The Effect of High Intensity Interval Training on VO2 Peak and Performance in Trained High School Rowers

by

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ABSTRACT

High Intensity Interval Training (HIIT) is a phrase quickly becoming popularized through current research due to the physical and physiological success this method of training has proven to yield in both untrained and trained individuals. There is no set definition used to describe HIIT, but it typically refers to repeated bouts of fairly brief intermittent exercise. A great deal of research outlines the benefits associated with utilizing HIIT in untrained and recreationally trained individuals. However, research on the effect HIIT has or could possibly have on the well-trained endurance athlete is limited, specifically in the sport of rowing.

The purpose of this study was to analyze the effect of HIIT on VO2 peak and performance in trained rowers when compared to traditional, endurance training. It was hypothesized that HIIT would be just as effective at improving VO2 peak and performance as the endurance training protocol in well-trained rowers. A total of 20 high school female rowers participated in the study (mean ± SD; age = 16 ± 1). Baseline testing was comprised of a 2000m time-trial test on the Concept IIc Rowing Ergometer and a maximal exercise test, which was also completed on the Concept IIc Ergometer, in order to determine VO2 peak. Subjects were randomly assigned to a HIIT or endurance group for four weeks of intervention. Three days/week the HIIT group completed a 6 by 30second repeated Wingate protocol on the Concept II Ergometer at or above 100% VO2 peak, in which each 30s maximal effort was
immediately followed by an active recovery of four-minutes. The endurance group completed 30 minutes of sub-maximal rowing at 65% of VO2 peak three days/week. After four weeks of intervention, post-testing took place, which was identical to baseline testing.

Results from this study suggest HIIT was just as effective as endurance training at improving 2k time (mean ± SD; HIIT: 498.7 ± 23.1; Endurance: 497.5 ± 17.6). There were no significant within or between group differences in VO2 peak post-intervention (mean ± SD; HIIT: 44.8 ± 4.0; Endurance: 45.8 ± 5.6). The current study suggests four-weeks of HIIT training can yield similar adaptations in performance when compared to endurance training.
DEDICATION

This thesis is lovingly dedicated to:

Daneon Riley, Veronica Riley and Dametreea Carr
I would like to first and foremost give thanks to God, my Heavenly Father, from whom all blessings flow. My favorite scripture in the Bible comes from the book of Philippians 4:13, which reads, "I can do all things through Christ who strengthens me." This scripture, although short in nature, is one that is near and dear to my heart because it is the scripture that always carries me through life’s many challenges. There truly is power in the Word of God, and it is this Word that has brought me the great success I have experienced in this season of my life. I thank you so much Lord for all the many blessings you have showered down upon me. I will forever love, praise, and worship you with my whole heart! I give you my all today and forever!

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Chapter 1

INTRODUCTION

Overview

High Intensity Interval Training (HIIT) is a phrase quickly becoming popularized through current research due to the physical and physiological success this method of training has proven to yield in both untrained and trained individuals. There is no set definition used to describe HIIT, but it typically refers to repeated bouts of fairly brief intermittent exercise. Each exercise bout is generally performed with an “all-out” effort at an intensity close to VO2 peak for several seconds, which is immediately followed by a few minutes of rest or low-intensity exercise. This sequence is repeated several times throughout the entirety of the exercise session, and due to the fact that this training technique is designed to stress the physiological systems to a greater extent than required when doing endurance training, the complete session is fairly short in duration (Gibala and McGee, 2008 & Laursen and Jenkins, 2002).

There is a plethora of research comparing the benefits of following an endurance training model to the benefits of utilizing a HIIT model, which suggests, in both untrained and trained subjects, that HIIT significantly improves endurance performance, fat oxidation, VO2 max, and maximal enzymatic activity (Laursen and Jenkins, 2002; Kubukeli, Noakes, & Dennis, 2002). Results from a recent study suggests that six sessions of low volume HIIT, when compared to high volume endurance
training, led to similar gains in muscle buffering capacity, oxidative capacity, and exercise performance, concluding that low volume HIIT is not only just as effective as traditional endurance training, but it is also a time-efficient training methodology (Gibala, Little, van Essen, Wilkin, Burgomaster et al., 2006). In 2006 Edge, Bishop, & Goodman came to a very similar conclusion suggesting that HIIT induced comparable, significant increases in VO2 peak and lactate threshold after comparing the data on moderate-intensity continuous training and HIIT.

Although a great deal of research outlines the benefits associated with utilizing HIIT in untrained and recreationally trained individuals, research on the effect HIIT has or could possibly have on the well-trained endurance athlete is limited. According to Laursen and Jenkins (2002) much of this issue may be due to the fact that it is often difficult to persuade coaches and athletes to alter training programs, specifically in the name of research. Several past HIIT studies performed on runners, swimmers, soccer players, and cyclists suggest that significant improvements can be made in VO2max, time-trial performance, lactate threshold, and peak-power output (Driller, Fell, Gregory, Shing, & Williams, 2009; Dupont, Akakpo, & Berthoin, 2004). However, when compared to the large amount of HIIT research available on the untrained individual, very little research has analyzed the physiological and performance effects of HIIT on the well-trained endurance athlete, and
even less has examined the effect of HIIT on actively trained rowers (Driller et al., 2009).

Due to the fact that increasing the volume of submaximal, endurance training rarely seems to significantly improve endurance performance, VO2 max, anaerobic threshold, economy, or oxidative muscle enzymes in athletes who are highly trained, (Laursen and Jenkins, 2002), it is important that alternative, effective training protocols are analyzed in an effort to afford athletes the opportunity to continually experience performance gains and physiological improvements. In addition, it is necessary that these alternative, effective training forms function to decrease overall time spent training because continually increasing daily exercise time, which is also referred to as monotonic training, increases the risk of injury due to overtraining (Steinacker, Lormes, Lehmann, & Altenburg, 1998). The results of this research will be useful for present and future head coaches, strength and conditioning coaches, and for trained athletes when deciding on an efficient and effective training protocol to utilize in and out of season.
**Purpose**

The purpose of this study was to analyze the effect of HIIT on VO2 peak and performance in trained rowers when compared to traditional, endurance training.

**Null Hypothesis**

It was hypothesized that HIIT would not be as effective at improving VO2 peak and performance as the endurance training protocol in well-trained rowers.
Definition of Terms

- **2k Performance Trial**: 2000m timed test performed on the Concept IIc rowing ergometer. 2000m is the standard race distance, on the water, for all national and world championships.

- **2k Split**: The average amount of time it takes to row 500m. It's the total 2k performance trial time divided by four; the term split is the standard language used by rowers, which expresses the amount of power utilized with each stroke.

- **Aerobic Metabolism**: A metabolic process occurring in the cells, in which the body uses oxygen to produce energy (ATP).

- **Anaerobic Metabolism**: A process converting glycogen or glucose into ATP in order to be utilized as a fuel for the muscles. This is a faster process than aerobic metabolism and is good only for a short period of time. Therefore it is used for higher intensity workouts.

- **Carbohydrate Oxidation**: The breakdown of carbohydrates into smaller units that can be used by the body for energy.

- **Concept IIc Rowing Ergometer**: A rowing machine designed to simulate and approximate the actual rowing motion, which has been accepted as valid and reliable in research, and has also been used in numerous research studies; the rower cannot display both
watts and split time on the screen, so split time is the standard training mode used by row athletes.

- **Control Group (Controls):** A group who follows the standard, sub-maximal endurance training protocol.

- **Economy:** The volume of oxygen consumed by the working musculature at a given steady-state workload.

- **Fat Oxidation:** The release of free fatty acids from the fat cells into the blood where they can circulate and enter muscle fibers providing the working muscle with energy.

- **Flow Mediated Dilation (FMD):** When blood flow increases through a vessel and causes the vessel to dilate.

- **High Intensity Interval Training (HIIT):** An interval training technique comprised of short training sessions and is completed approximately at or above 90% VO2 peak for no more than two minutes, which is immediately followed by one-to-four minutes of active recovery or rest.

- **Lactate Dehydrogenase:** Lactate dehydrogenase (LDH) describes a group of four enzymes involved in the oxidation of lactate to pyruvate.
• **Lactate Threshold:** Also known as the anaerobic threshold, it is the point where lactate (lactic acid) begins to accumulate in the bloodstream.

• **Maximal Aerobic Speed:** The lowest running speed that elicits VO2max.

• **Maximal Heart Rate:** Maximal heart rate is two-hundred twenty (220) minus the subject's age in years.

• **Monotonic Training:** A continual increase without any decrease.

• **Muscle Buffering Capacity:** The ability of muscles to neutralize the acid that accumulates in them during high-intensity exercise, thus delaying the onset of fatigue.

• **Muscle Fiber:** Muscle cell—an elongated contractile cell that forms the muscles of the body.

• **Muscle Fiber Cross Sectional Area:** The total area of the cross sections perpendicular to the muscle fibers. The cross sectional area of a muscle determines the amount of force it can generate; the strongest muscles are those with the largest cross sectional areas.

• **Muscle Oxidation Capacity:** Determined by the number of mitochondria, capillaries, and amount of myoglobin within or
surrounding a muscle fiber. High numbers of each will have a high aerobic capacity and will therefore be fatigue resistant.

- **Oxidative Capacity**: The amount of oxygen that a muscle is capable of using during exercise.

- **Peak Power Output**: The highest power output during a sprint test, often observed during the first five seconds of exercise. Indicates the energy generating capacity of the immediate energy system (intramuscular high energy phosphates ATP and PC).

- **Repeated Wingate Protocol for Rowers**: HIIT protocol for rowers comprised of 6 X 30second all out efforts at or above 100% VO2 peak, and each all out effort is followed by four minutes of active recovery.

- **Slalom**: A downhill race over a winding course defined by upright poles.

- **Time-trial Performance**: A competitive event in which participants are timed, as in covering a set distance, often used to select qualifiers for another event.

- **Type I Muscle Fiber**: The slow twitch muscle fibers are more efficient at using oxygen to generate more fuel (known as ATP) for continuous, extended muscle contractions over a long time. They
fire more slowly than fast twitch fibers and can contract repeatedly for a long period of time before they fatigue.

- **Type II Muscle Fiber:** Because fast twitch fibers use anaerobic metabolism to create fuel, they are much better at generating short bursts of strength or speed than slow muscles. However, they fatigue more quickly. Fast twitch fibers generally produce the same amount of force per contraction as slow twitch muscle fibers, but they get their name because they are able to fire more rapidly.

- **Ventilation:** The rate at which gas enters or leaves the lung.

- **VO2 Peak:** The greatest amount of oxygen that can be used at the cellular level for the entire body.
Delimitations

Study participants were comprised of a convenience sample from Xavier College Preparatory High School. A total of 26 female subjects between the ages of 15-18 were recruited to participate in the study. The participants had to be active members of the Xavier Prep Crew Team. All participants had to complete a PAR-Q and submit a signed parental consent and signed assent form.

Limitations

There are several identified limitations in this study. The participants were female high school rowers attending Xavier Prep High School in central Phoenix, so the results cannot be generalizable for other populations, (i.e. male rowers, college-level competitive rowers, etc). Although the sample size of 26 is comparable to sample sizes used in previous, similar HIIT research on athletic populations, it is still relatively small, and therefore may further limit generalizeability and statistical power.
Endurance Training (ET) versus High Intensity Interval Training (HIIT): Which is most effective? This is a question that has gained increasing attention in the literature as scientists have developed a growing interest in discovering which of the two training methods yields the most significant physiological and performance improvements. Based on previous literature, it is understood that physical fitness gains can be achieved through the application of either training method. A 2002 literature review by Laursen and Jenkins comparing and discussing 180 different endurance and/or HIIT studies indicated that HIIT in both sedentary and trained subjects improves VO2 peak, maximal enzymatic activity, peak anaerobic power output, time to fatigue, and improves endurance performance to a larger extent than continuous endurance training. This is partly due to an up-regulated contribution of anaerobic and aerobic metabolism. HIIT increases the availability of ATP, which improves the working muscle's energy status during the anaerobic, highly-intense intervals. In addition, during the recovery phase of HIIT, aerobic metabolism is important in phosphocreatine resynthesis and lactic acid removal, therefore HIIT functions to improve the capacity for aerobic metabolism.
Current research suggests that HIIT is just as effective, and sometimes even more effective, than continuous endurance training at producing physiological and performance-based improvements. However, the amount of HIIT research available on endurance athletes, specifically trained rowers, is extremely underdeveloped. To date, the 2009 article by Driller et al. is the only HIIT-versus-endurance training study in the literature focusing on trained rowers.

**HIIT in Sedentary and Untrained Populations**

A recent study compared metabolic adaptations from HIIT and endurance training in 20 healthy young adults who were not actively following a regular exercise training program. This study was comprised of a Sprint Interval Training (SIT) group who for six weeks, three days per week, completed four to six 30 second all out Wingate’s with a 4.5 minute recovery between each all out effort. The repeated Wingate’s were completed on a cycle ergometer. The second group was an endurance training group who completed continuous cycling on an ergometer for six total weeks (five days per week). Endurance training was completed at approximately 65% of VO2 peak for 40-60 minutes per day. Despite the fact that training volume was much lower with the SIT group than the endurance group, both protocols produced similar improvements in VO2 peak, peak power output, whole-body fat and carbohydrate oxidation, mean heart rate, ventilation, and muscle oxidative capacity (Burgomaster, Howarth, Phillips, Rakobowchuk, McGee, et al., 2008). The research
conducted by this cohort made it clear that low-volume HIIT does not only elicit similar physiological improvements as continuous training, but it is also a time-efficient strategy that can be utilized in an effort to achieve physiological gains and benefits. A group of researchers conducted an identical training protocol to the study previously mentioned and found that HIIT reduced steady-state exercising heart rate and improved flow-mediated dilation, so blood flow in the vessel was enhanced in untrained, healthy young adults (Rakobowchuk, Tanguay, Burgomaster, Howarth, Gibala, 2008).

HIIT has not only been shown to be effective in adult populations. The effect of HIIT in prepubertal children was analyzed in 2002 by Baquet, Berthoin, Dupont, Blondel, Fabre, et al., and this team of researchers compared a High Intensity Experimental Group (HIEG) to a control group. The HIIT group was comprised of 13 boys and 20 girls between the ages of 8-11 years. This experimental group participated in two additional HIIT-specific, physical education (PE) sessions each week. The additional PE sessions were 30 minutes in duration and were comprised of short intermittent exercises in which the students had to run at a velocity ranging between 100-130% of maximal aerobic speed (MAS) on a track for 10 or 20 seconds in one direction. After each student had 10 or 20 seconds of passive recovery, they had to once again run at MAS in the opposite direction, and each set (i.e. five sets of 10 x 10s at 110% MAS) was interspersed with three minutes of passive recovery. The control
group was comprised of 10 boys and 10 girls, and they participated in the standard PE program, which did not have the two additional 30 minute PE sessions each week. Data from this study suggests that after seven weeks of HIIT training the experimental group significantly improved absolute peak VO2 and VO2 peak relative to body mass and responses were similar in both the boys and girls. The control group’s absolute and relative VO2 peak remained unchanged. However, based on the protocols utilized, the HIEG group did a greater volume of work, so changes in VO2 could have been a result of the 14 additional 30 minute sessions over the 7 weeks of training.

In 2009 Tjonna, Stolen, Bye, Volden, Slordahl et al., compared an Aerobic Interval Training (AIT) model to a multidisciplinary model (MTG) in 62 overweight and obese adolescents with a mean age of 14. The AIT group performed 4 by 4 minute intervals at an intensity of 90-95% of VO2max with a three minute active recovery running and walking uphill on a treadmill for a total of 40 minutes per session. For the first three months they met twice a week for sessions, the following six months they met once every other week, and the last three months they met for one session each month. The MTG groups commitment to participating in 12 months of intervention, which included group meetings every two weeks and standard treatment exercise sessions. These group sessions were comprised of meetings with a physician, physiotherapist, clinical nutritional psychologist, and psychologist. Over the 12 months of intervention, the
MTG group participated in three activity sessions and three group conversational sessions each three to four hours in duration. The results from this study reported that three months of HIIT produced improvements in body mass index, VO2 max, body fat, mean arterial pressure, FMD, HDL cholesterol, and fasting glucose, which were greater than improvements seen in the MTG group. In addition to this, data suggested that after 12 months of intervention those in the AIT group maintained or improved these physiological changes better than those in the MTG group. The article did not provide specifics to the exercise program followed by the MTG group, but the research team did indicate that in order for the MTG group to experience similar physiological gains as the AIT group, either more of or a different physical activity program is necessary.

*HIIT in the Healthy and Recreationally Active*

Just as the literature supports the notion that HIIT can effectively induce physiological gains in sedentary and untrained populations, research seemingly suggests the same for healthy, recreationally active subjects. In 2005 Burgomaster, Hughes, Heigenhauser, Bradwell, & Gibala applied a two week SIT intervention comprised of four to seven repeated 30 second all out efforts on a cycle ergometer with a four minute recovery between each all out effort. The exercise protocol was performed on Monday, Wednesday, and Friday for the two weeks. The control group did not participate in any exercise training with the research team. However,
they continued to participate in their normal, weekly training routine which was comprised of two to three days of exercise per week (i.e. aerobics, cycling, jogging). Data from this research found that in a mere two week time period, six bouts of interval training improved muscle oxidative potential and increased time to fatigue, all in addition to increasing muscle glycogen content while at rest. The increase in time to fatigue in the SIT group was significantly greater than the controls.

In 2006 Gibala and colleagues compared SIT to endurance training in 16 healthy, active men. The SIT group completed between four and six 30 second maximal cycling efforts with four minutes of recovery between each 30 second bout, while the endurance group completed 90-120 minutes of continuous cycling at about 65% of VO2 peak. Each of the two groups met for sessions over a two week period every Monday, Wednesday and Friday. Post-testing data suggests that the time to complete the cycling performance test decreased by 10.1% and 7.5% respectively in the SIT and endurance groups after training, and there were no between group differences. In addition, similar between group improvements were seen in muscle oxidative capacity, muscle buffering capacity, and muscle glycogen content, concluding once again that HIIT is a time efficient training methodology that can yield the same performance and physiological benefits as endurance training.

HIIT and continuous endurance training was compared yet again in 2006 by Edge, Bishop, and Goodman as they analyzed and compared the
effect of the two protocols in sixteen recreationally active female subjects. For five weeks, three days per week, the HIIT group performed two minute intervals with one minute recovery at an intensity ranging between 120% and 140% of their pre-training power at lactate threshold, while the continuous group trained at an intensity ranging between 80-95% (total work was matched between the two groups). Training resulted in similar, yet significant differences in VO2 peak and lactate threshold. However, muscle buffering capacity ($\beta_m$ in vitro) was significantly improved in the HIIT group but not in the continuous training group despite the fact that total work was matched.

**How Does HIIT Effect an Athletic Population?**

The literature provides ample knowledge on HIIT and how it affects sedentary, healthy and recreationally active individuals, but research on how a HIIT protocol affects the endurance athlete seems to still be developing. To take this a step further, HIIT information on trained rowers seems to be one of the most underdeveloped in the literature. The 2009 study by Driller et al. compared the outcome of following a HIIT protocol to the outcome of following a traditional rowing protocol. Ten trained rowers, with a mean age of $19 \pm 2$, participated in the study and were placed into one of the two groups for four weeks of training. The HIIT group trained twice per week completing seven HIIT sessions total. Subjects in the HIIT group completed eight intervals at 90% peak power output for 2.5 minutes and had a recovery interval at 40% of peak power output until the heart
rate was less than or equal to 70% of the maximum. Once heart rate reached this point, the next high intensity interval began. The control group completed two erg sessions lasting between 55-60 minutes each week while working at a load that would yield between 2 and 3 mmol.L-1 of blood lactate concentration, which is below lactate threshold. Post-testing data suggests the HIIT group experienced significantly greater improvements in the 2k time when compared to the control group. In addition, the HIIT group experienced increases in VO2 peak and peak power output that were larger than the control group, but not significantly different between groups. To date, this seems to be the only literature available that specifically compared a HIIT protocol to a traditional row training program.

However, in 2008 Ingham, Carter, Whyte, & Doust analyzed the physiological and performance effects associated with low versus mixed-intensity row training. Eighteen experienced male rowers were randomly assigned to either a low-intensity (LOW) or mix of low and high intensity (MIX) group for 12 weeks of intervention. Training methodologies for the two groups were not explained in detail, but the LOW group trained below lactate threshold for 100% of the 12 week intervention and the MIX group trained below lactate threshold 70% of the time and 30% at an intensity halfway between lactate threshold and VO2 peak. Results from this study suggest both groups experienced increases in their 2k timetrial performance and VO2peak, thus LOW and MIX training had similar effects
on both physiological and performance training markers after 12 weeks of training.

A unique study conducted by MacPherson, Hazell, Olver, Patterson, & Lemon in 2010 compared the effects of SIT and endurance training in 20 active ultimate Frisbee players. All subjects completed six weeks of training, performing three sessions per week. The SIT group completed 4-6 repeated, 30 second maximal running efforts on the treadmill followed by four minutes of either active or passive recovery. The endurance group performed continuous running for 30-60 minutes at 65% of VO2 max on a treadmill. Upon completion of the study, there were no significant differences in body mass between groups, although fat mass decreased by 12.4% and 5.8% in the SIT and endurance groups respectively. There were also no between group differences in resting metabolic rate, 2000 meter run time, peak power output, or VO2 max. Maximal cardiac output increased with endurance training but did not increase after SIT. Based on the outcome of the data analysis, the research team concluded that both SIT and endurance training are useful exercise programs because endurance training functions to produce more central adaptations while SIT produces more peripheral adaptations.

The effect of HIIT in soccer players was analyzed in 2004 by Dupont, Akakpo and Berthoin, in which their findings were similar to outcomes discussed in the previous studies. Twenty-two professional male soccer players participated in a 20 week study. Ten weeks were completed under
control conditions which were comprised of technical and tactical skills and soccer games. The next ten weeks consisted of a similar exercise protocol with two additional HIIT sessions each week. During the HIIT portion of the study, the participants performed 12-15 40 meter sprints with 30 seconds of recovery. Adding in the two HIIT sessions per week led to significant improvements in maximal aerobic speed and 40m sprint time, and the team won a greater percentage of games during the HIIT training period.

In a recent 2010 study Breil, Weber, Koller, Hoppeler, & Vogt utilized a population of skiers and compared the effects of HIIT to a traditional ski-training protocol. Their study was comprised of 15 male and six female elite junior alpine skiers. Thirteen subjects were randomly assigned to the high intensity interval training group (IT), and eight subjects were assigned to the control training (CT) group. The statistical analyses revealed that there were no between group differences found in age, VO2max, peak power output or jump performance. Both groups participated in 11 days of a training intervention. The IT group participated in 15 high intensity interval sessions for three consecutive days, and each three day training block was separated by one rest day. The HIIT sessions were comprised of four, four-minute interval bouts between an intensity of 90-95% of maximal heart rate, which was followed by a three minute active recovery period. Twelve sessions were performed on a cycle ergometer and three sessions were completed on an obstacle-running
course specifically designed for skiers. The course contained slalom, jumping, and balancing elements, and heart rate was controlled by continuous monitoring, ratings of perceived exertion, and blood lactate measurements.

Subjects in the control training group followed their conventional endurance and strength training regime for the 11 day training period. The CT groups training methodologies were not explained in detail by the authors, but total training volume was significantly lower in the IT group (13.9 ± 2.7h) than in the CT group (23.9 ± 5.6h) . The study team found that there was a reduction in body mass in the IT group only. VO2max relative to body mass significantly increased in the IT group with no significant changes in the CT group, and absolute VO2max increased significantly in both groups. In addition, only the IT group experienced significant gains in peak power output. Overall, the HIIT protocol proved to be a time efficient, effective training method as it functioned to improve VO2 max and peak power output.

A rare crossover study analyzed the effects of HIIT in nine-to-eleven year old swimmers. A total of 26 subjects participated in the study (13 male and 13 female). Each subject participated in a five week HIIT protocol and a five week high-volume, low-intensity protocol (HVT). The two interventions were separated by a six week summer break where no training occurred. Training was comprised of five sessions per week in a 50 meter out-door pool, so a total of 25 sessions were completed for both
the HIIT and HVT training protocols. Both the HIIT and HVT protocols included identical warm-up and technical drills before differential training began each session. The HIIT protocol was 30 minutes in time and included 55 intervals of 50m, 47 intervals of 100m, 14 intervals of 200m, and 3 intervals of 300m. The HVT protocol was 60 minutes in duration and was comprised of 87 intervals of 100m, 60 intervals of 200m, 45 intervals of 300m, 19 intervals of 19m and 4 intervals of 800m.

Training intensity for HIIT was set at 92% of personal best time for each distance and set at 85% of personal best time for HVT. The research team recorded times manually and collected blood samples to determine lactate concentration. The mean total training volume for HIIT was 5.5km per week and for HVT was 11.9 km per week, and by the end of the five week study total volume was 27.4km of HIIT and 59.6km of HVT. Upon completion of the five week crossover intervention, pre and post testing data revealed that VO2 peak increased after both HIIT (10.2%) and HVT (8.5%). Competition performance improved 14.8% after HIIT with no changes after HVT, so 2000m time decreased after HIIT but not after HVT. Overall, there were significant improvements observed after HIIT that were not observed after HVT despite the fact that total training volume was lower in the HIIT protocol. (Sperlich, Zinner, Heilemann, Kjendlie, Per-Ludvic et al., 2010).

There are several studies that have discussed the effects of HIIT in trained endurance athletes, and the literature on runners seems to be a bit
more developed when compared to rowers, soccer players, skiers and swimmers. Acevedo and Goldfarb conducted what is known to be one of the first, and a classic HIIT study in 1989 with long distance runners. Seven male runners between 18-28 years of age performed increased intensity workouts three days per week for eight weeks. The interval workout was completed at an intensity of 90-95% of heart rate max with very little recovery time. After eight weeks of training, body weight remained unchanged and there were no significant differences in VO2 max. However, there was a significant decrease in the 10km timed trial, along with an increase in run time to exhaustion, and lactate concentrations were significantly lower when exercising at an intensity of 85-90% of VO2 max.

In 2008 Iaia, Hellsten, Nielsen, Fernstrom, Shalin et al., utilized 17 endurance-trained male runners in a four week study comparing speed endurance training (SET) to endurance training. Results from this study found that despite the decrease in total work time, there were no significant between group differences in body mass, VO2 max, muscle oxidative enzymes, muscle capillarization, or endurance performance. The findings in this study also suggests that in the already trained subjects the change from traditional endurance training to SET or HIIT training reduced energy expenditure during submaximal running.

In addition to the rowers, soccer players, skiers, swimmers and runners, HIIT when compared to endurance training seems to produce
similar effects with well trained cyclists. In 2002 Laursen, Blanchard and Jenkins analyzed the outcomes HIIT would produce in 14 highly trained male cyclists. Seven subjects were placed into a HIIT group who completed four sessions. Each session was comprised of 20 bouts of cycling at VO2 peak and peak power output (each bout was 60 seconds in duration), which was followed by two minutes of active recovery. Subjects in the control group were instructed to continue on with their normal training regimen. Upon completion of testing, the research team discovered there was a significantly greater increase in peak power output and in the first and second ventilatory thresholds, (measured during the VO2 peak test), in the HIIT group when compared to controls. However, there were no between group differences in VO2 peak.

*The Effect of HIIT on Other Physiological Markers*

Based on the array of previously discussed literature it can be concluded that utilizing a HIIT protocol can be just as effective, often times more effective than endurance training. The body of HIIT research has revealed that various physiological factors such as VO2peak, lactate threshold and muscle buffering capacity have each significantly improved after completion of a HIIT intervention. In addition, a recent study completed by Kohn, Essen-Gustavsson and Myburgh suggests that HIIT can also produce a few additional changes in physiological markers.

This particular HIIT study examined skeletal muscle and physiological adaptations in eighteen well-trained endurance runners after six weeks of
following a HIIT protocol. HIIT sessions were completed on a treadmill twice a week throughout the entirety of the six week intervention, and each participant performed six intervals at 94% of their peak treadmill speed with an active rest interval performed at 60% of their time to exhaustion on their peak treadmill speed test. Post training data from this study suggests that after HIIT, peak treadmill speed improved by 5.2% and heart rate max increased as well. VO2 max did not significantly change, and biopsies taken pre and post training suggest that muscle fiber type composition was not affected by HIIT. The six week intervention decreased plasma lactate concentrations and heart rate during submaximal exercise in the trained athletes. The cross-sectional area of type II fibers decreased after HIIT training. However, lactate dehydrogenase activity increased in the type IIa fibers (2010).

Concluding Thoughts

As demonstrated in numerous studies, HIIT has shown to be just as effective and often times more effective than continuous training in children, adults, sedentary, active, trained, untrained, male and female populations. In as little as two weeks of HIIT both physiological and performance-based improvements can be observed, and much of these improvements occur in a fraction of the total amount of work time it takes for endurance, continuous training. HIIT and its effects on the endurance athlete seem to be a research area that is gaining a great deal of interest. Currently there seems to be a small body of literature comparing the
benefits of utilizing a HIIT protocol to the benefits of following a traditional, endurance training protocol in cyclists and runners. Research on the well-trained rower seems to be one of the most underdeveloped areas, so it is in need of further investigation. If HIIT continually proves to be just as beneficial as continuous training, more coaches can begin to implement HIIT protocols into weekly training regimens, which will allow for more recovery time in conjunction with physiological and performance gains that can be experienced.
Chapter 3

METHODS

Participants and Study Design

A total of 26 school-aged female rowers from Xavier College Preparatory High School were initially recruited to participate in this study. All participants were highly active, healthy student athletes ranging between 15-18 years of age. Although 26 women were on the Xavier Crew Team, only data of 20 crew members could be utilized. Attrition occurred due to the fact that one of the subjects had surgery before the study began, one student-athlete quit the team half way through the study, one of the participants was out of town during baseline testing, and three of the participant’s data were not utilized due to the fact that they were coxswains and did not follow the same workout protocol as the rest of the crew team. A sample size of 20 subjects, although low in power, represents the average amount of participants utilized in previous research on trained, athletic populations. Due to the fact that this study involved the participation of human subjects, IRB approval by the ethics board and written consent and assent from volunteers were provided. Each participant was required complete all necessary baseline and post testing and had to be able to actively participate in the HIIT and endurance training programs. All volunteers had to be free of injury during time of testing and intervention.
The study was a randomized control trial with a convenience sample and the intervention stage was four weeks. Baseline testing took place one week before the intervention and post-testing occurred one week after. The PAR-Q, consent and assent forms were completed prior to baseline testing. Subjects participating in the study were randomly assigned to either the endurance (control) group or to the HIIT (experimental) group. Nine rowers comprised the control group, and the HIIT group consisted of 11 rowers. Baseline and post-testing took place at the Healthy Lifestyles Research Center (HLRC) at Arizona State University, Polytechnic Campus, and the four week training intervention took place at Brophy College Preparatory because Brophy was the location where all of the Concept II Rowing Ergometers were located. The research team was comprised of Undergraduate, Master and PhD students in the Exercise and Wellness program at Arizona State University (ASU), along with certified row coaches at Xavier College Preparatory High School.

Procedures and Measurements

Each student-athlete volunteering in the study was required to complete an assent form, along with a PAR-Q to determine their eligibility to actively participate in the study. Each parent was also required to complete a consent form. Before any measurements or testing was commenced, all volunteers and their parents were informed about the basic structure and objectives of the study. All risks and benefits
connected to the study were explained in great detail to each participant. All subjects were randomly assigned to either the HIIT group or the endurance group.

Baseline Testing

Baseline testing took place one week prior to the start of the four-week training program. Baseline testing was comprised of a 2000m time trial test, which was completed at Brophy Prep. Before the time trial test the crew team completed a 15 minute warm-up, and immediately following the warm-up, the rowing ergometer (erg) was set for 2000m. Once the test was complete, each participant’s 2k split time was recorded. After 48 hours of recovery, VO2 peak tests were completed at the HLRC. VO2 peak tests were completed on a Concept IIc Rowing Ergometer. During this time subjects underwent a continuous, incremental test with three minute stages. The initial rowing pace was set for subjects to complete 500m of rowing in 2.5 minutes, and after each three minute stage, 500m row time was decreased by five seconds. Subjects were given verbal encouragement during this time, and the test was stopped once participants could no longer maintain the rowing pace that was required or once they reached volitional fatigue (Weltman, Davis, Wood, Womack, Davis, Blumer et al., 1994; Womack, Wood, Sauer, Alvarez, Weltman et al., 1996). Gas exchange and minute ventilation was monitored during the VO2 peak test, as well as heart rate.
4 Week Training Program: HIIT Group

After VO2 peak testing was complete, subjects had 24 hours of recovery time. The four week training program began the following Tuesday after baseline testing. Each Tuesday, Wednesday, and Thursday the HIIT group began with a 10 minute warm-up led by the research team and coaches. Upon completion of the erg warm-up, they completed a 6 by 30second repeated Wingate protocol at or above 100% VO2 peak, in which each 30s maximal effort was followed by an active recovery of four-minutes. The coaches led the subjects through some stretching, flexibility, and core exercises after the HIIT training was complete for the day. Each Monday from 4-6pm the HIIT group participated in a 5-10 mile run led by crew coaches, and each Friday from 4-6pm the crew team rowed on the water gaining feedback from coaches on form and technique in the boat. On Fridays before rowing on the water, the crew team completed 10 minutes of flexibility and core strengthening exercises.

4 Week Training Program: Endurance Group

Each Tuesday, Wednesday and Thursday the endurance group began with a 10 minute warm-up. Once the erg warm-up was complete they were instructed to row on the erg continuously for 30 minutes at 65% of their VO2 peak. After 30 minutes of continuous endurance training, coaches led each subject through some stretching, core flexibility exercises. Each Monday and Friday, the endurance group completed the
same two-hour training protocol explained previously with the HIIT group. Mondays and Fridays were the only days each week that the HIIT group and endurance group underwent the same training.

Post-Testing

Post-testing began 48 hours after completion of the four week training program. Post testing began with the 2000m time trial test which allowed us to compare 2k split and overall performance changes post intervention. The subjects had a 48 hour recovery time, and after this two-day rest period, VO2 peak post testing took place once again at the HLRC. Post testing was identical to baseline testing procedures. Pre and post data were compared in each group so that both performance and physiological changes could be properly analyzed and discussed.
Statistical Analysis

All statistical analyses were performed using the PASW (formerly SPSS) Statistical Analysis system 18.0. A One-way ANOVA was used to determine between group differences present in pre and post-testing measurements. A Shapiro-Wilk’s test was used to test for normality because n<50. Within group differences between baseline and post-measurements of both groups were analyzed using a Wilcoxin Nonparametric T-Test. The level of significance was set at p<0.05. All results are reported as mean ± standard deviation (SD).
Chapter 4

RESULTS

A total of 26 crew members were recruited to participate in the study, but only 20 subjects completed all requirements which included one week of pre-testing, four-weeks of intervention, and one week of post-testing. The demographics of subjects in the HIIT and endurance groups are presented in Table 1. Thirteen participants completed 100% of the workouts over the course of the four-week intervention. Seven subjects completed 11 out of the total 12 workout sessions. One out of these seven subjects was absent the one day of practice, by doctor recommendation, due to a previous knee injury. Three of the subjects were seniors who missed one day of practice to attend college day at Xavier Prep, and three subjects were absent due to illnesses unrelated to training.

Table 1

<table>
<thead>
<tr>
<th>Characteristics &amp; Anthropometric Data of Subjects</th>
<th>HIIT Pre (n=11)</th>
<th>HIIT Post (n=11)</th>
<th>Endurance Pre (n=9)</th>
<th>Endurance Post (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>16 ± 1</td>
<td>16 ± 1</td>
<td>16 ± 1</td>
<td>16 ± 1</td>
</tr>
<tr>
<td>Experience (years)</td>
<td>2.9 ± 1.1</td>
<td>2.9 ± 1.1</td>
<td>3.1 ± 0.8</td>
<td>3.1 ± 0.8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.1 ± 5.9</td>
<td>168.1 ± 5.9</td>
<td>168.9 ± 4.1</td>
<td>168.9 ± 4.1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>62.3 ± 6.7</td>
<td>62.5 ± 6.4</td>
<td>67.7 ± 14.6</td>
<td>67.6 ± 14.7</td>
</tr>
</tbody>
</table>

*Note.* Characteristics & Anthropometric data of subjects pre and post-intervention. Parameters are shown as mean ±SD.
Oneway Anova statistical analysis showed there were no significant between group differences in VO2peak and total 2k time at baseline. A Wilcoxin Nonparametric T-Test revealed that both the HIIT and endurance groups, (p=0.005 and p=0.008), experienced significant improvements in their 2k performance trial. As displayed in table 2, the HIIT group decreased their 2k time trial performance by 15.8 seconds (514.5 ± 23.4 to 498.7 ± 23.1) and the endurance group decreased their 2k time trial by 16.2 seconds (513.7 ± 18.2 to 497.5 ± 17.6).

There were no between group differences in 2k time trial post-intervention. In contrast to performance measures, there were no within group significant differences, in the HIIT or endurance group, in VO2 peak pre versus post-intervention (p>0.05). The HIIT group experienced a slight decrease in VO2 peak (45.8 ± 5.7 to 44.8 ± 4.0), and the endurance group experienced a slight increase (45.0 ± 5.6 to 45.8 ± 5.6). However, changes in VO2 peak post intervention were not statistically significant in the HIIT or in the endurance group, and there were no between group differences.
Table 2

**Outcome Measures: 2k Time-trial and VO2 Peak**

<table>
<thead>
<tr>
<th></th>
<th>HIIT Pre (n=11)</th>
<th>HIIT Post (n=11)</th>
<th>Endurance Pre (n=9)</th>
<th>Endurance Post (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total 2k time</td>
<td>514.5 ± 23.4</td>
<td>498.7 ± 23.1</td>
<td>513.7 ± 18.2</td>
<td>497.5 ± 17.6</td>
</tr>
<tr>
<td>(s)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO2 peak</td>
<td>45.8 ± 5.7</td>
<td>44.8 ± 4.0</td>
<td>45.0 ± 5.6</td>
<td>45.8 ± 5.6</td>
</tr>
<tr>
<td>(ml.kg⁻¹.min⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant within group differences pre versus post-intervention (no between group differences), p<0.05.

Note. Outcome Measures: 2k time-trial and VO2 peak pre and post-intervention. Parameters are shown as mean ±SD.

**Figure 1.** 2k improvements before and after the four-week intervention

*Significant within group differences pre versus post-intervention (no between group differences), p<0.05.
Figure 2. VO2 peak results pre and post. No significant within group differences pre versus-post intervention in HIIT or endurance group (p>0.05).
Chapter 5
DISCUSSION

Although HIIT is a training methodology and research topic that is quickly gaining popularity in the literature, the amount of research available on the effect HIIT has on the trained, endurance athlete is still very limited. Specifically, the effect of HIIT on trained rowers is almost nonexistent, as there is only one published study that has analyzed the effects of HIIT, (when compared to endurance training), on a population of trained rowers (Driller et al., 2009). Rowing can be thought of as a strength-endurance sport. An average 2k, for elite rowers, typically lasts between 5.5-7.0 minutes and creates both aerobic and anaerobic stress on the body during training and competition. The total energy demanded during a 2k race is about 70% aerobic and 30% anaerobic (Mikulic, 2011; Cosgrove, Wilson, Watt, & Grant, 1999), so it is important to understand which type of training protocol proves to be most effective at improving performance and physiological measures.

The purpose of this study was to analyze the effect of HIIT on VO2 peak and performance in high school female rowers when compared to traditional endurance training. It was hypothesized that HIIT would produce similar adaptations in VO2 peak and performance as those experienced in the endurance training group of well-trained rowers. To my knowledge this study was the first to compare the effects of following a HIIT protocol, which was comprised of repeated 30 second maximal
efforts followed by four minutes of active recovery, to following a submaximal, endurance protocol comprised of 30 minutes of continuous rowing at 65% VO2 peak in a well-trained, high school female rower.

Results from this study suggest four weeks of HIIT training produced significant improvements in row performance. However, HIIT did not produce significant gains in VO2 peak. Data from this study reveals that both the HIIT group and endurance group significantly decreased their 2k time on the rowing ergometer. The HIIT group decreased their 2k time-trial by 15.8 seconds and the endurance group decreased their 2k time by 16.2 seconds. These findings are similar to the 2009 study conducted by Driller et al., in which data from this study found that both the HIIT and endurance group experienced significant improvements in their 2k time trial. The HIIT group decreased 2k time by approximately eight seconds, and the endurance group reduced their time trial by about two seconds. Similar to running, in the sport of rowing hundredths of a second could make the difference between first place and second place, so large improvements in 2k time could vastly improve final placement during competition on the water.

The VO2 peak data in this study seems to be a bit contrary to the significant performance-based improvements experienced in both groups. The results from this study reveal there were no significant differences in VO2 peak in the HIIT or endurance group following the four-week intervention. Post-testing data suggests the HIIT group’s VO2 peak
decreased about 1ml.kg-1.min-1, while the endurance group experienced a small increase of about 0.8ml.kg-1.ml-1. However the changes in VO2 peak were not statistically significant in either group. The results of this study support the 1989 findings of Acevedo and Goldfarb, which suggests HIIT can produce significant decreases in performance time without significant improvements in VO2 peak. However, These findings are contradictory to the 2009 results presented by Driller et al., who discovered the HIIT group experienced a significantly greater increase in VO2 peak, which improved by 7%, when compared to the endurance group. In that particular study all but one of the HIIT subjects improved VO2 peak, but the endurance participants were a bit varied with some of the rowers increasing and some decreasing after completion of the four-week intervention. These findings are also not in alignment with current research suggesting that VO2 peak increased in skiers, runners and swimmers post-intervention in both HIIT and endurance training groups (Breil, Weber, Koller, Hoppeler, & 2010; MacPherson, Hazell, Olver, Patterson, & 2010; Sperlich, Zinner, Heilemann, Kjendlie, Per-Ludvic, et al., 2010).

After analyzing VO2 peak data and the HIIT protocol utilized, the lack of improvement in VO2 peak measures could have largely been due to the fact that the HIIT protocol was anaerobic in nature, but the VO2 peak testing protocol was aerobic. It may have been more effective, beneficial, and efficient to employ an anaerobic maximal exercise test
when assessing and analyzing the effectiveness of the HIIT protocol on VO2 peak measures. Utilizing a maximal exercise test that was anaerobic in nature would have been more specific and better aligned with the HIIT protocol used in the intervention. Therefore, the resulting physiological adaptations in VO2 peak could have been present in the subsequent analyses.

Despite the fact that VO2 peak did not undergo any statistical increases, performance scores in the time-trial did significantly improve in both groups. It is important to note that prior to the intervention the participants had not done any rowing on the ergometer, which could possibly be a reason why such large performance gains were observed pre and post-intervention regardless of the fact that there were no improvements in VO2 peak. The subjects not participating in regular erg sessions is a limitation of the study because much of the decrease in 2k time could have been due to a learning effect. If the crew team had been rowing on the ergometer more frequently, prior to the four-week intervention, there is a possibility that we may not have observed such large improvements in performance time.

Due to the fact that participants were not regularly rowing on the ergometer prior to the start of the study, there is the possibility that the learning effect could have also led to improvements in economy, which in hand could have possibly been a reason for the improved performance times despite the lack of improvement in VO2 peak. Results from studies
on runners suggest that economy can be a distinguishing feature in performance time between athletes that have a similar VO2 max. Data from a recent study suggests the performance of elite Eritrean runners in several cross-country events was often significantly faster than performance times of their elite Spaniard counterparts, despite the fact that there were no significant between group differences in VO2 max. Based on the findings of this study, the research team concluded that the dominance in elite endurance runners of East African origin is largely due to a more efficient running economy. Similar to runners, if rowers could decrease their oxygen cost of rowing at a specific velocity, they could in-hand possibly improve their performance (Lucia, Esteve-Lanao, Olivan, Gomez-Gallego, San Juan, et al., 2006; Cosgrove, Wilson, Watt, & Grant, 1999).

There are several limitations associated with this study. The study was comprised of 20 subjects, which is a relatively small number. The small sample size limits generalizeability and statistical power. The study also only analyzed the effects of HIIT on performance and VO2 peak in high-school female rowers, in which all rowers attended the same high school. The specificity of the population causes the results of the study to be less generalizeable to other populations, (i.e. male rowers or college-level rowers). Many of the subjects remembered their time to exhaustion during their pre-VO2 peak test, so prior to completing the VO2 peak post-test many of them had already set a goal stopping point, which is another
limitation because several of the subjects were asking to stop the peak test before actually reaching a true state of exhaustion. During VO2 peak pre-testing the subjects participated in the continuous incremental test until they reached a state of exhaustion and volitional fatigue, however during post-testing several of the participants did not exercise as hard, oftentimes quitting the test before reaching their true VO2 peak. Discussions with the subjects following post-testing indicated that their focus was directed toward exceeding the pre-test time and not maximal effort. This is a limitation because some of the participants could have continued in stage elevation, and as a result could have possibly shown greater improvements in VO2 peak post-intervention.

The fact that the subjects in the HIIT group were told to perform a 30 second “all-out” effort, without being given specifics on what splits to attain is another limitation of the study. The term “all-out” effort is subjective, and it could be a strong possibility that these student-athletes thought they were giving 100% effort during the 30 second interval, when in fact they could have possibly pushed themselves more. In future HIIT research on rowers, which could include a replication of this study, it is important that the term “all-out” effort is defined by a specific split or wattage value to ensure all subjects are actually exercising at or above 100% of their VO2 peak. It is also important to ensure that the crew team has been rowing on the erg regularly prior to beginning to study to decrease the chances of observing a large learning effect. Covering the total time on the ergometer
screen during pre and post-testing of the VO2 peak test is highly recommended to ensure the subjects enter into pre and post-testing blindly and ask to stop the VO2 peak test once they have reached a true state of fatigue and exhaustion, as opposed to asking to stop once they surpassed their baseline, pre-test time.

This unique study was the first to utilize a repeated Wingate HIIT protocol in trained high school rowers. A major strength of this study is the fact that 100% of the intervention conditions were controlled, led, and monitored by a diverse research team comprised of row coaches knowledgeable in the sport and graduate-student researchers who understood the physiological principles involved in the study. The current study suggests that four-weeks of HIIT training (a total volume of three minutes of exercise/day) can yield similar adaptations in performance when compared to endurance training (a total volume of 30 minutes of exercise/day).

Although this study did not exemplify statistical differences in VO2 peak, there were significant improvements in the 2k time of both groups, which is of most importance because success in the sport of rowing is largely dependent on time performance during competition on the water. Both coaches and athletes aim to experience, observe and maximize time-based improvements during competition. Data from this study suggests that HIIT is an effective methodology that can improve 2k time in competitive rowers, which in hand could lead to the ultimate goal of
experiencing improved performance-time rankings during regional, state and national level competitions. However, due to the fact that HIIT research in trained rowers is underdeveloped, further research on this population of athletes is necessary in order to fully understand the physiological and performance benefits and gains that can be associated with following a HIIT protocol.
Practical Applications

The results of this study have shown that HIIT and endurance training can produce similar adaptations in performance in trained, high school female rowers. The information provided in this study could be useful for active members of a crew team as well as for row coaches. It is important that athletes get exposed to various methodologies of training, so they can continually progress physiologically and experience performance-based improvements during competition. Following a HIIT protocol may also be useful for both athletes and coaches who are aiming to reduce the risk of overuse injuries, increase recovery time, and the chance of athletes becoming bored from following a monotonous routine.

Research suggests that there are significant correlations between monthly ergometer time and injury, and the lumbar spine is reported to be the area in rowers that suffer the greatest percentage of injuries, which makes up about 31.82% of all injuries (Smolijanovic, Bojanic, Hannafin, Hren, Delimar et al., 2009; Wilson, Gissane, Gormley, Simms, 2010). The data from this study confirms that four weeks of committing to three minutes/day of HIIT are just as effective at improving performance time as committing to 30 minutes/day of endurance training. Therefore, both coaches and athletes can efficiently plan for fewer hours of training per week while still experiencing performance gains, and as a result decrease the risks associated with injury due to overuse and overtraining on the ergometer.
Due to the fact that HIIT and endurance training proved to be equally effective, coaches and athletes can utilize the findings of this data and apply it to weekly training regimens. Rowers and row coaches can design training programs that alternate days spent doing submaximal, endurance training with days spent following a HIIT protocol. Alternating daily workout methodologies, as opposed to utilizing and applying only one type of training protocol will add more diversity to weekly training routines and may possibly elicit a larger increase in possible performance and physiological improvements and gains that can be experienced by the elite athlete.


APPENDIX A

PARENTAL PERMISSION FORM FOR RESEARCH
Study Title: The Effect of High Intensity Interval Training on VO2 Peak and Performance in Trained High School Rowers

Sponsor: Arizona State University

Principal Investigator: Jack Chisum, PhD
College of Nursing and Health Innovation
7350 E Unity Avenue
Mesa, AZ 85212
Day Time Phone: 480.727.1943

INTRODUCTION
The purpose of this form is to 1) Provide you the parent / guardian of a potential research participant with information that may affect your choice to let your child participate in this research and 2). Record your consent if you agree to have your child involved in the study.

RESEARCHERS
Jack Chisum, PhD, Natasha Carr, Dana Ryan, and Sid Angadi, faculty and staff from Arizona State University (ASU), would like your child to be in a research study.

STUDY PURPOSE
The purpose of this study is to see if High Intensity Interval Training (HIIT) will be just as effective at improving VO2 max and time performance as the standard care endurance-based protocol. There are studies that suggest HIIT can significantly improve VO2 and performance in cyclists and endurance trained runners, but very little is known about the effects of HIIT on trained rowers. We will study 20 female rowers between the ages of 14-18. In addition to measuring changes in fitness level this study will also address any changes in endothelial function as a result of the different training plans. Endothelial dysfunction is strongly correlated with adverse cardiovascular events. In this study we will be measuring endothelial function by a non-invasive brachial artery flow mediated dilation.

DESCRIPTION OF RESEARCH STUDY.
If you and your child decide to participate, you both will come to the Healthy Lifestyles Research Center (HLRC) at ASU, Polytechnic Campus on 2 separate occasions, (once at the beginning of the study and once toward the end). The visits will be for baseline and post testing. You and your child will both participate in an informational session at the Xavier Boathouse where details about the study will be explained, and this is a time you both can ask us questions and complete consent forms. The
whole visit will last about one hour. The study will last for four weeks. Your child will be asked to follow either a standard care or HIIT protocol 5 days/week at Brophy Boathouse. We will be working collaboratively with the row coaching staff.

**Parent and Child Study Visit (Consent and PAR-Q).**

You and your child will have a chance to talk to the research staff about the study, read the consent form and have your questions answered. If you and your child are interested in participating you will sign the consent form and you both will sign the assent form. Once the consent form has been signed by the parent a standard questionnaire (Physical Activity Readiness-Questionnaire (PARQ)) will be administered to screen for contra-indications to exercise testing.

**Measurements:**

We will measure your child's height and weight. We will ask your child to take a VO2 max exercise test on a rowing ergometer. For this test, your child will breathe through a mouthpiece while they are rowing. The exercise test will last about 10 minutes and we will increase the resistance during the test until your child will no longer be able to continue. We will measure your child's heart rate before, during, and after the exercise test. This test will tell us how fit your child is. Your child will also complete a 2K time trial test, and we will record the time it takes to complete the time trial. Your child will we also have a non-invasive flow mediated dilation ultrasound test.

**RISKS.**

There may be parts of this study your child finds uncomfortable. Your child will take a difficult exercise test. As with any training protocol there are possible risks associated with physical activity, (i.e. muscle soreness, muscle strains, fatigue, etc.

**General Discomforts.**

The exercise test is likely to make your child sweat, breathe hard, feel tired and make their muscles sore. With any hard exercise, they may feel light-headed, out of breath, or nausea. In rare cases people do vomit and/or pass-out after exercise testing.

**COMPENSATION FOR ILLNESS AND INJURY.**

If you and your child agree to participate in the study, then your consent does not waive any of your legal rights. However, no funds have been set aside to compensate you in the event of injury.

**Alternative Treatments.**

There are no alternative procedures available for this study.
BENEFITS.
The information from this study will help researchers to better understand how effective high intensity interval training is at improving physiological markers and the benefits such a protocol will yield to the endurance athlete. Your child will have the opportunity to learn about their fitness levels, athletic performance, and health and how scientists use exercise to understand how the body works.

NEW INFORMATION.
If the researchers find new information during the study that would reasonably change your decision about participating, then they will provide this information to you.

CONFIDENTIALITY.
All information obtained in this study is strictly confidential unless disclosure is required by law. The results of the research study may be published or presented but your child’s name or identity will not be revealed without your consent in writing. In order to maintain confidentiality of your records, Dr Chisum and his team will use codes for all test results from all research volunteers and only the study team will have access. The study records will be kept locked in Dr. Chisum’s office.

The research team will have access to your name and telephone number.

WITHDRAWAL PRIVILEGE.
It is ok for you and your child to say no. Even if you say yes now, you both are free to say no later, and withdraw from the study at any time. Your decision will not affect your relationship with Arizona State University or otherwise cause a loss of benefits to which you might otherwise be entitled.

COST AND COMPENSATION.
The researchers want your family’s decision about participating in the study to be absolutely voluntary. Yet they recognize that participation may pose some time and inconvenience.

Your child will receive a $5 gift card for completing this study.

The Investigator may end your child’s participation in the study at anytime without consent. Your child will still be compensated the amount stated above if this occurs.

VOLUNTARY CONSENT.
Any questions you have concerning the research study or your
participation in the study, before or after your consent, can be answered by Natasha Carr by phone at 520.271.6428, or by email at nscarr@asu.edu

If you have questions about your child’s rights as a participant in this research, or if you feel your child has been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at 480-965-6788.

PARTICIPANT ACKNOWLEDGEMENT TO PARTICIPATE IN THE ABOVE STUDY.

This form explains the nature, demands, benefits and risks of the project. By signing this form you agree knowingly to assume any risks involved. Remember, your child’s participation is voluntary. You and your child may choose not to participate or to withdraw your consent and discontinue participation at any time without penalty or loss of benefit. In signing this consent form, you are not waiving any legal claims, rights, or remedies. A copy of this consent form will be given (offered) to you.

Your signature below indicates that you consent for your child to participate in the above study.

Your child’s name (please print): ____________________________

_________________________  ___________________________  __________
Parent’s Signature.  Printed Name.  Date

INVESTIGATOR’S STATEMENT.

"I certify that I have explained to the above individual the nature and purpose, the potential benefits and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature. These elements of Informed Consent conform to the Assurance given by Arizona State University to the Office for Human Research Protections to protect the rights of human subjects. I have provided (offered) the participant a copy of this signed consent document."
APPENDIX B

CHILD ASSENT FOR RESEARCH
Study Title: The Effect of High Intensity Interval Training on VO2 Peak and Performance in Trained High School Rowers

RESEARCHERS
Jack Chisum, PhD, Natasha Carr, Dana Ryan, and Sid Angadi, faculty and staff from Arizona State University (ASU), would like your child to be in a research study.

STUDY PURPOSE
We want to learn about High Intensity Interval Training and its effect on athletic performance in endurance athletes. In addition to measuring changes in fitness level this study will also address any changes in endothelial function as a result of the different training plans. Endothelial dysfunction is strongly correlated with adverse cardiovascular events. In this study we will be measuring endothelial function by a non-invasive brachial artery flow mediated dilation (FMD).

WHAT WILL I DO
If you agree you will:
- Have your height and weight measured
- We will also measure your VO2 max. For the exercise test will, we will ask you to complete a continuous graded exercise test on the rowing ergometer for no more than 10 minutes. We will have you breathe in and out of a mouthpiece to measure your breath. We will measure your heart rate during the exercise test. The test will progressively get harder and harder until you can't row any more. We will stop the exercise test at any time if you want us to.
- You will train 5 days/week in either a standard care or HIIT group at Brophy Boathouse for four weeks
- You will have your FMD analyzed by a non-invasive ultrasound technique

ARE THERE ANY RISKS
- The exercise test may make your muscles hurt or feel sore. The exercise test may make you sweat, breathe hard, and tired. Some people may get dizzy or nauseous (feel like they are going to throw up) when they exercise hard.
- During the 4 week training intervention, you may feel muscle soreness, nausea, fatigue, or any other risks associated with physical activity
- We will give you an ID number to keep your information private.

DO I HAVE TO DO THIS
You do not have to be in this project. The choice is yours. No one will be mad at you if you decide not to do this. Even if you start the project, you can stop later if you want. You may ask questions about the study at any time.

WHAT DO I GET FOR DOING THIS
- You will learn about your fitness levels.
- You will improve your athletic performance
- You will get a $5.00 gift card for participating in this study.
- You will help researchers learn about exercise, health and performance improvements in an athletic population.

If you have any questions about the study please call:
Natasha Carr, Co-investigator, Arizona State University, 520.271.6428.
Signing here means that you have read this form or have had it read to you and that you want to be in this project.

Signature of participant ________________________________

Participant’s printed name ________________________________

Date___________________________

Signature of parent ________________________________

Signature of Investigator ________________________________

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

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

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

<table>
<thead>
<tr>
<th>1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES □ NO □</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Do you feel pain in your chest when you do physical activity?</th>
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<tbody>
<tr>
<td>YES □ NO □</td>
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<table>
<thead>
<tr>
<th>3. In the past month, have you had chest pain when you were not doing physical activity?</th>
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</thead>
<tbody>
<tr>
<td>YES □ NO □</td>
</tr>
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<table>
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<tr>
<th>4. Do you lose your balance because of dizziness or do you ever lose consciousness?</th>
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<tbody>
<tr>
<td>YES □ NO □</td>
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</table>

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<thead>
<tr>
<th>5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?</th>
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</thead>
<tbody>
<tr>
<td>YES □ NO □</td>
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</table>

<table>
<thead>
<tr>
<th>6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?</th>
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<tbody>
<tr>
<td>YES □ NO □</td>
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</table>

<table>
<thead>
<tr>
<th>7. Do you have a diabetes or thyroid condition?</th>
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<tbody>
<tr>
<td>YES □ NO □</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8. Do you know of any other reason why you should not do physical activity?</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES □ NO □</td>
</tr>
</tbody>
</table>

If you answered "Yes" to one or more questions:

- A medical clearance form is required of all participants who answer 'yes' to any of the eight PAR-Q questions. Note: Personal training staff reserve the right to require medical clearance from any client they feel may be at risk.
  - Discuss with your personal doctor any conditions that may affect your exercise program.
  - All precautions must be documented on the medical clearance form by your personal doctor.

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

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

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

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

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

**STUDY #** _______________  **DATE** _______________  **Note:** This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.
ARIZONA STATE UNIVERSITY
EXERCISE & WELLNESS PROGRAM
PERSONAL HEALTH HISTORY FORM

Study #__________________________  Age_________________  Date_________________

Specify any activities which have been contraindicated by your physician:
__________________________________________________________________________________________
__________________________________________________________________________________________

Are there other activities about which you must be cautious?
__________________________________________________________________________________________

Are you currently taking any medications?
__________________________________________________________________________________________

Please ANSWER (YES/NO) if you have or you have ever been diagnosed with any of the following disease or symptoms.

Please circle YES or NO

YES  NO  Do you smoke?
YES  NO  Have you smoked in the past? If Yes: number of packs per day? _______.
YES  NO  Diabetic?
YES  NO  Family history of diabetes?
YES  NO  Any heart disease?
YES  NO  Heart murmur?
YES  NO  Chest pain?
YES  NO  Chest pressure with exertion?
YES  NO  Asthma or allergies?
YES  NO  Daily Coughing?
YES  NO  High blood pressure?
YES  NO  Any muscle injuries or illness?
YES  NO  Muscular weakness?
YES  NO  Muscle pain at rest?
YES  NO  Muscle pain with exertion?
YES  NO  Bone or joint injury or illness?
YES  NO  Bone or joint pain with movement?

What sports/exercise do you do now?

<table>
<thead>
<tr>
<th>Activity</th>
<th>How Often</th>
<th>How much time?</th>
<th>What is your heart rate?</th>
</tr>
</thead>
</table>

How long since you last exercised regularly? ____________________________________________

I estimate my current fitness level: (circle one)

Unfit  Below Average  Average  Above Average  Very Fit