CARDIAC DRIFT IN RESPONSE

TO ROWING ON AN ERGOMETER

By

MICAH HARTWELL

Bachelor of Arts in Psychology

University of Oklahoma

Norman, OK

2004

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2014

CARDIAC DRIFT IN RESPONSE

TO ROWING ON AN ERGOMETER

Thesis Approved:

Doug Smith, PhD

Thesis Adviser

Jennifer Volberding, PhD

Bert Jacobson, PhD

ACKNOWLEDGEMENTS

I would like to recognize Jason Miller, Ph.D., Chair of Exercise and Sport Science at Oklahoma City University for his assistance in allowing me to complete my research. I express a special thank you and much gratitude to Cam Brown, Head Coach of Oklahoma City University's Men's Rowing, as well as the team members who participated in my research. Without your support, this study would not have been possible.

I am indebted to my advisor, Doug Smith, PhD, and to my committee members, Bert Jacobson, PhD, and Jennifer Volberding, PhD, for their valuable input and support throughout my time as a graduate student. Your thoughtful comments on my thesis drafts helped me to become a better student and to grow academically.

Without the support of my supervisor and mentor, Sharon Thoele, MHR, I would not have been able to achieve this level of education. Your unwavering faith in me, both personally and professionally, have helped me to believe in myself and in my capabilities.

I would like to thank my mother-in-law, Barbara Prater, for being loving and supportive. Thank you for all your help during the last ten years. Last but not least, I would like to thank my wife, Marianne Wetherill, PhD, MPH, RD/LD, who, without her love and patience, I would not be where I am today. You have been my inspiration in continuing my education.

Name: MICAH HARTWELL

Date of Degree: MAY 2014

Title of Study: CARDIAC DRIFT IN RESPONSE TO ROWING ON THE ERGOMETER

Major Field: HEALTH AND HUMAN PERFORMANCE: APPLIED EXERCISE SCIENCE

Abstract:

Background. In rowing, there are many physiological strains imposed upon the body unlike those in any other sport. The process of rowing powerfully contracts and expands the entire body at a controlled rate between 18 to 40 strokes per minute. Unique characteristics of the rowing stroke may influence heart rate variability over time. *Cardiovascular drift* is a gradual increase of HR during steady-state exercise at moderate intensity; research shows that this phenomenon occurs after approximately 15 minutes of exertion during running and cycling. Measuring HR variability and the occurrence of cardiac drift has yet to be analyzed during rowing on an ergometer. **Methods.** Two groups of 10 male collegiate rowers (n = 20) performed a 60-minute session on an ergometer wearing HR monitors. During the bout, perceived rate of exertion was also measured at three-minute intervals. Demographic variables, post-workout dehydration, and ambient room temperature were measured. Descriptive statistics, dependent and independent samples t-tests, Pearson's correlation coefficients, and linear regression were conducted to analyze variables. **Results.** Cardiovascular drift occurred without a stabilization period as seen in other endurance exercise. The gradual increase in HR began after the early onset of the acclimation phase, approximately three minutes into the session, unlike that observed during running and cycling. A significant positive association between mean RPE and mean HR was observed ($r = .989$, $p < .01$). Ambient room temperature and additional weekly minutes of aerobic exercise apart from team practice affected RPE at the 60 minute mark. A colder room temperature and increasing minutes of aerobic exercise were associated with a higher 60-minute RPE ($R^2 = .409$). **Conclusion.** These findings may alter the current approach to adapting cycling and running HR training regimens to the sport of rowing and may even necessitate that rowing coaches develop their own training regimens when using HR as a monitoring mechanism. The early onset of cardiac drift suggests that target heart rate training zones may be unique for the sport of rowing.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

"Rowing is a sport for dreamers. As long as you put in the work, you can own the dream. When the work stops, the dream disappears." –Jim Dietz, professional rowing coach

The earliest rowing race in America was between British and American soldiers in the Chesapeake Harbor during the 1890's. Without racing shells or specially designed oars, that competition was more of a show of strength than a sporting event. However, the spirit of the sport of rowing had crossed the Atlantic and took hold in America. From the 1900's through the 1940's before professional sports teams took shape, rowing was one of the most popular pastimes in the country. Currently it is experiencing resurgence and is once again among the fastest growing sports in America.

In rowing there are many physiological strains imposed upon the body that are unlike those in any other sport. Rowing is a cyclical repetitive movement like running and cycling, but it involves the whole body. Instead of step-rates or cycling revolutions that alternate limbs and count upwards of 100 per minute, the process of rowing is an all-engaging power movement that contracts and expands the entire body at a controlled rate between 18 to 40 strokes per minute, depending on the distance of the race.

The process of pulling an oar through the water consists of three overlapping motions of force: the leg drive, the layback, and the arm pull. Relative to exercises done in the gym, the leg drive is most related to the leg-press. The layback is consistent with the dead lift; the arm pull is similar to a seated row. The overlaying of these exercises could be compared to a power clean, in which a maximal amount of force is generated close to the floor through the legs to accelerate the weighted bar upwards; the back extends from a slightly bent forward angle to become perpendicular to the floor, while the arms are pulling and controlling the movement of the final part of the lift.

Being such a physically demanding activity, a comparison study between elite high-school-aged male rowers and a control sample of the same age group revealed many differences in anthropomorphic measurements. According to Bourgois, et al. (2000), rowers were nearly 36 pounds heavier and nearly five inches taller than the control groups. Compared to the control group, the bone widths (humerus and femur) and limb girths (biceps, thigh, and calf), were significantly greater. Being a physically demanding sport, successful rowers must be fit and reasonably within the standard BMI (body mass index) ranges and possess a greater degree of flexibility than the average person (Richter, Hamilton, & Roemer, 2011). In turn, completing a 2000m sprint race is approximately 70% aerobic, making it also physiologically demanding. Elite male rowers tend to have maximum VO_2 measures greater than 6 L/min and incur oxygen deficits of up to 20 L (Yoshiga & Higuchi, 2003). During the standard racing distance, the energy expenditure has been estimated at 36 kcal/min or 2160 kcal/hr which makes it one of the most taxing sports recorded (Hagerman, 1984).

An Olympic race is 2,000 meters long and generally takes 240 to 265 strokes to finish the course. This race could be likened to performing 240 repetitions of power cleans at nearly maximal weight in a single set. The question then becomes, what is the best way to train for the event? What are the best monitoring systems? Additional questions arise regarding the techniques and training schedules that work best for athletes. The literature on effective training regimens for rowing is sparse, and because of the unique aspects of the sport, training methods from other sports cannot be automatically applied. While we have the marker to indicate the physical determinants of a successful rower, to begin to answer these questions, we must look at the physiology of the body in order to find how to expand its limits.

The place to start is the heart. As with all exercise, as the body starts moving, the heart has to work harder and faster to sustain blood flow to the rest of the body to provide nutrients and deliver oxygen while removing carbon dioxide and lactic acid as well as other cellular by-products. Different sports present unique stresses on the heart. Continuous motion sports (e.g., long distance running) and isometric (e.g., power lifting) sports present much different challenges to the heart, while some others- swimming, cycling, rowing and cross-country skiing, are a combination of both, requiring the use of anaerobic and aerobic energy systems. While these sports training regiments may have some common elements, the ultimate goal requires sports specific achievement (Fagard, 1997).

As rowing is a combination of continuous motion and isometric exercise, the stress placed on the heart is unique. The beginning of the stroke, much like a powerlift, dramatically increases the blood pressure within the body, as well as the stroke volume of the heart. The resulting effect of this repeated movement is embodied in the structure of the left ventricle. This forced output increases the size, although not the shape of the heart, especially the left ventricle (Volianitis & Secher, 2009). "During rowing blood flow is not allowed to increase at the expense of blood pressure, and muscle blood flow is reduced by 30% compared to that seen during exercise involving a small muscle mass" (p. 242). Unlike most sports where the movement and body fatigue are products of the heart, in rowing, the heart is at the mercy of the stroke and the constraints that come with it.

With the demands rowing places on the heart, and the mentioned constraints, the cardiac response may differ from other endurance sports. One response, measured in running and cycling occurring after the lapse of approximately 20 minutes, is that heart rate tends to gradually increase while blood outflow decreases. This phenomenon is known as cardiovascular (cardiac) drift. The purpose of this study is to observe if this phenomenon exists in rowing, the degree of heart rate change and at what point onset occurs.

Statement of the Problem

This study was designed observe heart rate variability and the occurrence of cardiovascular drift during rowing on the ergometer. This study was culminated from the introduction of heart rate monitoring in rowing training without precedents or valuations of long duration steady-state training when adapting regimens and protocols from running and cycling programs.

Need for the Study

As new methods become introduced for monitoring training in rowing, especially when adapting from other sports where there are major physiological differences, it is necessary to accumulate and validate data that supports or disproves current training methods. The overarching need for the study is to provide initial heart rate data during long-term rowing sessions for comparison to running and cycling sessions of the same duration. This research would allow future study into the comparison between groups of athletes related to heart rate measures. It could lend validity to implementing certain training methods used in running and cycling to the sport of rowing.

Limitations of the Study

1. The location and timing of the study were dependent on the training schedule of the athletes being tested.
2. The validity, reliability, and objectivity of the heart rate monitors and ergometers being used appear accurate, but are property of the university.

3. Environmental and psychological variables (sleep, diet, mood, weather) are not controllable.
4. Statistical calculations used have limitations.
5. The inherent uncontrollable factors that are present in field studies vs. those found in laboratory environments.

Delimitations of the Study

1. The study was confined to college university's men's rowing team.
2. The participants are experienced rowers which lends more validity to the study as the degree of experience is related to the workload consistency.
3. The observation was limited to 2 groups of 10 study participants, performing one 60' rowing session on an ergometer.
4. The observed exercise bout's target split was estimated using a predetermined formula estimating 65-70% effort, using the participants most recent 2000m time trial test, partaken with a team workout no more than three weeks before the observed test.

Basic Assumptions

1. It is assumed that the investigator and data collectors are familiar with make and model of ergometer and display, as well as the heart rate monitors, and are proficient in administering the 60-minute rowing session.
2. It is assumed that the extraneous variables (mentioned above) equally affect all groups evenly.
3. It is assumed that all equipment used was in good condition and provided accurate data.

Definitions

Rowing ergometer: A machine that emulates the motion of rowing on the water.

Valsalva maneuver: Forceful exhalation against a closed glottis, the narrowest part of the larynx through which air passes into the trachea, which stabilizes the abdominal and thoracic cavities and potentially enhances muscle action.

Cardiovascular drift (cardiac drift): The gradual time-dependent downward drift of several cardiovascular responses, most notably stroke volume with a concomitant heart rate increase during extended periods of submaximal exercise.

VO_2Max: maximal oxygen consumption

Endurance training: training for long durations at a submaximal exertion

Heart rate (HR): the number of beats of the heart over a set period of time, usually one minute

Cardiac output (Q): is the amount of blood pumped by the heart over one minute. Cardiac output is dependent on the stroke volume and heart rate.

Stroke volume (SV): The amount of blood pumped from the heart through each beat.

Mean arterial pressure (MAP): The average pressure exerted against the arterial walls during a cardiac cycle

Modified Borg's Rate of Perceived Exertion (RPE) Scale: The Borg's Scale is a measure of effort as perceived by the individual during exercise. The standard Borg's Scale ranges from 1 to 20, but a common modified version is from 1 to 10, where one is very light exertion and ten is extreme exertion (i.e., being unable to continue).

CHAPTER II

REVIEW OF LITERATURE

There are several traits that set competitive rowers apart from other athletes. Many elements of rowers' physiology have been recorded and are regularly used in the application of rower training regimens; however, some physiological elements that impact training remain untouched. One of these elements is how a prolonged session of rowing influences heart rate (HR) and output, and if those elements will drift as observed in other sports. As cardiac drift has not been studied in rowing, several factors may influence if and when it does, such as posture (i.e., the effects of a seated position as opposed to the more erect stances of cycling and running), heart size, and training regimens. Other elements that may play a factor is overall power output compared to other sports, as well as how training is monitored.

The heart pumps blood throughout the body at about 60 beats per minute (bpm) at rest and at a normal blood pressure (BP) of 120 systolic and 80 diastolic. The amount of blood pumped out of the heart at each beat is referred to as stroke volume (SV). The cumulative amount of blood pumped out of the heart per minute is referred to as cardiac output (Q).

$$Q = HR \times SV$$

Cardiovascular drift is the phenomenon in which, during steady-state exercise at moderate intensity, a gradual increase of heart rate occurs despite no overall change in workload (Goodman, McLaughlin, & Liu, 2001). As the increase in heart rate occurs, a decline in stroke volume happens simultaneously, resulting in a constant overall cardiac output (Figure 1). In exercise conditions, the onset of cardiovascular drift happens at roughly fifteen minutes of exercise and continues the gradual increase beyond two hours (Coyle & González-Alonso, 2001).

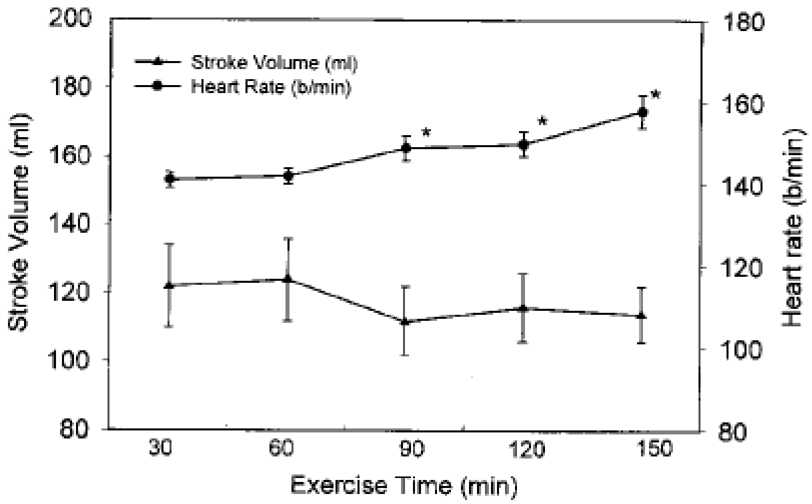

Figure 1. Heart rate and stroke volume during prolonged exercise. Asterisks indicate values significantly different from the 30 minute value ($p < 0.05$). From: Goodman, J. M., McLaughlin, P. R., & Liu, P. P. (2001).

The research regarding the phenomenon of cardiac drift has been observed and documented in many endurance sports. Running and cycling have provided much of the research that is known today about the condition. However, no research has been published observing cardiac drift in the sport of rowing.

Evidence suggests many factors may affect cardiovascular function and heart rate variability. Research indicates that increases in heart rate in runners and cyclists follow a certain pattern during exercise: acclimation, stabilization, and cardiac drift. Dehydration and core temperature are consistent factors that affect the degree of cardiac drift, as shown in Figure 2 (Coyle & Gonzalez-Alonso, 2001).

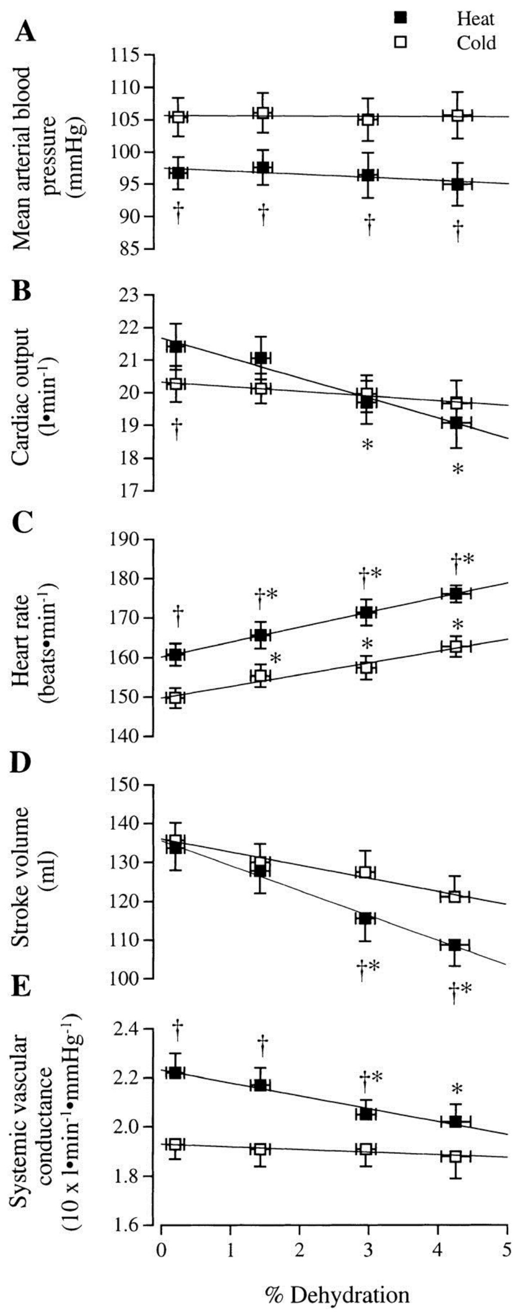

Figure 2. Dehydration during cycling. Mean arterial pressure (*A*), cardiac output (*B*), heart rate (*C*), stroke volume (*D*), and systemic vascular conductance (*E*) responses during the 20- to 30-min period of exercise in cold (8°C) and in heat (35°C) when euhydrated and dehydrated by 1.5, 3.0, and 4.2% of body weight. Values are means ± SE for eight subjects. *Significantly different from euhydrated condition, $p < 0.05$. † Significantly different from exercise in cold, $p < 0.05$ (González-Alonso, Mora-Rodríguez, & Coyle, 2000).

Physiological features that may influence heart rate while rowing could be the seated posture unique to rowing, as well as the athlete's heart size and pulmonary capacity. Another implication of this potential difference in cardiac drift between sports is the need for different training approaches. Training curriculum for one sport may not always translate well to other sports.

Recent studies of cardiac drift attribute the phenomenon to an increase in body temperature and dehydration status. While observing cardiovascular drift in cyclists over a 120 minute session in control conditions, Coyle & González-Alonso (2001) observed that the increase of heart rate was strongly correlated ($r = 0.95$) with increased core body temperature. Exercise is not a prerequisite for increased heart rate—increases in core temperature without exercise have been observed, showing that hyperthemia alone can stimulate an increase in heart rate.

Dehydration seems to have a similar and related effect on heart rate. In the same review, Coyle & González-Alonso (2001), noted that "dehydration by 3-5% of body weight during exercise also reduces blood volume by ~3-5% during the 5- to 120-min period of exercise" (p. 90). This reduction in blood volume inherently results in a decrease in stroke volume. In turn, the body responds with peripheral vasoconstriction which increases heart rate and cardiac drift. As the blood vessels near the surface of the body also constrict, the amount of heat dissipation lessens, partially contributing to the heart's activity. However, the effects of dehydration only account for approximately one half of the reduction in stroke volume. This process was demonstated in an experimental study by Hamilton, Gonzalez-Alonso, Montain, & Coyle (1991), where a non-fluid-replacement (NF) group was paired with a fluid-replacement (FR) group. The results showed that the FR group's cardiovacular variances in stroke volume and heart rate increases were present, but at fifty percent of the NF groups results. As these studies show, consuming water during exercise reduces the overall degree of change in heart rate; it does not fully block the onset of cardiovascular drift.

According to a study that compared heart rates of treadmill running and rowing, heart rate (HR) is higher in running than in rowing, although the power output in rowing is higher (Buckley, Innreiten, Sim, & Estion, 2000). Lower heart rates may demonstrate that during rowing, more control is needed throughout the cardiopulmonary system. Maximal oxygen uptake was significantly higher during rowing which suggests that the body position, the extenuated number of muscles used during rowing, or a combination of both, require a lower heart rate for the same exercise intensity. Despite the higher demand for oxygen circulation during rowing due to the power strain on muscles, the seated position allows for the elevated flow of blood to and from the limbs to be directed through horizontal, not vertical, transport (Yushiga & Higuchi, 2002).

Studies have shown that rowing and cycling have nearly the same oxygen requirements in step transition to moderate and heavy workload—it would seem that similar interaction of heart rate would follow (Roberts, Wilderson, & Jones, 2005). However, the cycling cadence has been shown to cause large variations in the onset of cardiac drift between pedal revolution frequencies of 40 and 80 revolutions per minute (rpm), where the higher rpm created a significant difference in the culmination of cardiac drift (Kounalakis & Geladas, 2012). The slower, more powerful stroke rate in rowing may produce a different pattern of cardiovascular drift.

During regular breathing, the displacement of atmospheric air through the lungs occurs with approximately a 3mm Hg change in air pressure during inhalation and exhalation. However, the lungs and associated muscles allow for much more forceful activity, such as coughing and sneezing. Using these muscles by forcefully closing the glottis at full inhalation can increase the pressure of the lungs and abdominal cavity up to 150mm Hg or higher (McArdle, Katch, & Katch, 2010). At the beginning of each stroke while rowing, athletes perform this action, called the Valsalva maneuver. More specifically, holding of the breath increases pressure through the central body that allows for increased pressure and force through the trunk, but requires a large increase the blood pressure, which the seated position can accommodate (Volianitis & Secher, 2009). Overall, the uniqueness of the rowing position and technique allows for a higher VO_2max and a maximized work load (Yoshiga & Higuchi, 2003).

The referenced Valsalva-like maneuvers also play a part in the hypertrophy of the hearts of rowers. In a meta-analysis, rowers' and cyclists' left ventricular mass was greater (288g, n = 414) compared to that of endurance athletes (249g, n = 413) and those in the control group (174g, n = 813) (Pluim, Zwinderman, Laarse, & Van der Wall, 2000). Heart size can also be attributed to the forced heightened blood pressure required for the repetitive Valsalva maneuver performed during all-out rowing, where the systolic blood pressure has been measured near 200 mmHg, while mean arterial blood pressure showed an increase from 110 to 122 mmHg (Secher, 1993).

Training regimens for competitive rowers usually require 70% or more sport specific exercise (Maestu, Jiirimae, & Jiirimae, 2005). Nearly 75% of the energy needed during a 2000m race will come from aerobic metabolism; the workload of the training regimen must be geared toward increasing aerobic fitness and pushing the lactic threshold—the point in which the buildup of lactic acid in the blood stream causes muscle fatigue—to the greatest possible duration. Training for this workload is possible with several long duration rowing sessions with moderate intensity mixed a with a few shorter duration high intensity pieces. This combination is thought to bring the best physiological adaptations to performance on race day. However, the duration of the longer rows, the influx of cardiac drift, and the need to push beyond their estimated target heart rate have yet to be determined.

Frequency, duration, and intensity are three critical factors in all competitive athletes' training. Determining the right combination over a season or career is a difficult challenge for any coach or personal trainer. Frequency and duration are parameters that can be controlled. The challenging aspect of any session is to optimize intensity in combination with the other two. The question of intensity often lies in how it is measured: by speed, power, energy expenditure, perceived exertion, heart rate, oxygen consumption, or lactate build-up (Jeukendrup & Van Diemen, 1998).

Jeukendrup and Van Diemen (1998) propose the most accurate measure of intensity is "the amount of ATP [adenosine triphosphate] that is hydrolysed and converted into mechanical energy each minute, and may therefore be best defined as the amount of energy expended per minute to perform a certain task (kJ min^{-1})" (p. S92). At the present time, collecting specific data for measuring intensity is very difficult, even in lab settings, and much less reliable during real training sessions or actual sporting events. However, there are more practically measured elements of intensity. Speed and power are measurements of intensity that have become much easier to monitor with the aid of GPS devices and technological devices to measure load and force.

Speed is one of the most easily measured components of energy expenditure as it can be assessed in shorter races as the absolute time it takes to cover a distance, such as Usain Bolt's world record of 9.68s in the 100m sprint. Longer races usually compare the instant speed at a certain interval as measured in kilometers or miles per hour. The elements of measuring speed throughout a race can be a simple guide to understanding how fast a course was completed previously, when to increase or decrease velocity, and how one athlete compares to another or against a previous trial. Improving speed through a bout of exercise that is the same duration as a previous bout shows that improvements are made (Jeukendrup & Van Diemen, 1998).

Power (P) is the measure of work (w) done in a given time (t) ($P = w/t$). The measure of watts (W) is a reflection of power output. As technological advances have led the way into the 21st century of cycling and rowing, many modifications have been implemented into bicycles, ergometers, and even rowing oars, which measure instantaneous wattage output per pedal or stroke. These instruments can also take into consideration the size of the person performing the exercise and give a very good estimate of the overall energy expenditure of the person. The drawback of power output is that it is often highly variable within a certain timeframe and even from one movement to the next, as shown in Figure 3 (Jeukendrup & Van Diemen, 1998).

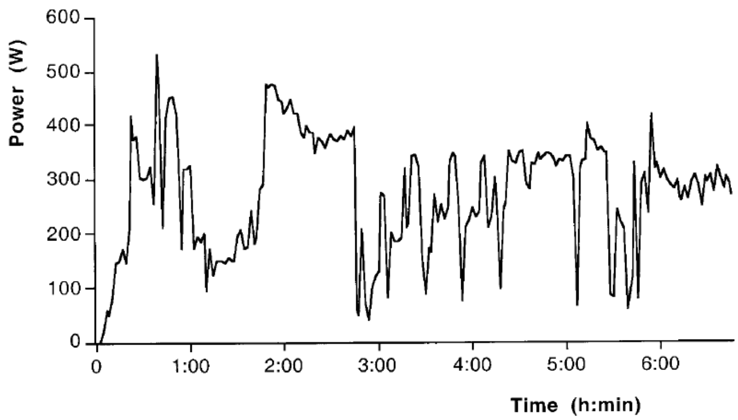

Figure 3. Power output during cycling. Power output from a professional cyclist during the 1996 Tour de France during a mountain stage over six hours. Output was obtained in 60" intervals (Jeukendrup & Van Diemen, 1998).

While both speed and power are easy to measure, they both have several limitations. A measure of speed and power can sometimes be inversely related, such as the observation of the cyclist climbing a mountain. During an uphill climb, more power would be exerted, while the speed of movement would slow; conversely, while moving downhill, power would decrease although the velocity of the bike is likely to increase or at least stay the same. This variance of exertion is also observed while drafting—riding behind another cyclist where the headwind is shielded from the second rider—this practice allows for less effort to maintain the same speed. However, the most significant drawback of using speed and power to develop a training plan is the lack of consideration for the athlete's physiological or psychological stress that may accumulate, as they measure only the data output with no regard for the human condition (Jeukendrup & Van Diemen, 1998).

Methods of monitoring intensity, training, and psychological factors have been used for decades. Recently a surge in studying biochemical blood markers has become a standard for scientists. Leptin and testosterone in the blood stream, as well as other hypothalamic influencers have been measured, but according to the review, *Monitoring of Performance and Training in Rowing*, none of the findings have been consistent (Maestu, Jiirimae, & Jiirimae, 2005). Measuring the blood lactate level of an individual is a good way to indicate the intensity of a single sprint workout, but blood lactate level does not measure the entire physiological toll on the body. Likewise, these tests are usually only available to those at the highest level of competitive rowing and are therefore usually expensive.

One simplistic way of measuring exertion is the Borg's Rate of Perceived Exertion (RPE) Scale (Borg, 1982). Initially being a scale of 1-20, a modified version ranging from 1-10 was validated for use. Table 1 provides a summary of the modified Borg's RPE Scale. In previous studies, there has been an established relationship between RPE and heart rate (Jeukendrup & Van Diemen, 1998).

Table 1

Borg's Rate of Perceived Exertion Scale. From: Borg, G. (1982).

Number	Perceived Exertion
0	None
0.5	Very, very weak (just noticeable)
1	Very weak
2	Weak (light)
3	Moderate
4	Somewhat strong
5	Strong (heavy)
6	
7	Very strong
8	
9	
10	Very, very strong (almost max)

As a result of the limited availability and cost of these tests, many athletes and coaches look for easy and cost-effective ways to set training parameters and to monitor athletes' response to established goals. Testing limitations have led many programs to use heart rate monitors to record athletes' training intensity and work load. While this method does not account for raw power output or skill level, heart rate monitoring has been shown to be a good marker for an individual to assess cardiac exertion for endurance sports such as running and cycling (Jeukendrup & Van Diemen, 1998).

Although there are several unique characteristics to rowing, the trend is that training applications from other sports are being applied without validation in the rowing setting. Comparing patterns of cardiac drift in rowing versus those observed in running and cycling can help to indicate whether different approaches to training and monitoring in this sport are warranted.

CHAPTER III

METHODOLOGY

Due to unique physiological demands of rowing, this observational study had three primary objectives:

1. To measure the heart rate variability of the collegiate athletes during a 60-minute ergometer session;
2. To determine whether cardiovascular drift follows a similar pattern observed in other sports during a 60-minute ergometer session; and
3. To identify variables related to increases of heart rate over time.

Participants

Collegiate male rowers (*n* = 20) from a small Midwestern university volunteered to participate in this study. This study used a convenience, purposeful, non-probability sample for observational research. The purpose for choosing experienced rowers is that the difference in technique and skill varies significantly between novice and veteran rowers (Richter, Hamilton, & Roemer, 2011), with experienced rowers having a high reliability of performance (Schabort, Hawley, Hopkins, & Blum, 1999). Inclusion criteria for the study were age 18 years or older, male sex, active membership in the Oklahoma City University collegiate rowing team, and negative responses to all seven questions of the Physical Activity Readiness Questionnaire (PAR-

Q). If a participant provided a positive response to any question on the PAR-Q, the Principle Investigator verified physician clearance for rowing activity prior to the start of the study.

Protocol

Prior to the study, the men's rowing team performed their initial 2000m test of the season providing maximal exertion scores for each rower. Maximal exertion scores were used to calculate the targets for wattage output during the 60-minute bout. The projected output for each rower was determined at his 65% heart rate reserve (HRR), or the difference between the maximum heart rate and resting heart rate. Under the assumption that the athlete's resting heart rate was under 99 bpm, this study followed the formula and generated calculations of the training zones using the following equation:

$$\text{Target HR} = (\text{HRR} * 65\%) + \text{RHR}$$

The data was collected in two sessions comprised with 10 participants each (*n* = 20). The first session occurred at 3:00 p.m. and the second session at 6:30 p.m., in accordance with the team's practice schedule. After informing the volunteers of the risks and protocols for the study, the study administrator obtained written consent. The Physical Activity Readiness Questionnaire (PAR-Q) was administered to determine physical eligibility (Appendix D). Athletes were then assigned a subject number and asked to complete a self-administered demographic survey. The Principle Investigator then explained the procedures of the test to the participants. Approval for the study was obtained by Institutional Review Boards of Oklahoma State University as well as Oklahoma City University, where the research was conducted.

In this study, water consumption was permitted to minimize participant risk, and changes in hydration status were documented with pre- and post-weighing. Weight change was used to indicate the amount of water lost during exercise. The degree of dehydration was examined in percent of body weight lost. Because temperature also plays a role in the onset of cardiac function, the ambient room temperature was recorded during each session. The Principle Investigator did not have control of this variable.

Fitted with heart rate monitor chest straps, subjects were given a 10 minute period to stretch and warm-up. This period included static stretching as well as light rowing on the ergometer. Heart rates were measured in beats per minute (bpm) before the start of the session. Completing a 60-minute row on the ergometer, participants were instructed to maintain the same workload as measured by wattage output. At each minute interval from beginning to the conclusion of the session, the HR of each athlete was recorded by the Principle Investigator or the research assistant, as displayed on a monitor via Bluetooth capability of the HR chest strap. The RPE was reported by the athletes using the modified Borg's RPE Scale and was recorded at three minute intervals. This measure was discussed with the athletes prior to exercise and has also been previously used in team practices. After the conclusion of the exercise following a three minute rest, a final HR was recorded as well as a post-exercise weight.

Equipment

The *Concept2* ergometer (Concept2 Inc., Morrisville, Vermont) is the standard equipment used in indoor rowing. This study used the Model C with PM4+ monitors (Figure 4). The monitor can display the stroke rate at which the rower is moving, while showing the watts, time per 500m, and average calories per hour calculated at each stroke. During this observation, we set the monitor to count down 60 minutes, show the standard display for the participants, and capture wattage output every three minutes to assess that the standard energy exertion per athlete was within limit.

Figure 4. Image of Concept2 Model D ergometer. From:
http://www.concept2.com/files/images/indoor-rowers/model-d/slides/gray_profile.jpg

Polar Wearlink®+ Transmitter with Bluetooth® (Polar Electro Inc., Hyde Park, New York) heart rate chest straps were used due to the ease of which they can be fitted and displayed on a monitor concurrently with up to 16 athletes being monitored simultaneously (Figure 5). The use of the ergometers and the heart rate monitor systems were provided and allowed by Oklahoma City University and well as the use of their facility.

Figure 5. Image of Polar Wearlink®+ Transmitter with Bluetooth® Heart Rate Monitor. From:
http://www.polar.com/us-en/products/accessories/Polar_WearLink_transmitter
_with_Bluetooth.

Data analysis

Participant demographic data was recorded using a self-administered participant demographic survey (Appendix C). Room temperature was recorded on the study protocol checklist (Appendix E). Participant heart rate, RPE, and wattage were recorded by study personnel throughout the study (Appendix F).

Data was analyzed using IBM SPSS Statistics for Windows, version 20.0, Armonk, NY: IBM Corp. Demographic data, physiological measures, and psychological measures were reviewed using descriptive statistics. Between-group differences were analyzed using an independent-samples t-tests. Bivariate correlations using Pearson's correlation coefficient were used to identify significant associations between variables of interest. Scatterplots and interpolation lines were constructed to examine mean heart rate over time, mean RPE over time, mean heart rate and mean RPE, and mean heart rate and mean RPE by groups. Lastly, a multiple linear regression was performed to examine and predict the RPE in relation to ambient room temperature (degrees F) and participant's weekly aerobic exercise outside of practice (minutes).

CHAPTER IV

RESULTS

The focus of the research was to track the heart rate variability and to observe if cardiovascular drift occurs during a 60-minute ergometer session at moderate intensity. The data was collected in two sessions comprised of 10 participants each (n = 20) consisting of collegiate male rowers from a small collegiate rowing team. Completing a 60-minute row on the ergometer, participants were instructed to maintain the same workload as measured by wattage output. Participant heart rate at 60-second intervals and rate of perceived exertion at three minute intervals were recorded by the Principle Investigator and another member of the research team.

The participants' experience ranged from three to nine years of rowing in a team setting (*M* = 5.60, *SD* = 1.93), with 20% of the participants competing on either the junior or U23 (under 23) national teams. The participants ranged from 18 to 21 years of age (*M* = 20.10, *SD* = 1.17). Participant's height in inches (*M* = 73.39, *SD* = 3.01) and pre-weights in pounds (*M* = 192.32, *SD* = 24.50) were taken wearing appropriate rowing attire. The collective average BMI was 25.1 kg/m^2. Paired samples t-test found significant pre-weight (*M* = 192.32, *SD* = 24.50) and post-weight (*M* = 189.65, *SD* = 24.14) differences ($p < .001$), indicating dehydration. There were no significant differences between groups with the exception of minutes of aerobic exercise training per week outside of team practice, with Group 2 having a higher average compared to Group 1 (Table 2). Additionally, the ambient room temperature differed between groups (67°F Group 1 and 61°F Group 2).

Table 2

Comparison of Characteristics between Participant Groups

	Combined Groups (n = 20)	Group 1 (n = 10)	Group 2 (n = 10)	Significance (α = 0.05)
Age (years)	M = 20.10, SD = 1.17	M = 19.90, SD = 1.10	M = 20.30, SD = 1.25	$t(18) = .759$, $p = .458$
College Schooling (years)	M = 2.40, SD = 1.14	M = 2.40, SD = 1.17	M = 2.40, SD = 1.17	$t(18) = .000$, $p = 1.00$
Experience Rowing (years)	M = 5.60, SD = 1.92	M = 5.55, SD = 2.03	M = 5.65, SD = 1.92	$t(18) = .113$, $p = .911$
Aerobic Exercise (min)	M = 31.00, SD = 35.82	M = 14.00*, SD = 20.66	M = 48.00*, SD = 40.50	$t(18) = 2.365$, $p = .029$
Strength Training (min)	M = 15.75, SD = 30.58	M = 22.5, SD = 40.77	M = 9.00, SD = 14.49	$t(11.238) = .987$, $p = .345$
Body Mass Index (kg/m^2)	M = 25.10, SD = 2.88	M = 25.08, SD = 3.52	M = 25.12, SD = 2.26	$t(18) = .030$, $p = .976$
Height (in)	M = 73.39, SD = 3.01	M = 72.48, SD = 3.19	M = 74.3, SD = 2.67	$t(18) = 1.389$, $p = .182$
Baseline Weight (lbs.)	M = 192.32, SD = 24.5	M = 187.18, SD = 27.25	M = 197.46, SD = 21.59	$t(18) = .935$, $p = .362$
Weight Loss (%) *Baseline wt. – post-test wt./baseline wt.*	M = 1.39, SD = 0.48	M = 1.47, SD = 0.27	M = 1.30, SD = 0.63	$t(18) = .783$, $p = .444$

Independent t-tests between Group 1 and Group 2.
* *Statistically significant difference between groups* ($p < 0.05$)

Descriptive statistics were also reviewed to compare physiological measures across and between groups (Table 3). Independent samples t-tests were conducted. There were no observed differences between groups for average HR, starting HR, peak HR, percent HR change from Time 3 to Time 60, and percent RPE change from Time 3 to Time 60. Significant differences were found between groups for average RPE and peak RPE. Group 1 had a significantly lower mean RPE (M = 2.84, SD = 0.45) compared to Group 2 (M = 3.97, SD = 1.10), p = .011. Peak RPE was also significantly higher for Group 2 (M = 5.60, SD = 1.51) than for Group 1 (M = 4.00, SD = 0.67), p = .009.

Bivariate correlations were reviewed to determine associations between variables (Table 4). There were significant, inverse correlations between ambient room temperature and average RPE (r = -.578, p < .01) and 60-minute RPE (r = -.629, p < .01). A higher ambient room temperature (67°F) was associated with lower average RPE and 60-minute RPE. No significant correlations were identified for room temperature and average heart rate, 60-minute heart rate, and dehydration. Participant 60-minute heart rate was significantly associated with additional minutes of aerobic exercise per week (r = -.529, p < .05) as well as number of years rowing (r = -.471, p < .05). As additional minutes of weekly exercise and number of years' experience rowing increase, 60-minute heart rate decreased.

Table 3

Comparison of Physiological Measures between Participant Groups

	Combined Groups (n = 20)	Group 1 (n = 10)	Group 2 (n = 10)	Significance (α = 0.05)
Average HR (bpm)	M = 160.47, SD = 7.21	M = 162.99, SD = 7.91	M = 157.95, SD = 5.76	$t(18) = 1.629$, $p = .121$
Starting HR (bpm) *Time 0*	M = 79.50, SD = 12.88	M = 83.50, SD = 14.68	M = 75.50, SD = 9.96	$t(18) = 1.426$, $p = .171$
Peak HR (bpm)	M = 170.35, SD = 7.49	M = 173.10, SD = 7.75	M = 167.60, SD = 6.43	$t(18) = 1.727$, $p = .101$
% HR change *(Time 60-Time 3/Time 3)*	M = 120.04%, SD = 39.08%	M = 114.27%, SD = 45.03%	M = 125.81%, SD = 33.55%	$t(18) = .650$, $p = .524$
Average RPE	M = 3.41, SD = 1.00	M = 2.84*, SD = 0.45	M = 3.97*, SD = 1.10	$t(11.931) = 3.002$, $p = .011$
Peak RPE	M = 4.80, SD = 1.40	M = 4.00**, SD = 0.67	M = 5.60**, SD = 1.51	$t(12.399) = 3.073$, $p = .009$
% RPE change *(Time 60-Time 3/Time 3)*	M = 155.00%, SD = 105.01%	M = 235.00%, SD = 100.14%	M = 275.00%, SD = 111.18%	$t(18) = .845$, $p = .409$

*Statistically significant difference between groups (*p* < .05, ***p* < 0.01)

Table 4

Correlations between Select Variables of Interest

	No. Years Rowing	Aerobic Minutes per Week	Temperature	Average HR	60 minute HR	Average RPE	60 minute RPE	Dehydration (% change)
No. Years Rowing (3-9)	--							
Aerobic Minutes per Week (0-120 mins)	.300	--						
Temperature (67°F [Group 1] or 61°F [Group 2])	-.027	**-.487***	--					
Average HR (bpm)	**-.502***	-.432	.358	--				
60 minute HR (bpm)	**-.471***	**-.529***	.399	**.940****	--			
Average RPE (2.15-5.8)	-.216	.409	**-.578****	-.061	-.193	--		
60 minute RPE (3-7)	-.101	.409	**-.629****	-.139	-.218	**.869****	--	
Dehydration (-0.2% - 2.3% weight loss)	-.216	**-.571****	.181	.233	.186	-.003	-.116	--

*$p < .05$, **$p < .01$

Cardiovascular drift occurred during each of the trials after the initial acclimation phase in which the body assesses the exertion needed to maintain the energy expenditure. Figure 6 shows the mean heart rate for the athletes from combined groups over time. No settling phase was observed between the first 5 to 20 minutes of the session as identified in other sports, rather the HR increased at a steady increment following the acclimation phase. A paired-samples *t* test was used to compare the mean HR at 3 minutes (M = 149.16 bpm, SD = 6.67) to the mean HR at 60 minutes (M = 168.37 bpm, SD = 8.43). A significant increase in mean HR was found, $t(18) = 14.10$, $p < .001$. A paired-samples *t* test was used to determine whether a significant difference between exertion (watts) at Time 3 (M = 199.95 watts, SD = 25.63) and Time 60 (M = 199.40 watts, SD = 23.77) existed as a possible explanation for the significant difference in heart rate increase. There was not a significant change in wattage from Time 3 to Time 60, $t(19) = 0.566$, $p = .578$.

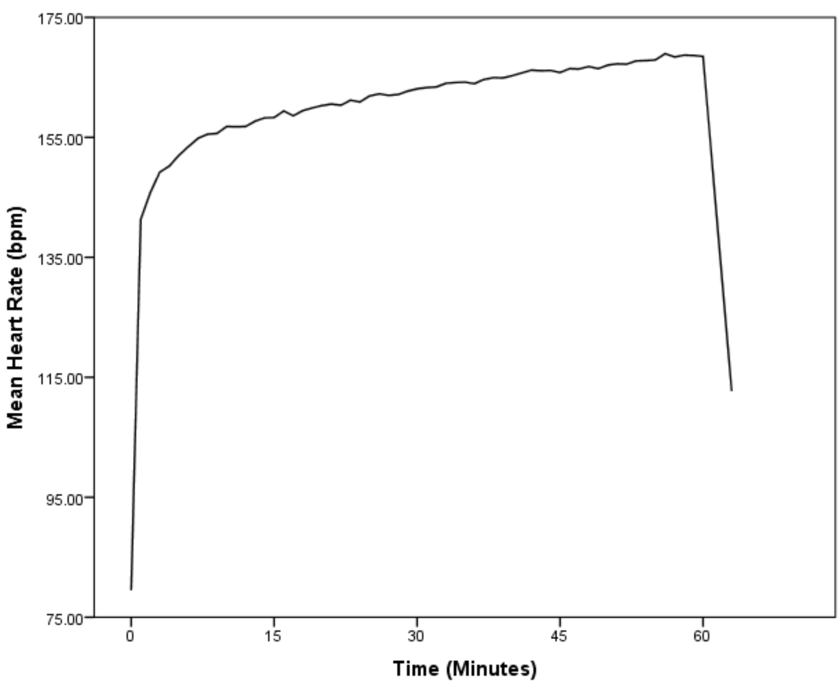

Figure 6. HR progression during 60' of rowing on an ergometer at 65% projected HRR. Observation of heart rate during steady-state rowing on an ergometer shows cardiac drift occurring after approximately three minutes.

The rate of perceived exertion was recorded at each three minute interval. Participants' RPE progressed upwards over time despite maintaining a constant workload (Figure 7). A Pearson correlation demonstrated a strong, positive correlation between time and RPE, $r = .971$, $p < .01$.

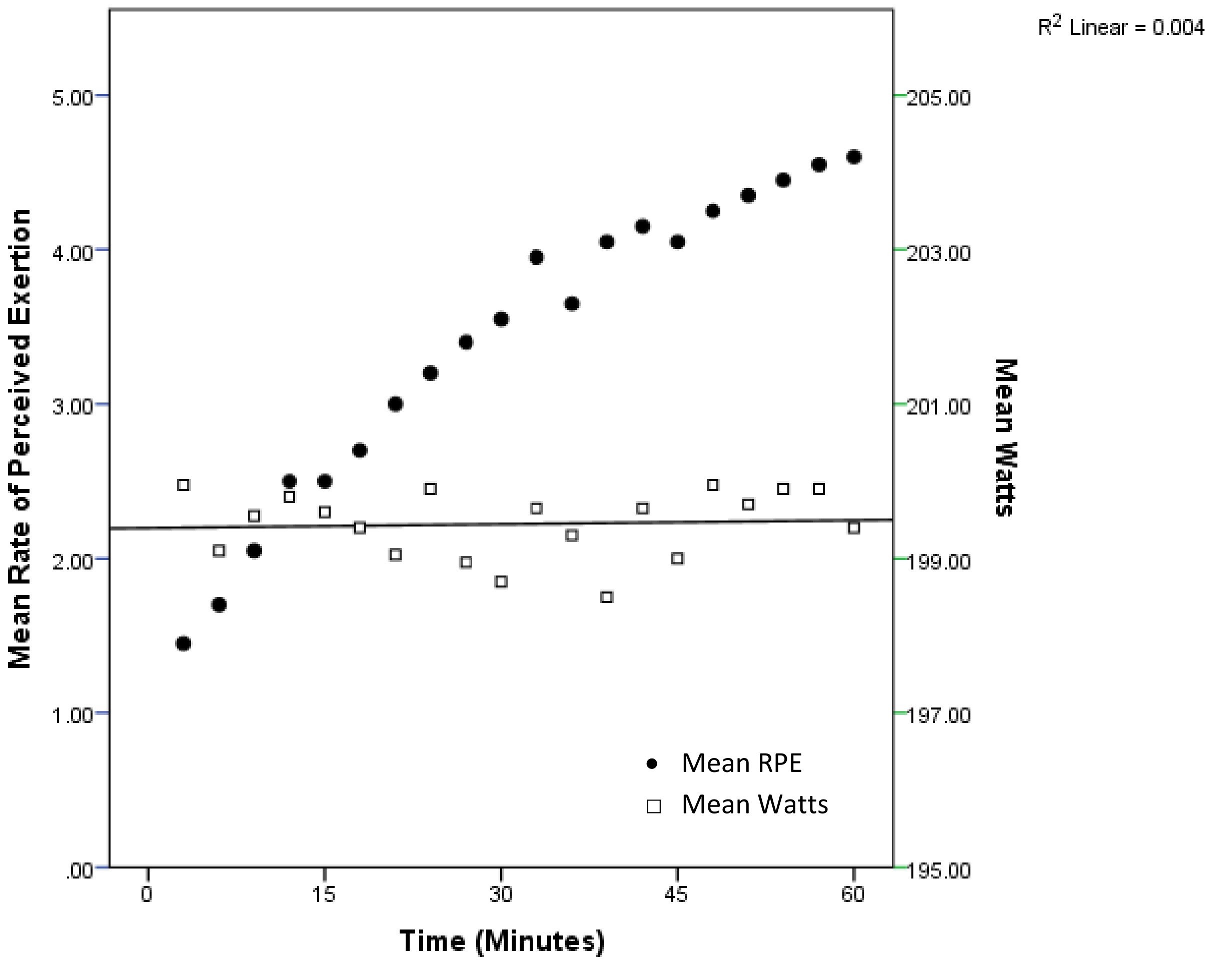

Figure 7. Mean RPE and mean Watts during 60' of rowing on an ergometer at 65% HRR.

Additionally, the association between the mean RPE and the mean HR was reviewed (Figure 8). There was a significant positive linear correlation between RPE and HR (r = .989, p < .01). This supports previous work validating the Borg's Modified RPE Scale as a measure of heart rate.

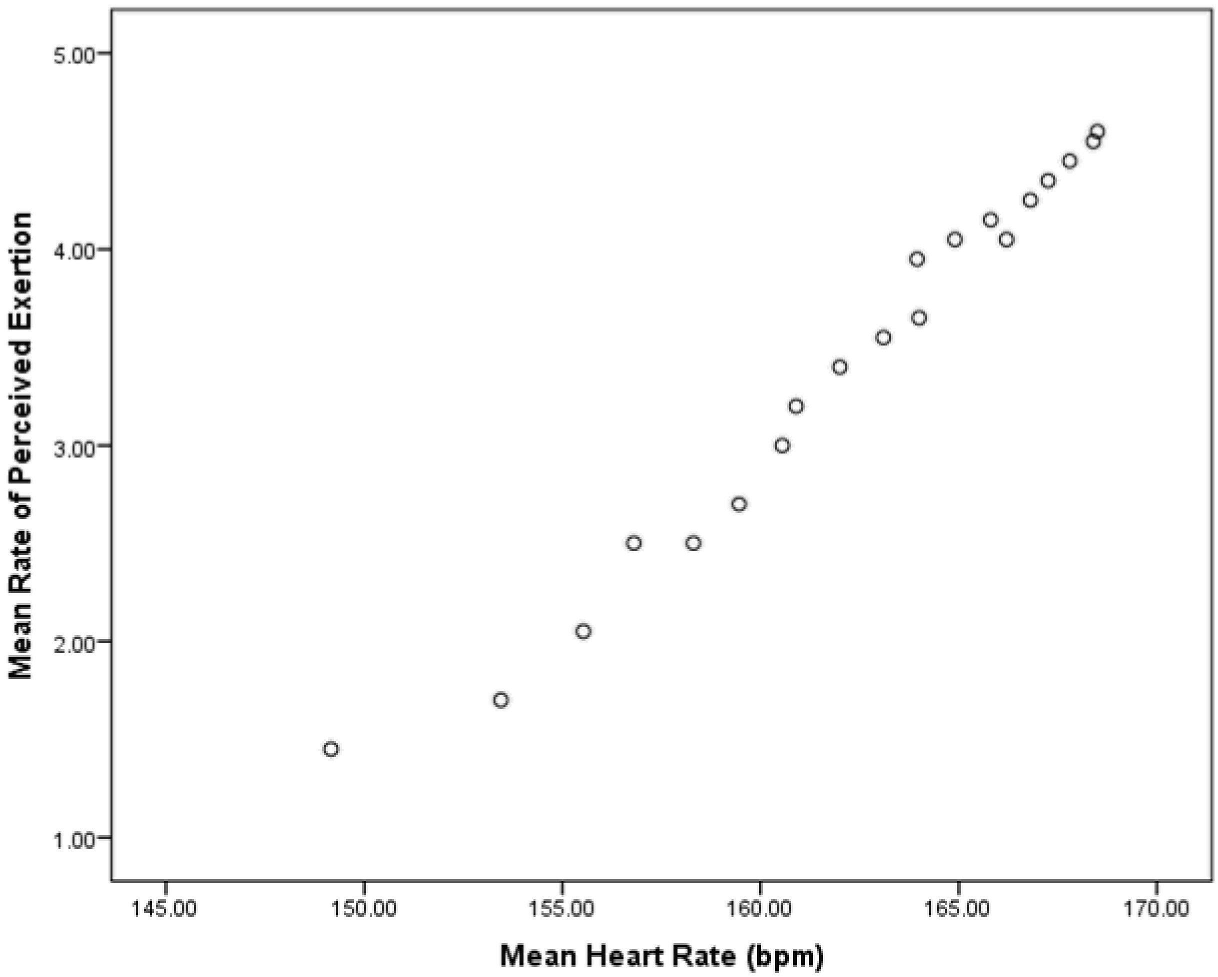

Figure 8. Association between mean RPE and mean HR (bpm).

Due to the significant difference between the mean RPE of the two groups, $t(11.931) = 3.002$, $p = .011$, and a difference between the mean HR of the two groups that bordered significance, $t(18) = 1.629$, $p = .121$, correlations between mean HR and mean RPE were divided between groups (Figure 9). Group 2, rowing in lower ambient room temperature, experienced a higher mean RPE despite having a lower mean heart rate.

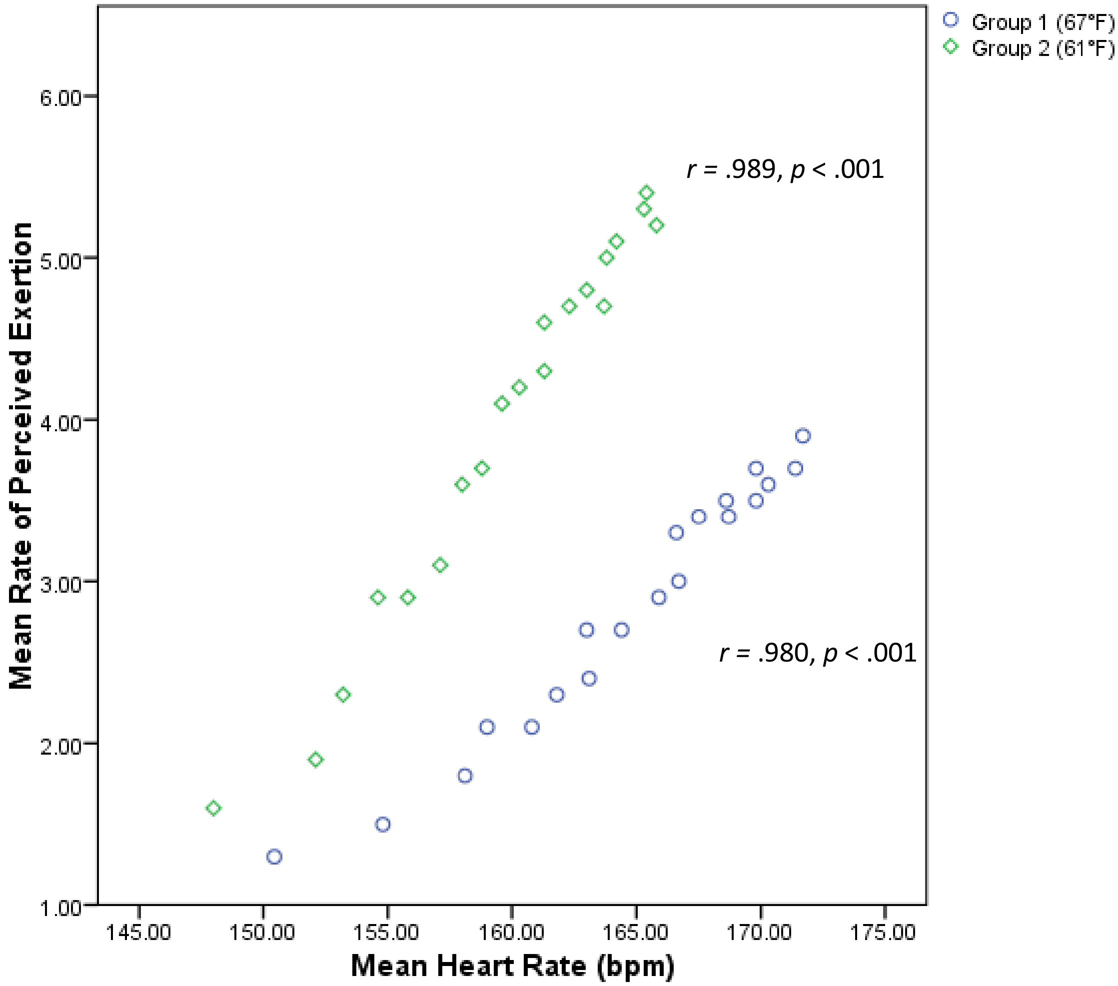

Figure 9. Comparison of correlation between mean RPE and mean HR (bpm) at different ambient temperatures. There is a significant correlation between mean heart rate and mean perceived rate of exertion in both groups.

Since there was a positive correlation between 60-minute RPE and weekly aerobic minutes of exercise performed as well as between temperature and aerobic minutes of exercise, a multiple linear regression was performed to determine the impact of aerobic exercise minutes and ambient temperature on the 60-minute perceived rate of exertion (Table 5). A significant linear regression equation was found, $F(2,17) = 5.883$, $p = .011$, with an R^2 of .409. The equation is as follows:

$$\text{RPE}_{\text{60 minutes}} = 17.840 - 0.209_{\text{degrees F}} + .004_{\text{weekly minutes aerobic activity}}$$

Participants' predicted RPE at 60 minutes is equal to 17.840 - .209 (temperature) + .004 (aerobic activity) when temperature is measured in degrees F and aerobic activity is measured in minutes per week. Participants RPE was -.209 units higher as temperature decreased by one degree. Also with each minute of weekly exercise outside of team practice, RPE increased by .004 units. Temperature appears to have a stronger effect on RPE than additional weekly exercise.

Table 5

Effects of ambient room temperature and minutes of weekly aerobic exercise on RPE.

	B	SE B	β
Model			
Constant	17.840	5.181	
Temperature (67F or 61F)	-.209	.079	-.563*
Weekly minutes of aerobic exercise (min)	.004	.007	.135

Note: R^2 is .409. *$p < .05$

CHAPTER V

DISCUSSION

Several studies have shown that the progression of heart rate variability in other endurance sports such as running and cycling, yet none have looked at this phenomenon in experienced rowers.

The aims of this study were:

1. To measure the heart rate variability of the collegiate athletes during a 60-minute ergometer session;
2. To determine whether cardiovascular drift follows a similar pattern observed in other sports during a 60-minute ergometer session; and
3. To identify variables related to increases of heart rate over time.

Study Aims 1 and 2

The results of the current study indicate cardiac drift occurs during a prolonged session of rowing without a noticeable stabilization phase. As the graphs in the results section indicate, there is a continual gradual shift upwards in heart rate over the duration of exercise exhibiting the attributes of cardiac drift. Studies of heart rate variability during running and cycling indicate a significant stabilization period occurring from 5 to15 minutes from the start time before a drift in heart rate occurs. The implication of the study shows that under steady-state rowing conditions, the onset of cardiovascular drift may not be as delayed as in other sports such as running and cycling. The lack of a stabilization period of heart rate during rowing may be caused by several mechanisms, as well as the physiological differences and ergonomic position of the body between sports.

This study showed no settling phase with the slowing in HR progression at the three minute mark but progressing upwards at a steady rate through the 56’ mark. Factors that may be involved here are: 1) the lower cadence of the repetitive motion of rowing versus that of running and cycling; 2) the motion of rowing involves all the major muscle group working in synch forcing the transition through the energy cycles more quickly than in running or cycling; 3) the increased size of the rowers’ left ventricle, which may be better equipped to maintain a steady workload, increasing the HR earlier but with a lower consistent incline; and 4) the larger VO_2max that is generally attributed to rowers (Yoshiga & Higuchi, 2003).

The onset of cardiovascular drift established in this study occurs earlier than that observed in other sports. For example, the stabilization period during cycling is reached after approximately 10 minutes and continues until 20’ have passed (Figure 10). At this time, HR accelerates much more quickly through the end of the session (Fritzche, Switzer, Hodgkinson, & Coyle, 1999). Mean HR in rowers did not accelerate quickly, but rather a gradual rise in heart rate began earlier and continued at a steady upward rate, accounting for an average increase of 120.04% from Time 3 to Time 60 (*SD* = 39.08%).

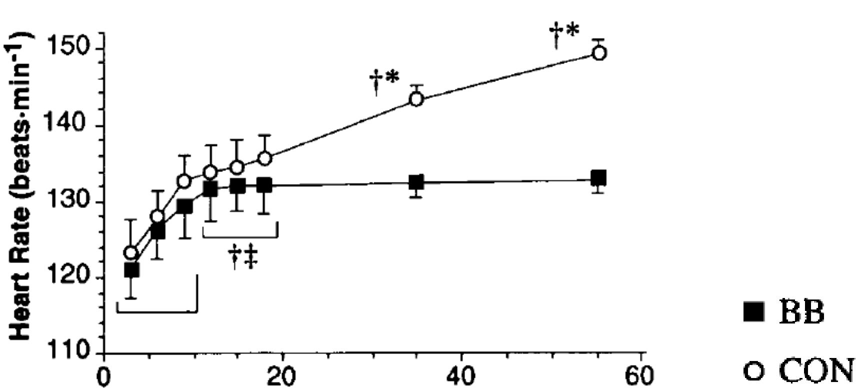

Figure 10. Heart rate variability during cycling. HR during 60’ of cycling with control group (CON) vs. test group (BB) given a beta-blocker to stabilize HR (Fritzche, Switzer, Hodgkinson, & Coyle, 1999).

Study Aim 3

Several variables may affect the cardiovascular drift observed in rowers. One contributing factor to cardiovascular drift in this study may be the dehydration status of the rowers. Increased dehydration increases HR and can exacerbate cardiovascular drift (González-Alonso, Mora-Rodríguez, & Coyle, 2000). The participants of the study had a mean weight loss of 2.67 pounds, an average of 1.39% of bodyweight (*SD* = 0.48%). Dehydration, as previously discussed, can have a significant impact on cardiac drift where the percentage of body weight lost results in a decrease in the same percentage of blood volume as suggested by the data. Figure 11 demonstrates how the major factors regulate HR during prolonged exercise:

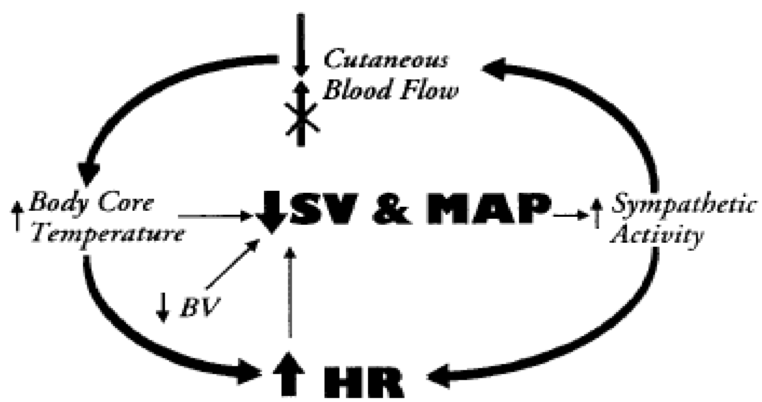

Figure 11. Factors mitigating cardiovascular drift during exercise. The mechanisms that account for cardiac drift are increases in core body temperature and sympathetic activity, in combination with reductions in blood volume (dehydration), a decrease in stroke volume, and mean arterial pressure, culminating in an increased HR (Coyle & Gonzalez-Alonso, 2001).

One uncontrollable variable between the two groups was the ambient room temperature of the exercise facility. Several previous studies show that higher ambient temperature intensifies the phenomenon of cardiac drift (Lambert, Mbambo, & St Claire Gibson, 1998). During the first group, the temperature was measured at a steady 67°F (19.44°C) while the second group completed the session at 61°F (16.11°C). While heart rate rose at a similar steady pace between groups (Figure 12), the second group had lower average heart rates across time. The only observed differences between groups were additional minutes of weekly aerobic exercise and ambient room temperature. The American College of Sports Medicine (ACSM) guidelines specify appropriate exercise room temperatures are 68°F - 72°F (20°C - 22°C) (American College of Sports Medicine, 2014).

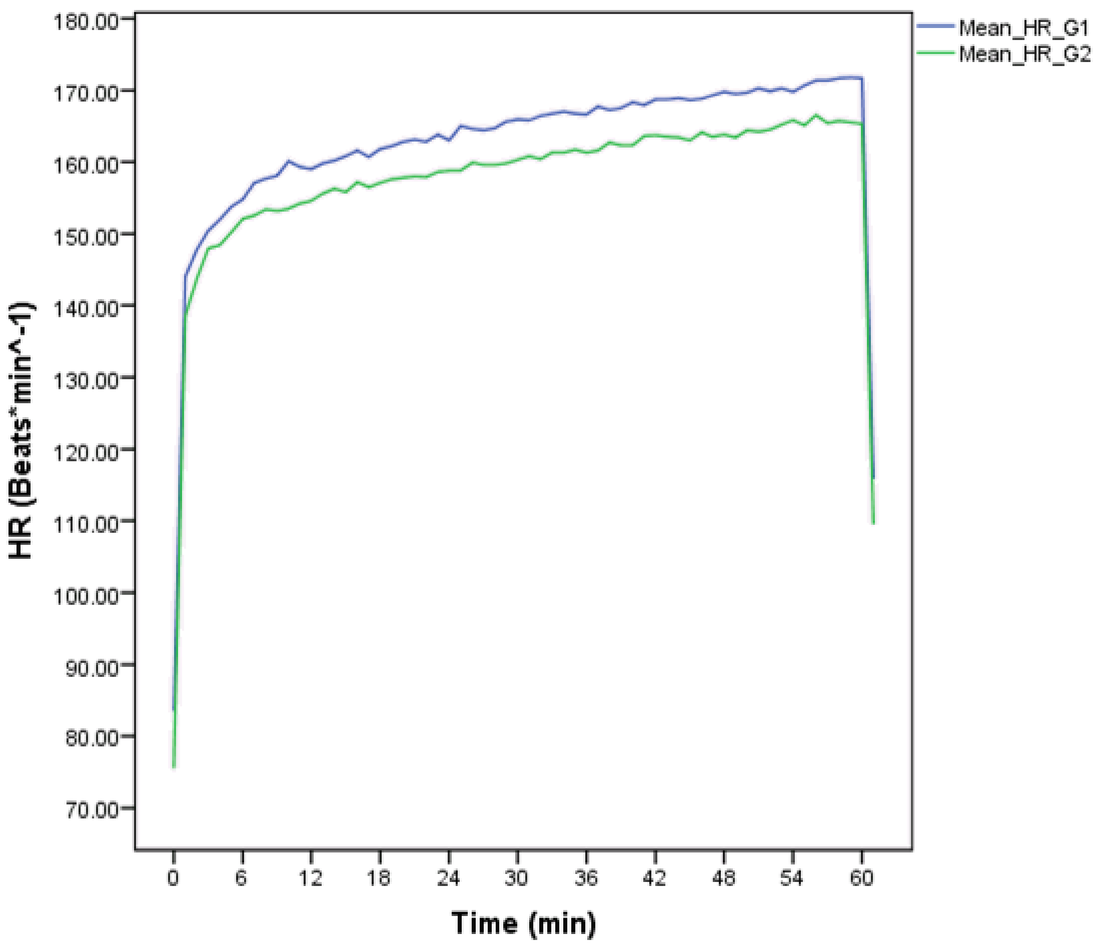

Figure 12. HR variability between groups of rowers at different ambient temperatures.

The maximum mean HR occurred at the Time 59 for Group 1 (*M* = 171.8, *SD* = 7.68 bpm) and at Time 56 for Group 2 (*M* = 166.5, *SD* = 6.14 bpm). The average number of heart beats in this total session for Group 1 was 10,055 versus 9,738 in Group 2. The observed average difference of 317 beats may warrant additional research on the effects of temperature on overtraining among rowers.

In addition to time of max heart rate, the data also found a significant inverse relationship between 60-minute RPE and room temperature. Group 2 was conducted in field conditions below ACSM recommendations, but reported a higher average RPE than Group 1, which contradicts previous literature (Maw, Boutcher, & Taylor, 1993). The lower temperature of Group 2 would explain their lower mean HR. Therefore, the impact of temperature on heart rate and RPE should be also considered in further research.

CHAPTER VI

CONCLUSION

In summary, the phenomenon of cardiovascular drift was demonstrated in this study of rowing on an ergometer. The climb of HR after the first three minutes was almost linear with a lack of settling phase as seen in cycling. The similarity of the increase in HR between the two groups observed indicates the test could be replicated and the results are applicable to further research within the sport of rowing.

This study's findings are important in application because it may change the way rowing coaches implement similar training methods to cycling and running. Because of the lack of settling phase during the first 15 minutes of exercise, monitoring heart rate during rowing may need more research to determine optimal training zones. Training methods and optimal zones may need to be altered and re-evaluated throughout the rowing season when athletes change from rowing long distances in the fall to shorter sprints in the spring and summer.

In conclusion, the phenomenon of cardiovascular drift occurs during long duration steady-state rowing on an ergometer. Cardiovascular drift happened without a stabilization period, unlike cycling, after a brief acclimation phase and continued through the end of the trial. The difference in ambient temperature of Groups 1 and 2 did not appear to appear to affect the onset nor the progression of cardiovascular drift between groups, but temperature was positively associated with heart rate while inversely associated with perceived rate of exertion.

Limitations

Some limitations were experienced during this research. First, the location and timing of the study was dependent upon coordination with the coach, set in accordance to the athlete's school schedule, and built into the team's training regimen. The study was completed within the team's training facility and relied on the accuracy and reliability of their equipment. Use of the team's facility is open to other groups of rowers which could generate distraction, impact a participant's mood, or open the door to other confounding variables that may affect the validity of the study. The equipment was visually inspected by the Principle Investigator and appeared to be of sound condition; however, equipment outside of a lab environment may provide invalid outputs due to wear, lack of upkeep, and age. Secondly, this study did not incorporate externally controlled variables such as food intake or the use of ergogenic aids, and did not administer any psychological testing to measure mood or attitude in general or toward the testing. The measures on record were recorded by the Principle Investigator and other members of the research team, leaving room for human error. Lastly, the study was done in a field setting rather than in a laboratory, resulting in some uncontrollable factors that may have not been encountered otherwise.

Delimitations

Cooperation with a collegiate team ensured the research team was working with experienced rowers in which test reliability has been demonstrated. Two groups of ten participants strengthened the power of the study design.

Future Research

Future studies could examine heart rate variability in the sport of rowing with the variable of temperature to test whether indoor training on an ergometer at a lower ambient temperature affects training parameters or maximal performance. Other research may include interval and fartlek training techniques at higher energy expenditure and %HRR to determine heart rate variability at greater speeds.

Another area of interest may be to replicate this research with on-the-water rowing. A major emphasis of rowing on the ergometer is to translate indoor training regimens to boat speed. With advancements in technology, it may be possible wirelessly capture heart rate over a period of time and use an oar equipped with the ability to measure force and acceleration to ensure a consistent workload.

REFERENCES

American College of Sports Medicine. (2014). Cardiorespiratory and Health-Related Physical Fitness Assessments. In M. Paternostro Bayles, ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription (7th ed., p. 339). Baltimore, MD: Lippincott Williams & Wilkins.

Buckley, J., Innreiten, B., Sim, J., & Estion, R. (2000). Treadmill and rowing ergometer heart rate response at a pre-set Rating of Perceived Exertion. *Physiotherapy, 86*(11), 589.

Concept 2. (n.d.). *Model D*. Retrieved April 12, 2014, from Concept 2: http://www.concept2.com/indoor-rowers/model-d

Coyle, E. F., & Gonzalez-Alonso, J. (2001). Cardiovascular drift during prolonged exercise: New perspectives. *Sports Science Review, 29*(2), 88-92.

Fagard, R. H. (1997). Impact of different sports and training on cardiac structure and function. *Cardiology Clinics, 15*(3), 397-412.

Fritzche, R. G., Switzer, T. W., Hodgkinson, B. J., & Coyle, E. F. (1999). Stroke volume decline during prolonged exercise is influenced by the increase in heart rate. *Journal of Applied Physiology, 86*(3), 799-805.

González-Alonso, J., Mora-Rodríguez, R., & Coyle, E. F. (2000). Stroke volume during exercise: Interaction of environment and hydration. *American Journal of Physiology Heart and Circulatory Physiology, 278*, 321-330.

Goodman, J. M., McLaughlin, P. R., & Liu, P. P. (2001). Left ventricular performance during prolonged exercise: Absence of systolic dysfunction. *Clinical Science, 100*, 529-537.

Hagerman, F. (1984). Applied physiology of rowing. *Sports Medicine, 252*(4), 303-326.

IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

Jeukendrup, A., & Van Diemen, A. (1998). Heart rate monitoring during training and competition in cyclists. *Journal of Sports Sciences, 16:sup1*, 91-99.

Jim Dietz Quotes. (2014). Retrieved March 9th, 2014, from Http://www.Quotes.net.

Kounalakis, S. N., & Geladas, N. D. (2012). Cardiovascular drift and cerebral and muscle tissue oxygenation during prolonged cycling at different pedalling cadences. *Appl. Physiol. Nutr. Metab., 37*, 407-417.

Lambert, M. I., Mbambo, Z. H., & St Claire Gibson, A. (1998). Heart Rate during training and competition for long distance running. *Journal of Sports Sciences, 16:sup1*, 85-90.

Maestu, J., Jiirimae, J., & Jiirimae, T. (2005). Monitoring of performance and training in rowing. *Sports Medicine, 35*(7), 597-617.

Maw, G. J., Boutcher, S. H., & Taylor, N. A. (1993). Rating of perceived exertion and affect in hot and cold environments. European Journal of Applied Physiology and Occupational Physiology, 67(2), 174-179.

McArdle, W. D., Katch, F. I., & Katch, V. L. (2010). *Exercise Physiology: Nutrition, Energy, and Human Performance.* Philadelphia, PA: Lippincott Williams & Wilkins.

Montain, S. J., & Coyle, E. F. (1992). The influence of graded dehydration on hyperthermia and cardiovascular drift during exercise. *Journal of Applied Physiology, 73*, 903-910.

Pluim, B., Zwinderman, A., Laarse, A., & Van der Wall, E. (2000). The athlete's heart: A meta-analysis of cardiac structure and function. *Circulation, 101*, 336-344.

Polar. (n.d.). *The Polar WearLink®+ Transmitter with Bluetooth®* . Retrieved April 12, 2014, from http://www.polar.com/us-en/products/accessories/Polar_WearLink_transmitter_with_Bluetooth.

Richter, C., Hamilton, S., & Roemer, K. (2011). The impact of body mass and skill level on rowing kinematics. *Biomechanics in Sports, 29*(Suppl. 2), 613-616.

Roberts, C. L., Wilderson, D. P., & Jones, A. M. (2005). Pulmonary O_2 uptake on-kinetics in rowing. *Respiratory Physiology & Neurobiology, 146*, 247–258.

Schabort, E. J., Hawley, J. A., Hopkins, W. G., & Blum, H. (1999). High reliability of performance of well-trained rowers on a rowing ergometer. *Journal of Sports Sciences, 17*(8), 627-632.

Secher, N. H. (1993). Physiological and biomechanical aspects of rowing. *Sports Medicine, 15*(1), 24-42.

Volianitis, S., & Secher, N. (2009). Rowing, the ultimate challenge to the human body–implications for physiological variables. *Clinical Physiology and Functional Imaging, 29*(4), 241-244.

Yoshiga, C. C., & Higuchi, M. (2003). Oxygen uptake and ventilation during rowing and running in females and males. *Scandinavian Journal of Medicine and Science in Sports, 13*, 359-363.

Yoshiga, C., & Higuchi, M. (2003). Rowing performance of female and male rowers. *Scandinavian Journal of Medical Science and Sports, 5*, 317-321.

Yoshiga, C., & Higuchi, M. (2002). Heart rate is lower during ergometer rowing than during treadmill running. *European Journal of Applied Physiology, 87*, 97-100.

APPENDICES

Appendix A

Oklahoma State University Institutional Review Board

Date:	Monday, November 11, 2013	**Protocol Expires:**	10/16/2014
IRB Application No:	ED13153		
Proposal Title:	Cardiac Drift in Response to Rowing on an Ergometer		

Reviewed and Processed as: Expedited

Modification

Status Recommended by Reviewer(s): **Approved**

Principal Investigator(s):

Micah Hartwell
1548 E 34th St
Tulsa, OK 74104

Douglas Smith
180 CRC
Stillwater, OK 74078

The requested modification to this IRB protocol has been approved. Please note that the original expiration date of the protocol has not changed. The IRB office MUST be notified in writing when a project is complete. All approved projects are subject to monitoring by the IRB.

- The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

The reviewer(s) had these comments:

Modification to change the project title and add Dr. Jason Miller from Oklahoma City University to study.

Signature :

Shelia K

Shelia Kennison, Chair, Institutional Review Board

Monday, November 11, 2013
Date

Appendix B

ADULT CONSENT FORM
OKLAHOMA STATE UNIVERSITY

PROJECT Cardiac Drift in Response to Rowing on an Ergometer

INVESTIGATORS:

Micah Hartwell	Oklahoma State University
Doug Smith PhD	Oklahoma State University
Jason Miller PhD	Oklahoma City University

PURPOSE:
The purpose of the research study is to observe the phenomenon of cardiac drift in the sport of rowing as demonstrated on the Concept2 rowing machine.

PROCEDURES
You will complete a 60' minute workout on a Concept2 rowing machine at a submaximal level determined by your most recent 2000 meter test time while wearing a heart rate monitor and indicating the rate of perceived exertion at certain intervals throughout the piece.

RISKS OF PARTICIPATION:
There are no risks associated with this project which are expected to be greater than those ordinarily encountered in regular physical fitness activities engaged in by rowers.

BENEFITS OF PARTICIPATION:
You may gain knowledge that will be applicable in future workouts and throughout your rowing career. Results of the study will be shared with interested participants.

CONFIDENTIALITY:
The records of this study will be kept private. Subjects will be initially assigned a number/code which will correspond to any information provided to ensure that subject's information within data sets will not be identifiable. Any written results will discuss group findings and will not include information that will identify you. Hard copy records will be stored securely in a locked case, kept with the PI until all data is entered electronically. Afterwards, hard copies will remain with the Primary Advisor until the conclusion and then destroyed. Electronic information will be stored on Oklahoma State University's secure password protected server, and files will individual be password protected when possible. Only researchers and individuals responsible for research oversight will have access to the records. It is possible that the consent process and data collection will be observed by research oversight staff responsible for safeguarding the rights and wellbeing of people who participate in research. These protocols will be included on the participant agreement and will be communicated before participation in study. In measure to reduce bias, a list of athletes and codes will not be kept.

Non-individually-identifiable study results will be shared with the participants and the coach.

COMPENSATION:
There will be no monetary compensation for participating in this study.

CONTACTS:

You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study: Micah Hartwell, Graduate Student, Dept. of Education, Oklahoma State University, Stillwater, OK 74078, 918 -809-1004 or micah.hartwell@okstate.edu or Dr. Doug Smith, Assistant Professor, Dept. of Education, Oklahoma State University, Stillwater, OK 74078, 405-744-5500. If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

PARTICIPANT RIGHTS: Participation in this study is voluntary and you may discontinue exercise at any point in the study without any reprisal or penalty. Participation may be denied in the event of a negative finding on the PAR-Q health survey.

I understand that my participation is voluntary, that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time, without penalty.

CONSENT DOCUMENTATION:

I have been fully informed about the procedures listed here. I am aware of what I will be asked to do and of the benefits of my participation. I also understand the following statements:

I affirm that I am 18 years of age or older.

Preface the signature lines with the following statement (expand if appropriate):

I have read and fully understand this consent form. I sign it freely and voluntarily. A copy of this form will be given to me. I hereby give permission for my participation in this study.

______________________________ ____________________

Signature of Participant Date

I certify that I have personally explained this document before requesting that the participant sign it.

______________________________ ____________________

Signature of Researcher Date

Appendix C

Subject #:__________________

Cardiac Drift and Rowing on the Concept 2 Ergometer
Participant Demographic Survey

1. What is your age?___________

2. Classification:
   - ☐ Freshman
   - ☐ Sophomore
   - ☐ Junior
   - ☐ Senior
   - ☐ Graduate Student

3. How long have you been rowing?

   __________ years

4. Have you competed on any National Team?
   - ☐ Yes
   - ☐ No

   - 4a. If Yes, what level?
     - ☐ Junior National Team
     - ☐ U23 National Team
     - ☐ Senior National Team

5. Excluding normal rowing practices, how many minutes per week do you spend doing aerobic exercise?

   ___________ minutes

6. Excluding normal rowing practices, how many minutes per week do you spend doing resistance exercise or strength training?

   ___________ minutes

To be collected by researcher:

Height:________ Pre-weight_________ Post-weight_________

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

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

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

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

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

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

If you answered

YES to one or more questions

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

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

NO to all questions

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

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

DELAY BECOMING MUCH MORE ACTIVE:

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

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

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

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

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

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

NAME ____

SIGNATURE ________________________________ DATE ________________________

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

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

continued on other side...

Appendix E

Checklist:

Room Temp before: ______
Athletes Participants waiver/consent_____
Athletes Questionnaire____
Athletes Par-Q_____
Athlete weights before_____
Workout Playlist_____

Purpose of the study is to measure changes in heart rate during the workout and compare it to other sports- running and cycling. Individual data will be kept confidential, but the group results will be shared with the team.

Instructions-
60’ piece at 24spm at your target split
The goal is to stay as close as you can to the split through the entire piece- not as fast as you can go.
You will be asked to give an RPE on the Borgs scale. 1-20. 7 is light workout, 17 is intense, 20 is unbearable-unable to continue.
After you are done rowing please stay where you are for 3 minutes, we will get 1 more reading at that time. We will get your post exercise-weight.

The monitors will be set such as this:
>Select workout
>New workout
>Single time
>1:00:00
>Set split length to 3:00min
>Set pace-boat given pace

Room Temp After:________
Athletes weight After_______

Date:____________

Time:____________

PI:______________

GSA:_____________

Appendix F

Heart Rate/RPE/Wattage Record

	Athlete: a__	Pre-wt:	
	Target Split:		
	HR	RPE	Watts
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			

	Athlete: a__	Post-wt:	
	Target Split:		
	HR	RPE	Watts
31			
32			
33			
34			
35			
36			
37			
38			
39			
40			
41			
42			
43			
44			
45			
46			
47			
48			
49			
50			
51			
52			
53			
54			
55			
56			
57			
58			
59			
60			
63			

VITA

Micah Hartwell

Candidate for the Degree of

Master of Science

Thesis: CARDIAC DRIFT IN RESPONSE TO ROWING ON AN ERGOMETER

Major Field: Health and Human Performance, Applied Exercise Science

Biographical:

Education:

Completed the requirements for the Master of Science in Health and Human Performance at Oklahoma State University, Stillwater, Oklahoma in May 2014.

Completed the requirement for the Graduate Certificate in Public Health at the University of Florida, Gainesville, Florida in 2008.

Completed the requirements for the Bachelor of Arts in Psychology at the University of Oklahoma, Norman, Oklahoma in 2004.

Experience:

Tulsa CARES: Nutrition Services Director 2007-Present

Tulsa Rowing Club Juniors: Men's Varsity Rowing Coach 2010-Present

Professional Memberships:

US Rowing

Association of Nutrition and Food Service Professionals