffey et al., 2004; L. Hermansen & Stensvold, 1972). The secondary pathway for lactate elimination is reconversion of lactate into glycogen via gluconeogenesis in the liver. Researchers have reported that 13-27% of lactate may be converted to glycogen during recovery (Bangsbo, Gollnick, Graham, & Saltin, 1991). Therefore, active recovery increasing lactate elimination is mostly due to an increased blood flow to active muscle (Coffey et al., 2004).

High blood and muscle lactate levels following high intensity exercise can have possible negative effects on subsequent performance (Neric et al., 2009). Lactate production is associated with the elevation of hydrogen ion concentration which results in a low pH in the muscle and blood, thereby resulting in the body being in a state of acidosis and contributing directly to muscle fatigue (Neric et al., 2009). Muscle fatigue is a result of high hydrogen ion concentrations affecting the contractile process of muscle

through the hydrogen ions inhibiting calcium release from the sarcoplasmic reticulum or by interfering with the binding of calcium and troponin on the cross-bridges of muscle fibers (Neric et al., 2009). An increase hydrogen concentration also inhibits phosphofructokinase and lactic dehydrogenase, two rate-limiting enzymes that are crucial to glycolysis (Beckett & Steigbigel, 1993; Bonen & Belcastro, 1976). Muscle fatigue reduces the force of muscular contraction and consequently lowers power output and performance due to the effects on contractility and rate-limiting enzymes (Neric et al., 2009). Therefore, the removal of blood lactate and hydrogen ions from the active muscle is critical for subsequent peak performance (Dotan, Falk, & Raz, 2000; Lindinger & McKelvie, 1995).

SEX BIAS

A possible sex bias between male and female responses and performance to supramaximal exercise and recovery has been noted by researchers (Ben-Sira & Sagiv, 1997; Bulbulian, Jeong, & Murphy, 1996; Mageean, Alexander, & Mier, 2011; McLester, Green, Wickwire, & Crews, 2008; Mendonca et al., 2010; Ouergui et al., 2015). The difference in power output has been well documented, with males having a higher power output when compared to the power outputs of females (Ben-Sira & Sagiv, 1997; Bulbulian et al., 1996). However, when power output values for males and females are made relative to body weight, the gender difference between power output values virtually disappears (Haff & Triplett, 2015; Mageean et al., 2011). Mageean et al. (2011) also indicated that females had a greater recovery of mean power output compared to males as observed in the females having higher mean power outputs following the recovery period and just prior to the 30 second sprint as compared to the males' mean power outputs at the same time.

Due to the sex bias, few studies have included women, and virtually no studies have been conducted solely on female subjects for supramaximal recovery investigations (Ben-Sira & Sagiv, 1997; Bogdanis et al., 1998; Connolly et al., 2003; Harbili, 2015; McLester et al., 2008; Ouergui et al., 2015; Spierer et al., 2004). McLester et al. (2008), cited reasons for not using female subjects due to expected large differences between male and female VO_{2peak}, body fatness, and power output capabilities and to insure homogeneity of the population.

Female participation in sport is currently estimated as more than 200,000 women in college athletics and an estimated three million girls who participating in interscholastic athletics (Kennedy, 2010). Increased sport participation requires increases in research on female responses to exercise and recovery methods to discover any possible differences between males and females and to ensure physiological demands are met to reduce injury and optimize performance. Due to potential differences in males and females, researchers chose to exclude females from their studies rather than investigate the potential differences and determine what, if any, differences exist and what potential effects those differences may have on how recovery is implemented, and/or how exercise tests are carried out.

MENSTRUAL CYCLE

Many research studies on the effect of menstrual cycle on performance have yielded results indicating that there is no significant effect of menstrual cycle phase on anaerobic performance, aerobic endurance performance, or isokinetic muscle strength (Bushman, Masterson, & Nelsen, 2006; Lebrun, McKenzie, Prior, & Taunton, 1995; Miskec, Potteiger, Nau, & Zebas, 1997; Smekal et al., 2007; Tsampoukos, Peckham, James, & Nevill, 2010). Furthermore, the menstrual cycle has no effect on perceived exertion, blood lactate, pulmonary ventilation, carbon dioxide production or oxygen consumption during short constant-load exercise (Bemben, Salm, & Salm, 1995; De Souza, Maguire, Rubin, & Maresh, 1990; Eston & Burke, 1984; Tsampoukos et al., 2010). Researchers suggest that in future studies, it potentially will not be necessary to control the timing of testing due to menstrual cycle phase (Tsampoukos et al., 2010). Additionally, Miskec et al. (1997) discovered that menstruation is not detrimental to anaerobic power production during repeated exercise. Subjects in the respective study had similar average power outputs in the trials during menstruation and trials where the subjects were not menstruating. Tsampoukos et al. (2010) also reported no significant differences in peak power or mean power output, and no significant difference in fatigue index during the different phases of the menstrual cycle. Blood lactate values did not differ significantly across all phases of the menstrual cycle (Bemben et al., 1995; De Souza et al., 1990; Eston & Burke, 1984; Miskec et al., 1997; Smekal et al., 2007; Tsampoukos et al., 2010).

PURPOSE

To the knowledge of the author, no research study exists on investigating the effects of active versus passive recovery on blood lactate and anaerobic performance in repeated Wingate trials solely on female subjects. The purpose of this study is to determine if an active recovery of a long duration at a moderate intensity or a passive recovery is more beneficial for subsequent anaerobic performance by tracking blood lactate and comparing anaerobic performance variables across Wingate tests.

HYPOTHESIS

It is hypothesized that the active recovery trials will allow for lower blood lactate levels following recovery as compared to the passive recovery trials. It is also hypothesized that the active recovery trials will allow for higher peak and mean power output levels in regard to the outputs of the initial Wingate test, as compared to the passive recovery trials.

METHODS

Permission from the Institutional Review Board was obtained prior to collection of data. An informed consent (Appendix A), Medical History Questionnaire (Appendix B), and Screening Form (Appendix C) were administered prior to any data collection.

PARTICIPANTS

Twenty-two healthy, active female subjects between the ages of 18-25 were recruited for this study. The subjects were asked to maintain their current lifestyle, eating, and exercise habits. Subjects could be taking birth control or not taking birth control, as research indicated no difference between the variables being measured in this study across all phases of the menstrual cycle while taking birth control or not taking birth control. Subjects were excluded if they had any internal pacemaker, defibrillator, medication pump, or any other medical devices, metal joint replacement or metal rod/pin implants of any kind since these items can have serious negative medical implications during a Wingate test. Participants had to be free of any orthopedic, neuromuscular, metabolic, and cardiorespiratory conditions. A questionnaire (Appendix B) and screening form (Appendix C) were used to determine if subjects qualify for the study.

EXPERIMENTAL PROTOCOL

Subjects were required to come to Humboldt State University's Human Performance Lab for four testing sessions. Subjects were asked to not eat 2 to 3 hours prior to assessment. Subjects were instructed not to exercise for 24 hours prior to coming in for each session to minimize chances of muscle soreness and fatigue to negatively impact the assessments. Proper and regular hydration was stressed to reduce risks of dehydration, muscle cramps, discomfort, and excessive fatigue following the assessments.

Session 1

During the first session, the subjects completed the informed consent, medical history, body composition assessment, and a peak test on the Velotron (Racermate Inc., Seattle, WA) electronically braked cycle ergometer. Following the informed consent, medical history, and subjects fitting the inclusion criteria, the subjects sat quietly in a chair for 5 minutes, after which time, the investigator took resting heart rate and blood pressure measurements. Subjects were then given a clean singlet to change into in a private room and instructed to meet the test administrator in the hydrostatic weighing room. Subjects were instructed on protocols for hydrostatic weighing and the body composition of the subject was estimated via hydrostatic weighing. Height was measured using a Seca mechanical wall mount stadiometer (Seca 216, Chino, CA). Weight was measured on a beam balance scale (437 Physician's Scale, Detecto, Webb City, MO).

Measurement of body composition was estimated using hydrostatic weighing which required subjects to submerged themselves in a hydrostatic weighing tank (Exertech, La Crescent, MN), get their hair wet, to remove any air pockets in their swimsuits, and to rub their skin and hair to rid them of any air bubbles. The test administrator waited until the water level of the tank steadied and was no longer draining after the subject submerged themselves before calibrating the scale. After calibration, the subject was instructed to sit on the scale in the center of the tank, to hold on to the handles on the scale, exhale all the air out of their lungs they could before submerging their head and continuing to exhale until there were no more bubbles, and to hold themselves under water for a few seconds to come up out of the water after a test administrator slapped the side of the tank. If the subjects could not hold their breath under water until signaled by a technician, they were instructed to raise his or her head out of the water when they felt like they had to come up for air. For estimation of body fat percentage, the flattest portion of data in the graph depicting the subjects' body density in water was selected at 150 samples per second which automatically calculated body density and body fat percentage. The Siri equation was used for body fat percentage calculations. The standard error of the estimate for hydrostatic weighing is $\pm$2.7%.

The subjects were then allowed to change back in to their exercise clothing and given a Polar FT1 heart rate monitor (Polar Electro Oy, Kempele, Finland) to put on once they had redressed. Subjects were fitted to the cycle ergometer using a goniometer after all preliminary measurements were taken. Each subject was oriented to the cycle

ergometer with safety procedures and subject instructions prior to the peak oxygen consumption test. Subjects completed a two-minute warm-up at 25 watts on an electronically-braked cycle ergometer. Following the warm up, subjects completed the peak oxygen consumption test. Expired gases were collected and analyzed using open circuit spirometry (Parvo-Medics TrueOne® 2400 Metabolic Measurement System, Sandy, UT). Subjects completed a warm-up for two minutes at a self-selected cadence at a work rate of 50 watts. The protocol selected started at a work rate of 50 watts and was increased by 25 watts every three minutes until exhaustion was determined (Bishop, 1998). Heart rate was recorded at one minute of each stage using the Polar FT1 heart rate monitor. The rating of perceived exertion on the Borg scale was recorded at the second minute of each stage. VO_2 (ml/kg/min), VCO_2, VCO_2, RER, and HR were recorded at the end of each stage. For this test, subjects were instructed to exercise as long as possible. Subjects were considered exhausted when the respiratory exchange ratio (VCO_2/VO_2) exceeded 1.2, when VO_2 did not increase by more than 1.5 ml/kg/min with an increase in work rate, heart rate was greater than 95% of the individual's age-predicted maximum heart rate, or the subjects indicated volitional exhaustion. The power at the last completed stage was retained as the power output at 100% of VO_{2peak}.

Session 2

For the second visit, upon arrival to the Human Performance Lab, subjects sat quietly in a chair for 5 minutes, after which time, the investigator took resting heart rate and blood pressure measurements. The subjects were given a heart rate monitor to put on

and were fitted to the cycle ergometer using a goniometer after all preliminary measurements were taken. Each subject was oriented to the cycle ergometer with safety procedures and subject instructions prior to the Wingate test. The purpose of this singular Wingate test was to familiarize subjects with the intensity of the exercise and the exercise protocols themselves so subjects knew what to expect during the two following testing sessions. Subjects remained seated during each of the 30 second trials. Each subject performed a five-minute warm-up at 75 watts at a self-selected cadence. At the conclusion of the warm-up, subjects were instructed to begin pedaling as fast as possible five seconds prior to the start of the test by the test administrator counting down from five-four-three-two-one. Subjects were verbally encouraged to pedal their hardest and continue to pedal throughout the Wingate test. After completion of the Wingate test, the subject recovered with a standardized cool down protocol. Subjects were instructed to pedal at a self-selected cadence at 50 watts for five minutes. Once the subject's heart rate returned to measures observed in warm up, subjects were allowed to get off the bike and the session was over. Subjects were encouraged to eat and drink water to replenish fluids and fuels. Subjects were instructed to drink the number of ounces that corresponds to one half of their body weight. Subjects were provided 8 oz. of chocolate soy milk at the end of the testing session to help with replenishing carbohydrates and fluids.

Session 3

For the third visit, upon arrival to the Human Performance Lab, subjects sat quietly in a chair for 5 minutes, after which time, the investigator took resting heart rate

and blood pressure measurements. The subjects were given a heart rate monitor to put on and were fitted to the cycle ergometer using a goniometer after all preliminary measurements were taken. Each subject was oriented to the cycle ergometer with safety procedures and subject instructions prior to the Wingate test. Subjects remained seated during each of the 30 second trials. Each subject performed a five-minute warm-up at 2.0 W/kg at a self-selected cadence, with short sprints occurring periodically. At the conclusion of the warm-up, subjects were instructed to begin pedaling as fast as possible five seconds prior to the start of the test by the test administrator counting down from five-four-three-two-one. Subjects were verbally encouraged to pedal their hardest and continue to pedal throughout the Wingate test. Peak power, anaerobic power, mean power, anaerobic capacity, fatigue index, total work, and mean RPM values were recorded on individual subject data sheets immediately following completion of the Wingate test. After completion of the first Wingate test, one of the two recovery types, (active or passive), was implemented for 15 minutes. The type of recovery was determined in a randomized counterbalanced fashion. The active recovery protocol was carried out at 50% of each individual subjects' peak power output value from the peak oxygen consumption test during the first visit. Passive recovery protocol required subjects to sit still in a chair for 15 minutes. During the 15-minute recovery, blood lactate was a primary measure taken a total of 4 times. Before a blood sample was taken, the finger was cleaned with an alcohol wipe and dried with gauze. Blood samples were taken via fingerstick using a sterile single-use lancet, with the first drop of blood wiped away and discounted. Blood samples were collected on Nova lactate test strips as part of the

Nova Lactate Plus Analyzer (Waltham, MA). The blood lactate samples were taken immediately following the Wingate tests and at five-minute increments of the recovery protocol for both passive and active recovery protocols. Blood lactate values were recorded on individual subject data sheets. The Borg 6-20 rating of perceived exertion scale (Borg, 1982) was recorded immediately following the first Wingate and then again immediately following the second Wingate test for both recovery protocol testing sessions. Following the 15-minute recovery period, subjects performed a second Wingate test. Blood lactate, peak power, anaerobic power, mean power, anaerobic capacity, fatigue index, total work, and mean RPM were recorded on individual subject data sheets immediately following the second Wingate test. After completion of the second Wingate, the subject recovered with a standardized cool down protocol. Subjects were instructed to pedal at a self-selected cadence at 50 watts for five minutes. Once the subject's heart rate returned to measures observed in warm up, subjects were allowed to get off the bike and the session was over. Subjects were encouraged to eat and drink water to replenish fluids and fuels, and not to take a hot shower for the next two to three hours to avoid syncope associated with vasodilation of the blood vessels in the legs taking blood away from the heart and brain.

Session 4

The fourth visit was identical to the third, with the exception of the recovery type, which was the opposite of the recovery type in the previous visit. If the subject completed the active recovery protocol during the third visit, then that subject completed the passive

recovery protocol during the fourth visit and vice versa. Once the subject's heart rate returned to warm-up measures, the session was over. Subjects were encouraged to eat and drink water to replenish fluids and fuels, and not to take a hot shower for the next two to three hours to avoid syncope associated with vasodilation of the blood vessels in the legs taking blood away from the heart and brain.

STATISTICAL ANALYSIS

A power analysis was conducted using G*Power 3 (Faul, Erdfelder, Buchner, & Lang, 2009) with the alpha level set at 0.05, beta level set at 0.2, and effect size set at 0.2 which concluded that sample size to find significance should be twenty-two participants for a small effect, six participants to calculate a moderate effect, and four participants to calculate a large effect.

A total of two repeated measure analysis of variances (ANOVA) were used to assess differences between experimental trials. A 2 x 2 repeated measures ANOVA was used to assess differences in peak power, anaerobic power, mean power, anaerobic capacity, fatigue index, total work, and mean RPMs between experimental trials. The independent variables were condition and time. The two levels of the first independent variable (condition) were active recovery and passive recovery conditions. The two levels of the second independent variable (time) were time point one, defined as the measurements taken following the first Wingate, and time point two, defined as the measurements taken following the second Wingate. A 2 x 5 repeated measures ANOVA was used to assess differences in blood lactate between experimental trials. The independent variables were condition and time. The two levels of the first independent variable (condition) were active recovery and passive recovery conditions. The two levels of the second independent variable (time) were time point one, defined as the measurement taken immediately following the first Wingate, time point two, defined as the measurement taken 5 minutes into the recovery, time point three, defined as the

measurement taken 10 minutes into recovery, time point four, defined as the measurement taken 15 minutes into recovery, and time point five, defined as the measurement taken immediately following the second Wingate. Statistical analysis was performed using IBM SPSS 24 (IBM SPSS, Chicago, IL.). Alpha level was set at .05.

ASSUMPTIONS

Assumptions of the study were that subjects gave their full effort in all the Wingate tests, did not consume food 2 to 3 hours prior to assessment and did not to exercise for 24 hours prior to coming in for each session. It was also assumed that the Wingate test is an accurate and reliable test for measuring the variables studied, the recovery duration selected allowed for adequate resynthesis of energy systems, the active recovery intensity did not cause fatigue, sand the selected statistical analyses were capable of finding statistical difference.

DELIMITATIONS

Participation in the study was delimited to healthy, active females aged 18-25 years. Participants had to be free of any internal pacemaker, defibrillator, medication pump, or any other medical devices, metal joint replacement or metal rod/pin implants of any kind.

LIMITATIONS

Limitations of the study include the use of healthy, active females that may be unfamiliar with the demands of the Wingate test, leading to smaller power outputs and possible lack of significant differences between conditions. Another limitation of the study was the selection of a stage based protocol for peak oxygen consumption instead of a ramp based protocol, which could cause the subject to fatigue before a true measure of peak oxygen consumption and peak power output could be recorded. A small subject population may not be an accurate cross section of the true population in both size and ethnic makeup.

OPERATIONAL DEFINITIONS

Terms that were operationalized in this study were mean RPMs, minimum power, anaerobic power, anaerobic capacity, peak power, mean power, and fatigue index. Anaerobic power is peak power divided by and individual's body weight. Anaerobic capacity is mean power divided by body weight. Peak power is measured as the maximum power achieved during the 30 second sprint. Mean power is the average power output for the 30 second sprint. Fatigue index is measured as the amount of decline in power during the test expressed as a percentage of peak power by subtracting peak watts from minimum watts divided by test duration.

RESULTS

The purpose of the current study was to determine if an active recovery of a long duration at a moderate intensity or a passive recovery is more beneficial for subsequent anaerobic performance by tracking blood lactate and comparing anaerobic performance variables across Wingate tests. The active recovery protocol was carried out at 50% of each individual subjects' peak power output value from the VO_{2peak} test for a duration of 15 minutes. The passive recovery protocol required subjects to sit still in a chair for 15 minutes. A total of 23 female subjects participated in the study. The mean age of the subjects was 22.0 ± 2.1 years. The mean height of the subjects was 166.3 ± 7.0 cm. The mean weight of the subjects was 74.4 ± 23.6 kg. The mean percent body fat of the subjects as estimated by hydrostatic weighing was 27.1 ± 12.5%. The mean of the peak watts achieved by the subjects on the VO_{2peak} test was 178.3 ± 30.8 watts. The mean ml/kg/min achieved by the subjects on the VO_{2peak} test was 34.3 ± 6.8 ml/kg/min. Descriptive statistics for age, height, weight, and body fat of the subjects are presented in Table 1.

A 2 x 5 repeated measures ANOVA was performed for the blood lactate. The independent variables were condition and time. The two levels of the first independent variable (condition) were active recovery and passive recovery conditions. The five levels of the second independent variable (time) were time point one, defined as the measurement taken immediately following the first Wingate, time point two, defined as the measurement taken 5 minutes into the recovery, time point three, defined as the

measurement taken 10 minutes into recovery, time point four, defined as the measurement taken 15 minutes into recovery, and time point five, defined as the measurement taken immediately following the second Wingate. Mauchly's Test of Sphericity was used to determine if the basic assumption of homogeneity of variance was violated. If the basic assumption of homogeneity of variance was violated, the Huynh-Feldt correction was used. If a significant interaction was found, a simple effects test was conducted to determine where differences existed. Assumptions of homogeneity of variance and normality were checked and corrected for if violated.

A significant interaction was found between recovery and time for blood lactate ($F = 6.935$; $p = 0.000$). Blood Lactate levels were significantly lower for the active recovery condition as compared to the passive recovery condition at time point two, time point three, time point four, and time point five. See Table 1 for descriptive statistics of lactate values and Figure 1 for the differences in lactate values between recovery types.

Table 1 Descriptive Statistics of Blood Lactate

Time	Active Recovery	Passive Recovery
W1	9.4 ± 2.4	9.4 ± 3.3
5 min	10.5 ± 2.6*	12.1 ± 3.0
10 min	8.0 ± 2.0*	10.6 ± 2.6
15 min	6.0 ± 2.2*	9.4 ± 2.5
W2	11.0 ± 3.0*	13.1 ± 3.2

W1= 0 min, immediately post Wingate 1; 5 min= 5 minutes into recovery; 10 min= 10 minutes into recovery; 15 min= 15 minutes into recovery; W2= immediately post Wingate 2; * Significant difference vs. recovery types ($p < .05$)

A total of nine 2 x 2 repeated measures ANOVAs were used to assess the differences in peak power, anaerobic power, mean power, anaerobic capacity, fatigue index, total work, peak RPM, mean RPM, and RPE across experimental conditions. The independent variables were condition and time. The two levels of the first independent variable (condition) were active recovery and passive recovery conditions. The two levels of the second independent variable (time) were time point one, defined as the measurements taken following the first Wingate, and time point two, defined as the measurements taken following the second Wingate. Mauchly's Test of Sphericity was used to determine if the basic assumption of homogeneity of variance was violated. If the basic assumption of homogeneity of variance was violated, the Huynh-Feldt correction was used. If a significant interaction was found, a simple effects test was conducted to

determine where differences existed. Assumptions of homogeneity of variance and normality were checked and corrected for if violated.

There were no significant interactions for any of the nine variables included in the 2 x 2 repeated measures ANOVAs. A significant main effect for attempt was found for peak power ($p = 0.001$). The peak wattage was significantly higher during attempt one compared to attempt two. The mean for peak watts for attempt one was 702 ± 168 watts, and the mean peak watts for attempt two was 671 ± 157.

A significant main effect for attempt was found for anaerobic power ($p = 0.020$). The mean anaerobic power for attempt one was 10.0 ± 1.1watts/kg, while 9.7 ± 1.1 watts/kg for attempt two.

A significant main effect for attempt was found for mean power ($p = 0.009$). The mean power wattage was significantly higher during attempt one compared to attempt two. The mean power for attempt one was 495 ± 89 watts, and the mean power for attempt two was 479 ± 86 watts.

A significant main effect for attempt was found for anaerobic capacity ($p = 0.021$). Anaerobic capacity was significantly greater during attempt one when compared to attempt two. The mean anaerobic capacity for attempt one was 7.2 ± 1.0 watts/kg, and the mean for attempt two was 7.0 ± 1.1 watts/kg.

There was a significant main effect for attempt for total work ($p = 0.013$). Total work was significantly greater during attempt one compared to attempt two. The mean

for total work for attempt one was 14,770 ± 2,652 J, and the mean for attempt two was 14,360 ± 2,496 J.

Peak RPM had a significant main effect for attempt ($p = 0.018$). The peak RPM was significantly higher in the first attempt than it was in the second attempt. The mean of the peak RPM for attempt one was 136 ± 15, and the mean for attempt two was 132 ± 15.

There was a significant main effect found for attempt for mean RPM ($p = 0.028$). The mean RPM for the first attempt was significantly higher than the second attempt. The mean for the mean RPM for attempt one was 98 ± 14, and the mean for attempt two was 95 ± 17.

RPE had a significant main effect for attempt ($p = 0.006$). The RPE score was significantly higher during attempt two compared to attempt one ($p = 0.023$). The mean RPE score for attempt one was 17.1 ± 1.9, and the mean RPE score for attempt two was 18.0 ± 1.9.

There were no significant differences for main effects for fatigue index.

DISCUSSION

In several previous studies, active recovery after supramaximal exercise has been shown to result in lower blood lactate concentrations as compared to passive recovery (Ahmaidi et al., 1996; Bond et al., 1991; Cazorla et al., 1983; Cristi-Montero et al., 2015; L. Hermansen & Stensvold, 1972; Losnegard et al., 2015; Menzies et al., 2010; Neric et al., 2009; Reaburn & Mackinnon, 1990; Signorile et al., 1993; Smilios et al., 2006; Spierer et al., 2004; Stamford et al., 1978; Stamford et al., 1981; A. Weltman et al., 1979). The present study demonstrated that a moderate intensity active recovery reduced the blood lactate more than passive recovery. Previous studies have indicated that the 15-20-minute range of recovery duration is where the greatest differences in blood lactate values between recovery types occur (L Hermansen & Vaage, 1977; A. Weltman et al., 1979). In the current study, the blood lactate values were significantly lower in the active recovery condition at all of the recovery time points excluding the first blood sample collection immediately following the first Wingate, indicating that active recovery enhanced removal making it superior to passive recovery in blood lactate clearance

Similar to previous research, the current study documented active recovery as having lower blood lactate values, although there was no difference in repeated exercise performance between the two recovery types (Bond et al., 1991; A. Weltman et al., 1979; Arthur Weltman, Stamford, Moffatt, & Katch, 1977). Researchers have previously noted that improved performance and active recovery was not associated with a lower blood lactate concentration (Bogdanis et al., 1996; Coffey et al., 2004; Thiriet et al., 1993).

Furthermore, the exact relationship between blood lactate clearance and subsequent performance is uncertain and requires more research to fully understand (Coffey et al., 2004).

One possible explanation for why the lower blood lactate values were seen without a difference between recovery types for performance is that acidosis, as a result of H+ buildup, may alter the ability of the muscle cells to produce force. Therefore, even if there is greater clearance of lactate, the effect of H^+ buildup might keep the skeletal muscle cells from producing the same level contractility as seen in the first bout of supramaximal intensity due to H+ ions interfering with the binding of calcium and troponin (Bogdanis et al., 1996; L. Hermansen & Osnes, 1972; Lopez et al., 2014; McCully, Authier, Olive, & Clark, 2002). Larson et al. (2013) conducted a study comparing active recovery carried out at an intensity of 58% for 16 minutes and passive recovery for 15 minutes, and found no significant differences between the two recovery types and performance.

Siegler, Bell-Wilson, Mermier, Faria, and Robergs (2006) suggested that subsequent performance during multiple bouts of intense exercise to exhaustion might not be influenced by blood acidosis, thus recommending that research focus on intramuscular activity during intense exercise as it might be more reflective of buffering potential and its influence on performance. The researchers also proposed that training specificity may influence time to recovery during multiple bouts of intense exercise independent of recovery type (Siegler et al., 2006). Participants in the current study were

generally healthy individuals with no training specificity for the intense exercise they completed and therefore performance differences may have been nonexistent due to a lack of training. Training specificity may influence the recovery time as different recovery types utilize and consequently train different metabolic pathways. Therefore, the participants in the current study were not anaerobically trained and as such, the anaerobic metabolic pathways are not trained to handle recovering from intense and repeated anaerobic exercise.

Another possible explanation for the decline in power output with repeated exercise bouts is the influence of the fatigue index. Lopez et al. (2014) discovered that the declines in peak and average power were relatively and proportionally affected by fatigue regardless of the recovery type. Another idea as to why there was no difference in performance between the two recovery types is due to the recovery duration. Losnegard et al. (2015) stated that the recovery time is a significant component in reference to the ability to achieve a high performance. This idea leads to the possibility that the recovery duration of the current study was not a sufficient amount of time to allow for a subsequent high performance. Losnegard et al. (2015) concluded that a recovery duration of 15 to 20 minutes, or even 25 minutes would potentially be needed in order to see significant differences.

CONCLUSION

In the current study, the active recovery condition resulted in significantly lower lactate levels at the four time points during recovery, but no significant difference in performance was observed. Based on previous research, the lower lactate values and performance might not be as connected as previously thought. However, the lower lactate levels can still be beneficial to recovery after intense exercise and repeated attempts, but there could be no effect of blood lactate clearance on performance. It is possible that a buildup of H+ ions decreases muscle cell contractility enough for both active and passive recovery that differences in performance between the two conditions are miniscule and therefore negligible.

FUTURE RESEARCH

Future research should focus on anaerobically trained athletes, such as sprinters and power lifters, as those types of athletes train with the ATP-PC and anaerobic glycolysis energy systems. Any differences measured in their lactate would be more indicative as to which recovery type is better for lactate clearance. Anaerobically trained athletes would also be expected to have higher and more consistent power outputs, so any differences measured in the performance variables would be a more accurate indicator as to which recovery type is optimal for maintaining performance. Females should be included in more research to add their demographic to the pool of research and to further investigate the optimal recovery type for their sex. In addition, future studies should include a male control group to investigate any possible sex bias between males and females as the research has conflicting data as to whether or not there is a sex bias. To get a more definitive measurement of lactate clearance, future research should focus on taking samples of lactate in the active skeletal muscle. Additionally, more studies are needed on the 15-minute duration of recovery and 50% of peak power active recovery intensity to test how effective they are at lactate clearance and maintenance of performance. To ensure diversity of the population, a large sample size that includes a variety of ethnicities should be investigated using the methods from this study.

TABLES AND FIGURES

Table 1 *Descriptive Statistics of Blood Lactate*

Time	Active Recovery	Passive Recovery
W1	9.4 ± 2.4	9.4 ± 3.3
5 min	10.5 ± 2.6*	12.1 ± 3.0
10 min	8.0 ± 2.0*	10.6 ± 2.6
15 min	6.0 ± 2.2*	9.4 ± 2.5
W2	11.0 ± 3.0*	13.1 ± 3.2

W1= 0 min, immediately post Wingate 1; 5 min= 5 minutes into recovery; 10 min= 10 minutes into recovery; 15 min= 15 minutes into recovery; W2= immediately post Wingate 2; * Significant difference vs. recovery types ($p < .05$)

Table 2 *Descriptive Statistics of Subjects (N = 23)*

Variable	Mean	SD
Age	21.83[a]	2.17
Peak Oxygen Consumption	34.31[b]	6.94
Height	1.64[c]	0.08
Weight	74.38[d]	23.60
Body Fat	27.09[e]	12.31
Peak Test Wattage	178.26 [f]	30.44

[a] Age = years; [b] Peak Oxygen Consumption = $ml \cdot kg^{-1} \cdot min^{-1}$; [c] Height = m; [d] Weight = kg; [e] Body Fat = %; [f] Peak Test Wattage = watts

Table 3 *Descriptive Statistics of Main Effects for Attempt for the Performance Variables*

Variable	Attempt One	Attempt Two
Peak Power	702 ± 168*	671 ± 157
Anaerobic Power	10.0 ± 1.1*	9.7 ± 1.1
Mean Power	495 ± 89*	479 ± 86
Anaerobic Capacity	7.2 ± 1.0*	7.0 ± 1.1
Total Work	14,770 ± 2, 652*	14,360 ± 2,496
Peak RPM	136 ± 15*	132 ± 15
Mean RPM	98 ± 14*	95 ± 17
RPE	17.1 ± 1.9*	18.0 ± 1.9

Peak Power= watts; Anaerobic Power= watts/kg; Mean Power= watts; Anaerobic Capacity= watts/kg; Total Work= Joules; Peak RPM= revolutions per minute; Mean RPM= revolutions per minute; RPE= Likert scale; *Significant difference between attempts

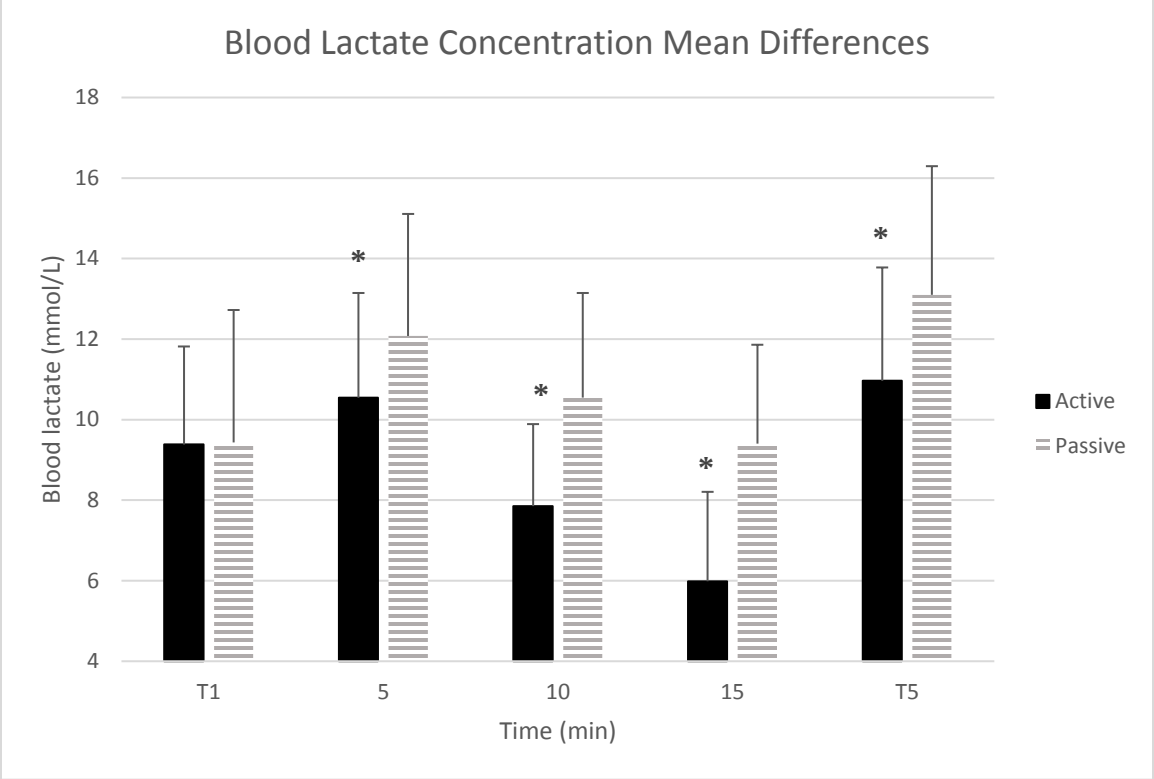

Figure 1. Blood Lactate Concentration Mean Differences.

T1= 0 min, immediately post Wingate 1; 5 min into recovery; 10 min into recovery; 15 min into recovery; T2= immediately post Wingate 2; * Significant difference vs. recovery types ($p < .05$)

REFERENCES

Ahmaidi, S., Granier, P., Taoutaou, Z., Mercier, J., Dubouchaud, H., & Prefaut, C. (1996). Effects of active recovery on plasma lactate and anaerobic power following repeated intensive exercise. *Medicine & Science in Sports & Exercise, 28*(4), 450-456.

Bangsbo, Gollnick, P. D., Graham, T. E., & Saltin, B. (1991). Substrates for muscle glycogen synthesis in recovery from intense exercise in man. *Journal of Physiology*(434), 423-440.

Bangsbo, Krustrup, P., González-Alonso, J., & Saltin, B. (2001). ATP production and efficiency of human skeletal muscle during intense exercise: effect of previous exercise. *American Journal of Physiology - Endocrinology And Metabolism, 280*(6), E956-E964.

Bangsbo, J., Graham, T., Johansen, L., & Saltin, B. (1994). Muscle lactate metabolism in recovery from intense exhaustive exercise : impact of light exercise (Metabolisme du lactate musculaire lors de la recuperation d'un exercice intense epuisant : influence d'un exercice leger). *Journal of Applied Physiology, 77*(4), 1890-1895.

Beckett, K. D., & Steigbigel, K. (1993). Effects of warm down techniques on the removal of lactate acid following maximal human performance. / Effets des techniques de retour au calme sur l'elimination de l'acide lactique apres une epreuve maximale chez l'homme. *Journal of Swimming Research, 9*(Fall), 32-35.

Bemben, D. A., Salm, P. C., & Salm, A. J. (1995). Ventilatory and blood lactate responses to maximal treadmill exercise during the menstrual cycle. / Reponses ventilatoires et du lactate sanguin a un exercice maximal sur tapis roulant, la fonction du cycle menstruel. *Journal of Sports Medicine & Physical Fitness, 35*(4), 257-262.

Ben-Sira, D., & Sagiv, M. (1997). The effect of gender on left ventricular function immediately after the Wingate test. / Les effets du genre sur les fonctions du ventricule gauche apres le test de Wingate. *European Journal of Applied Physiology & Occupational Physiology, 75*(6), 549-553.

Beneke, R., Pollmann, C., Bleif, I., Leithäuser, R., & Hütler, M. (2002). How anaerobic is the Wingate Anaerobic Test for humans? *European Journal of Applied Physiology, 87*(4), 388-392. doi:10.1007/s00421-002-0622-4

Bishop, D. (1998). The effect of stage duration on the calculation of peak VO2 during cycle ergometry. *Journal of Science & Medicine in Sport, 1*(3), 171-178.

Bogdanis, G. C., Nevill, M. E., Boobis, L. H., Lakomy, H. K., & Nevill, A. M. (1995). Recovery of power output and muscle metabolites following 30 s of maximal sprint cycling in man. *The Journal of Physiology, 482*(Pt 2), 467-480.

Bogdanis, G. C., Nevill, M. E., Lakomy, Boobis, & Nevill. (1998). Power output and muscle metabolism during and following recovery from 10 and 20 s of maximal sprint exercise in humans. *Acta Physiologica Scandinavica, 163*(3), 261-272.

Bogdanis, G. C., Nevill, M. E., Lakomy, H. K. A., Graham, C. M., & Louis, G. (1996). Effects of active recovery on power output during repeated maximal sprint

cycling. *European Journal of Applied Physiology & Occupational Physiology, 74*(5), 461-469.

Bond, V., Adams, R. G., Tearney, R. J., Gresham, K., & Ruff, W. (1991). Effects of active and passive recovery on lactate removal and subsequent isokinetic muscle function. . *Journal of Sports Medicine & Physical Fitness, 31*(3), 357-361.

Bonen, A., & Belcastro, A. N. (1976). Comparison of self-selected recovery methods on lactic acid removal rates. *Medicine & Science in Sports, 8*(3), 176-178.

Borg, G. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise*(14), 371-381.

Bulbulian, R., Jeong, J. W., & Murphy, M. (1996). Comparison of anaerobic components of the Wingate and Critical Power tests in males and females. / Comparison des composantes anaerobie du test de Wingate et du test de puissance critique obtenues chez les hommes et les femmes. *Medicine & Science in Sports & Exercise, 28*(10), 1336-1341.

Bushman, B., Masterson, G., & Nelsen, J. (2006). Anaerobic power performance and the menstrual cycle: eumenorrheic and oral contraceptive users. *Journal of Sports Medicine & Physical Fitness, 46*(1), 132-137.

Cazorla, G., Dufort, C., Cervetti, J. P., & Montpetit, R. R. (1983). The influence of active recovery and blood lactate disappearance after supramaximal swimming *In, Hollander, A.P. (ed.) et al., Biomechanics and medicine in swimming: proceedings of the Fourth International Symposium of Biomechanics in*

Swimming and the Fifth International Congress on Swimming Medicine, June 21-25, 1982, Champaign, Ill., Human Kinetics Publishers, c1983, p. 244-250.;.

Coffey, V., Leveritt, M., & Gill, N. (2004). Effect of recovery modality on 4-hour repeated treadmill running performance and changes in physiological variables. *Journal of Science & Medicine in Sport, 7*(1), 1-10.

Connolly, D. A. J., Brennan, K. M., & Lauzon, C. D. (2003). Effects of Active Versus Passive Recovery on Power Output During Repeated Bouts of Short Term, High Intensity Exercise. *Journal of Sports Science & Medicine, 2*(2), 47-51.

Cristi-Montero, C., Rodriguez-Rodriguez, F., Mendoza-Muñoz, J., Baronti-Correa, F., Leiva-Olivares, S., Rojas-Hube, M., & Bresciani, G. (2015). Blood lactate removal after a rowing all-out test depends on the active protocol proposed. *Science & Sports, 30*(5), 283-289.

Dahlstedt, A. J., Katz, A., & Westerblad, H. (2001). Role of myoplasmic phosphate in contractile function of skeletal muscle: studies on creatine kinase-deficient mice. *The Journal of Physiology, 553*(2), 379-388. doi:10.1111/j.1469-7793.2001.0379a.x

De Souza, M. J., Maguire, M. S., Rubin, K. R., & Maresh, C. M. (1990). Effects of menstrual phase and amenorrhea on exercise performance in runners. / Effets de la phase du cycle menstruel et de l ' amenorrhee sur la performance d ' exercice chez des athletes pratiquant la course de fond. *Medicine & Science in Sports & Exercise, 22*(5), 575-580.

Dotan, R., Falk, B., & Raz, A. (2000). Intensity effect of active recovery from glycolytic exercise on decreasing blood lactate concentration in prepubertal children. / Effet de l'intensite d'une phase de recuperation active, apres un exercice en filiere glycolytique, sur la baisse de la concentration du lactate sanguin chez des enfants prepuberes. *Medicine & Science in Sports & Exercise, 32*(3), 564-570.

Dupont, G., Moalla, W., Guinhouya, C., Ahmaidi, S., & Berthoin, S. (2004). Passive versus active recovery during high-intensity intermittent exercises. *Medicine & Science in Sports & Exercise, 36*(2), 302-308.

Dupont, G., Moalla, W., Matran, R., & Berthoin, S. (2007). Effect of Short Recovery Intensities on the Performance during Two Wingate Tests. *Medicine & Science in Sports & Exercise, 39*(7), 1170-1176.

Eston, R. G., & Burke, E. J. (1984). Effects of the menstrual cycle on selected responses to short constant-load exercise. *Journal of Sports Sciences, 2*(2), 145-153.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*(4), 1149-1160. doi:10.3758/BRM.41.4.1149

Gladden, L. B. (1989). Lactate uptake by skeletal muscle. *Exercise & Sport Sciences Reviews, 17*, 115-155.

Haff, G. G., & Triplett, T. N. (2015). *Essentials of Strength Training and Conditioning (4th edition)* (4th ed.). Champaign, IL: Human Kinetics.

Harbili, S. (2015). The Effect of Different Recovery Duration on Repeated Anaerobic Performance in Elite Cyclists. *Journal of Human Kinetics, 49*(1), 171-178.

Harris, R. C., Edwards, R. H. T., Hultman, E., Nordesjo, L. O., Nylind, B., & Sahlin, K. (1976). The time course of phosphorylcreatine resynthesis during recovery of the quadriceps muscle in man. *Pfluegers Arch*(367), 137-142.

Hermansen, L., & Osnes, J. B. (1972). Blood and muscle PH after maximal exercise in man. *Journal of Applied Physiology, 32*, 304-308.

Hermansen, L., & Stensvold, I. (1972). Production and removal of lactate during exercise in man. *Acta Physiologica Scandinavica, 86*, 191-201.

Hermansen, L., & Vaage, O. (1977). Lactate disappearance and glycogen synthesis in human muscle after maximal exercise. *American Journal of Physiology - Endocrinology And Metabolism, 233*(5), E422.

Houston, M. E. (2006). *Biochemistry Primer for Exercise Science* (Third ed.): Human Kinetics.

Inbar, O., Bar-Or, O., & Skinner, J. S. (1996). *The Wingate Anaerobic Test*. Champaign, Ill.;: Human Kinetics Publishers.

Jacob, C., Zouhal, H., Vincent, S., Gratas-Delamarche, A., Berthon, P. M., Bentue-Ferrer, D., & Delamarche, P. (2002). Training status (endurance or sprint) and catecholamine response to the Wingate-test in women. / Statut d ' entrainement (endurance ou sprint) et reponse des catecholamines au test de wingate chez des femmes. *International Journal of Sports Medicine, 23*(5), 342-347.

Katch, V. L., Gilliam, T., & Weltman, A. (1978). Active vs. passive recovery from short-term supramaximal exercise. *Research Quarterly, 49*(2), 153-161.

Kennedy, C. L. (2010). A New Frontier For Women's Sports (Beyond Title IX). *Gender Issues, 27*(1), 78-90. doi:10.1007/s12147-010-9091-y

Larson, L. M., Smeltzer, R. M., Petrella, J. K., & Jung, A. P. (2013). The Effect of Active versus Supine Recovery on Heart Rate, Power Output, and Recovery Time. *International Journal of Exercise Science, 6*(3), 180-187.

Lebrun, C. M., McKenzie, D. C., Prior, J. C., & Taunton, J. E. (1995). Effects of menstrual cycle phase on athletic performance. *Medicine & Science in Sports & Exercise, 27*(3), 437-444.

Lima-Silva, A. E., Pires, F. O., Bertuzzi, R., Silva-Cavalcante, M. D., Oliveira, R. S. F., Kiss, M. A., & Bishop, D. (2013). Effects of a low- or a high-carbohydrate diet on performance, energy system contribution, and metabolic responses during supramaximal exercise. *Applied Physiology, Nutrition & Metabolism, 38*(9), 928-934. doi:10.1139/apnm-2012-0467

Lindinger, M., & McKelvie, R. (1995). K+ and Lac- distribution in humans during and after high intensity exercise. Role in muscle fatigue attenuation (Distribution du potassium et du lactate chez l'homme pendant et apres un exercice intense. Role de la reduction de la fatigue musculaire). *Journal of Applied Physiology, 78*(3), 765-777.

Lopez, E.-I. D., Smoliga, J. M., & Zavorsky, G. S. (2014). The Effect of Passive Versus Active Recovery on Power Output Over Six Repeated Wingate Sprints. *Research Quarterly for Exercise and Sport, 85*(4), 519-526. doi:10.1080/02701367.2014.961055

Losnegard, T., Andersen, M., Spencer, M., & Hallén, J. (2015). Effects of Active Versus Passive Recovery in Sprint Cross-Country Skiing. *International Journal of Sports Physiology & Performance, 10*(5), 630-635.

Mageean, A. L., Alexander, R. P., & Mier, C. M. (2011). Repeated Sprint Performance in Male and Female College Athletes Matched for VO2max Relative to Fat Free Mass. *International Journal of Exercise Science, 4*(4), 229-237.

McCully, K. K., Authier, B., Olive, J., & Clark, B. J. (2002). Muscle Fatigue: The Role of Metabolism. *Canadian Journal of Applied Physiology, 27*(1), 70-82. doi:10.1139/h02-005

McLellan, T. M., & Skinner, J. S. (1982). Blood lactate removal during active recovery related to the aerobic threshold. *International Journal of Sports Medicine, 3*(4), 224-229.

McLester, J. R., Green, J. M., Wickwire, P. J., & Crews, T. R. (2008). Relationship of VO2 Peak, Body Fat Percentage, and Power Output Measured During Repeated Bouts of a Wingate Protocol. *International Journal of Exercise Science, 1*(2), 79-90.

Mendonca, G. V., Heffernan, K. S., Rossow, L., Guerra, M., Pereira, F. D., & Fernhall, B. (2010). Sex differences in linear and nonlinear heart rate variability during early recovery from supramaximal exercise. *Applied Physiology, Nutrition & Metabolism, 35*(4), 439-446.

Menzies, P., Menzies, C., McIntyre, L., Paterson, P., Wilson, J., & Kemi, O. J. (2010). Blood lactate clearance during active recovery after an intense running bout

depends on the intensity of the active recovery. *Journal of Sports Sciences, 28*(9), 975-982.

Miladi, I., Temfemo, A., Mandengué, S. H., & Ahmaidi, S. (2011). Effect of Recovery Mode on Exercise Time to Exhaustion, Cardiorespiratory Responses, and Blood Lactate After Prior, Intermittent Supramaximal Exercise. *Journal of Strength & Conditioning Research (Lippincott Williams & Wilkins), 25*(1), 205-210.

Miskec, C. M., Potteiger, J. A., Nau, K. L., & Zebas, C. J. (1997). Do varying environmental and menstrual cycle conditions affect anaerobic power output in female athletes? *Journal of Strength & Conditioning Research (Allen Press Publishing Services Inc.), 11*(4), 219-223.

Neric, F. B., Beam, W. C., Brown, L. E., & Wiersma, L. D. (2009). Comparison of Swim Recovery and Muscle Stimulation on Lactate Removal After Sprint Swimming. *Journal of Strength & Conditioning Research (Lippincott Williams & Wilkins), 23*(9), 2560-2567.

Ohya, T., Aramaki, Y., & Kitagawa, K. (2013). Effect of Duration of Active or Passive Recovery on Performance and Muscle Oxygenation during Intermittent Sprint Cycling Exercise. *International Journal of Sports Medicine, 34*(7), 616-622.

Ouergui, I., Hammouda, O., Chtourou, H., Gmada, N., & Franchini, E. (2015). Effects of Recovery Type after a Kickboxing Match on Blood Lactate and Performance in Anaerobic Tests. *Asian Journal of Sports Medicine, 6*(2), 99-107.

Reaburn, P. R. J., & Mackinnon, L. T. (1990). Blood lactate responses in older swimmers during active and passive recovery following maximal sprint swimming.

European Journal of Applied Physiology & Occupational Physiology, 61(3-4), 246-250.

Sahlin, K., Harris, R. C., Nylind, B., & Hultman, E. (1976). Lactate content and pH in muscle samples obtained after dynamics exercise. *Pfluegers Arch*(367), 143-149.

Siegler, J., Bell-Wilson, J., Mermier, C., Faria, E., & Robergs, R. (2006). Active and passive recovery and acid-base kinetics following multiple bouts of intense exercise to exhaustion. *International journal of sport nutrition and exercise metabolism, 16*(1), 92-107.

Signorile, J. F., Ingalls, C., & Tremblay, L. M. (1993). The effects of active and passive recovery on short-term, high intensity power output (Effets de la recuperation active et passive sur la production de puissance intense et de courte duree). *Canadian Journal of Applied Physiology, 18*(1), 31-42.

Sjogaard, G. (1987). Muscle fatigue (Fatigue musculaire) *Muscular function in exercise and training: 3 rd international symposium on biological sciences in sport, Nice, 1986 Karger, Basel SUISSE 1987, pp 98-109, ill*.

Smekal, G., von Duvillard, S. P., Frigo, P., Tegelhofer, T., Pokan, R., Hofmann, P., . . . Bachl, N. (2007). Menstrual Cycle: No Effect on Exercise Cardiorespiratory Variables or Blood Lactate Concentration. *Medicine & Science in Sports & Exercise, 39*(7), 1098-1106.

Smilios, I., Bogdanis, G. C., Mavridis, G., Tokmakidis, S. P., & Toubekis, A. G. (2006). Effect of different intensities of active recovery on sprint swimming performance. *Applied Physiology, Nutrition & Metabolism, 31*(6), 709-716.

Soderlund, K., & Hultman, E. (1991). ATP and phosphocreatine changes in single human muscle fibers after intense electrical stimulation. *American Journal of Physiology - Endocrinology And Metabolism, 261*(6), E737.

Spencer, M., Bishop, D., Dawson, B., Goodman, C., & Duffield, R. (2006). Metabolism and Performance in Repeated Cycle Sprints: Active versus Passive Recovery. *Medicine & Science in Sports & Exercise, 38*(8), 1492-1499.

Spierer, D. K., Goldsmith, R., Baran, D. A., Hryniewicz, K., & Katz, S. D. (2004). Effects of Active vs. Passive Recovery on Work Performed During Serial Supramaximal Exercise Tests. *International Journal of Sports Medicine, 25*(2), 109-114.

Stamford, B. A., Moffatt, R. J., Weltman, A., Maldonado, C., & Curtis, M. (1978). Blood lactate disappearance after supramaximal one-legged exercise. *Journal of Applied Physiology, 45*(2), 244-248.

Stamford, B. A., Weltman, A., Moffatt, R., & Sady, S. (1981). Exercise recovery above and below anaerobic threshold following maximal work. *Journal of Applied Physiology, 51*(4), 840-844.

Thiriet, P., Gozal, D., Wouassi, D., Oumarou, T., Gelas, H., & Lacour, J. R. (1993). The effect of various recovery modalities on subsequent performance, in consecutive supramaximal exercise. / Effet de differentes modalites de recuperation sur la performance subsequente, dans des exercices supramaximalux consecutifs. *Journal of Sports Medicine & Physical Fitness, 33*(2), 118-129.

Toubekis, A. G., Adam, G. V., Douda, H. T., Antoniou, P. D., Douroundos, I. I., & Tokmakidis, S. P. (2011). Repeated Spring Swimming Performnce After Low- or High-Intensity Active and Passive Recoveries. *Journal of Strength & Conditioning Research (Lippincott Williams & Wilkins), 25*(1), 109-116.

Tsampoukos, A., Peckham, E. A., James, R., & Nevill, M. E. (2010). Effect of menstrual cycle phase on sprinting performance. *European Journal of Applied Physiology, 109*(4), 659-667.

Weltman, A., Stamford, B. A., & Fulco, C. (1979). Recovery from maximal effort exercise: lactate disappearance and subsequent performance. *Journal of Applied Physiology, 47*(4), 677-682.

Weltman, A., Stamford, B. A., Moffatt, R. J., & Katch, V. L. (1977). Exercise Recovery, Lactate Removal, and Subsequent High Intensity Exercise Performance. *Research Quarterly. American Alliance for Health, Physical Education and Recreation, 48*(4), 786-796. doi:10.1080/10671315.1977.10615493

Appendix A

Effects of Active Versus Passive Recovery on Blood Lactate and Performance in Repeated Wingate Tests.

Principal Investigator: Madison Kirkpatrick, B.S.

(Approval Date: _____)

PARTICIPANT INFORMED CONSENT FORM

Please read the following material that explains this research study. Signing this form will indicate that you have been informed about the study and that you want to participate. We want you to understand what are you are being asked to do and what risks and benefits are associated with the study. This should help you decide if you want to participate in this study.

You are being asked to participate in a research project conducted by Madison Kirkpatrick under the supervision of Boe Burrus, Ph.D., Department of Kinesiology and Recreation Administration, 1 Harpst St., Arcata, CA, 95521. Dr. Boe Burrus may be reached at (707) 826-3557 or bmb803@humboldt.edu to answer any questions or concerns.

Project Description:

Procedure:

If you agree to take part in this study, you will be asked to come to the laboratory for four experimental sessions. There is no monetary compensation for participation in this study. All experimental sessions will take place in the HSU Human Performance Lab.

Orientation (10 minutes)

- We will explain the study and what we will ask you to do.
- You will read the informed consent.
- We will answer any questions you may have.
- You will sign the informed consent form, if you agree to participate in the study.
- You will complete a medical history questionnaire.

Participation in this study should take a total of 4 hours. Of four total sessions, the total time commitment for each individual session is broken up as follows; orientation will take approximately 40 minutes, session two will take approximately twenty minutes, and sessions three and four will take approximately 1.5 hours. A maximum of 22 participants will be invited to participate in this research study.

Risks and Discomforts:

To ensure subject safety during the Wingate test, a researcher will be standing beside the subject as a "spotter", acting to physically help the subject in the case of discomfort. The spotter will be in place to help the subject throughout the trial to reduce the risk of falls and to assist the participant with reasonable requests if need be. All lab personnel are current in their CPR/AED and first aid training. The Human Performance Lab has its own AED and first aid kit that the researchers can easily locate and use. You may experience discomfort from the finger prick during blood sampling. Risk of infection and transmission of blood-borne pathogens exist when blood is sampled. You may experience discomfort from supramaximal bouts of exercise. You may injure yourself while performing any of these activities. As is true for any exercise, you might experience abnormal heart rate, blood pressure, and in rare instances, death. While highly unlikely, subjects have the potential to faint from performing the peak oxygen consumption test, lactate profile tests, or the Wingate test.

Benefits:

The benefits to the participant would be an understanding of the Wingate test, an accurate measure of both anaerobic and aerobic fitness, descriptive data on themselves that could be used as individual baseline data or in comparison to others.

Subject Payment:

You will not be paid for participation in this research study.

Injury and Compensation:

If you feel that you have been harmed while participating in this study, you should inform the faculty supervisor, Dr. Boe Burrus, (707) 826-3557 immediately. If you are injured, Humboldt State University will not be able to pay for your medical care. State law may limit Humboldt State University's legal responsibility if an injury happens because of this study.

Study Withdrawal:

You have the right to withdraw your consent or stop participating at any time. You have the right to refuse to answer any question(s) or participate in any procedure for any reason.

Confidentiality:

Every effort will be made to maintain the privacy of your data. From the beginning of your participation, you will be given a unique identity code. This code will be used instead of your name for all documentation of your participation. Your individual data

and results confidential including computer files, paper files, and any personal information. In written or oral presentations of the results of this research, your identity and individual information will be kept confidential. After the project is complete, the materials associated with the project, including computer files, paper files, digital video files, and personal information will be secured in a locked cabinet in a locked office under the supervision of Dr. Boe Burrus for five years in case there is a need for future verification or reanalysis of the data. Upon completion of this informed consent form, you will receive a signed copy of the consent form.

Other than the research team, only regulatory agencies, such as the Humboldt State University Committee for the Protection of Human Subjects in Research may see your individual data as a part of routine audits.

Invitation for Questions:

If you have questions about this study, you should ask the researcher before you sign this consent form. You may also contact Madison Kirkpatrick, the primary investigator to answer any questions or concerns about the study at mlk313@humboldt.edu or (707) 499-1726. IF YOU HAVE ADDITIONAL QUESTIONS OR CONCERNS YOU MAY ALSO CONTACT DR. BOE BURRUS, THE FACULTY SUPERVISOR AT bmb803@humboldt.edu OR (707) 826-3557.

If you have any concerns with this study, contact the Chair of the Institutional Review Board for the Protection of Human Subjects, Dr. Ethan Gahtan, at eg51@humboldt.edu or (707) 826-4545.

If you have questions about your rights as a participant, report them to the Humboldt State University Dean of Research, Dr. Steve Karp, at karp@humboldt.edu or (707) 826-4190.

Authorization:

I have read this paper about this study or it was read to me. I know the possible risks and benefits. I know that being in this study is voluntary. I know that I can withdrawal at any time. I have received, on the date signed, a copy of this document containing 4 pages. I understand that the researcher will answer any questions that I may have concerning the investigation or procedures at any time. I also understand that my participation in this study is entirely voluntary and that I may decline to enter this study or may withdraw from it at any time without any penalty. I understand that the investigator may terminate my participation in the study at any time.

Participant name (print): _____

Participant signature: _____ Date_____

Appendix B

AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire

Assess your health status by marking all *true* statements

History

You have had:

___ a heart attack
___ heart surgery
___ cardiac catheterization
___ coronary angioplasty (PTCA)
___ pacemaker/implantable cardiac
___ defibrillator/rhythm disturbance
___ heart valve disease
___ heart failure
___ heart transplantation
___ congenital heart disease

If you marked any of these statements in this section, consult your physician or other appropriate health care provider before engaging in exercise. You may need to use a facility with a **medically qualified staff.**

Symptoms

___ You experience chest discomfort with exertion.
___ You experience unreasonable breathlessness.
___ You experience dizziness, fainting, or blackouts.
___ You take heart medications.

Other health issues

___ You have diabetes.
___ You have asthma or other lung disease.
___ You have burning or cramping sensation in your lower legs when walking short distances.
___ You have musculoskeletal problems that limit your physical activity.
___ You have concerns about the safety of exercise.
___ You take prescription medication(s).
___ You are pregnant.

Cardiovascular risk factors

___ You are a man older than 45 years.
___ You are a woman older than 55 years, have had a hysterectomy, or are postmenopausal.
___ You smoke, or quit smoking within the previous 6 months.
___ Your blood pressure is >140/90 mm Hg.
___ You do not know your blood pressure.
___ You take blood pressure medication.
___ Your blood cholesterol level is > 200 mg/dL.
___ You do not know your cholesterol level.
___ You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister).
___ You are physically inactive (i.e., you get <30 minutes of physical activity on at least 3 days per week).
___ You are > 20 pounds overweight.

If you marked two or more of the statements in this section, you should consult your physician or other appropriate health care provider before engaging in exercise. You might benefit from using a facility with a professionally qualified exercise staff to guide your exercise program.

___ None of the above

You should be able to exercise safely without consulting your physician or other
appropriate health care provider in a self-guided program or almost any facility that meets your exercise program needs.

AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire (Modified from American College of Sports Medicine Position Stand and American Heart Association. Recommendations for cardiovascular screening, staffing, and emergency policies at health/fitness facilities. *Med Sci Sports Exerc.* 1998;30(6):1009–18.)

Appendix C

SCREENING FORM
EFFECTS OF ACTIVE VS. PASSIVE RECOVERY ON BLOOD LACTATE AND PERFORMANCE DURING REPEATED WINGATE TESTS

Read to Candidate:
"Hello my name is _____. Thank you for calling in regard to our cycling study at Humboldt State University. If you have about 5 minutes to talk, I would be happy to tell you a little bit about the study and read you the requirements to be in the study. All the information discussed on this telephone screening call is confidential. This information will only be shared with members of the investigative team and will be stored in a locked cabinet in our laboratory. The purpose of this screening is to determine your eligibility for inclusion in the study. The primary investigator of this study is Madison Kirkpatrick".

Name:
_____
Phone number: _____

"I will now read you a list of requirements to be in the current study, after I finish this list please let me know if you feel that you meet these criteria."

Major inclusion/exclusion criteria via telephone:

a. Participant is a female
b. Participant is between 18 to 25 years of age
c. Participant exercises at a moderate to vigorous intensity at least thirty minutes for three days of the week and has done so for at least 6 months.
d. Participant has no orthopedic disorders including surgeries or injuries within the past year
e. Participant has no history of nervous system disorders including tremors, numbness, or tingling in lower limbs
f. Participant has not been diagnosed with any spinal disease or any spinal injury or surgery
g. Participant has no other conditions that may limit their ability to exercise (pain, disorders, diseases, etc.)

Included or Excluded (circle one)

If included, schedule experimental session: Date_____
Time_____

Read to caller:
"If you have any further questions, please contact the primary investigator, Madison Kirkpatrick, at (707) 499-1726 or project supervisor, Dr. Boe Burrus, at (707) 826-3557"
Investigator performing this screening _____ Date: _____

Appendix D

WITH REGARD TO RISKS OF INFECTION AND TRANSMISSION OF BLOOD-BORNE PATHOGENS, A NUMBER OF PROCEDURES ARE IN PLACE TO LESSEN THE CHANCE OF THESE OCCURING. THESE PROCEDURES ARE DESCRIBED BELOW.

-The student investigator has successfully completed the HSU Blood Borne Pathogen Training.

-The student investigator will be the only blood lactate technician.

-All blood samples will be treated as potentially infectious, so proper handling will occur.

-Lancets used to pierce fingertip are of the "single-use type" and manufacturer instructions on use of lancets and handling of samples will be followed. Lancets will be placed in the sharps container after use.

-Gloves will be worn by the lactate technician. Gloves will be changed between subjects.

-Very small quantities (drops) of capillary blood will be taken (< 32 uL) after preparing the site using alcohol swab and piercing skin with a lancet.

-Blood samples will be collected in 32uL capillary tube prior to analysis via portable lactate analyzer

-Biohazard waste disposal containers will be used.