Influence of athlete heart rate, rate of perceived exertion, and anxiety in rowing practice and competition

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Influence of Athlete Heart Rate, Rate of Perceived Exertion, and Anxiety in Rowing Practice and Competition

by

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Thesis
Submitted to the School of Health Promotion and Human Performance
Eastern Michigan University
In partial fulfillment of the requirements

for the degree of
MASTER OF SCIENCE
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Abstract

The purpose of this study was to investigate whether there is a significant correlation between heart rate (HR) and rate of perceived exertion (RPE) in rowing, how athlete perception of pre-race anxiety relates to HR and RPE, and how these variables change between practice and competition. Four subjects were tested over the course of their rowing season for somatic and cognitive anxiety, self-confidence, HR, and RPE in three different 2000 meter racing conditions: indoor ergometer, on-water racing, and on-water practice. There was no correlation between HR and RPE, and only maximum HR showed a difference between trial types. Studying more subjects and ensuring the same number of each type of trial would enhance the results of this study.
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Chapter I: Introduction

Rowing has existed from the time of the ancient Egyptians approximately 5000 years ago, when it was an important means of locomotion (Redgrave, 1992). The first recorded rowing competition was in England in 1716, and the sport has continued to evolve since then (Redgrave, 1992). Even for the ancients, moving the boat as fast as possible has always been the goal of rowing. Equipment design, training techniques to enhance physiology and psychology, and understanding of the mechanics of rowing have all evolved over the centuries, yet coaches and athletes still strive to find more speed. Rowers spend a great deal of time in practice, preparing for just a few 2000 meter races over the course of the competitive season to achieve that top speed. The ultimate goal of modern rowing is to win races, and to accomplish this crews must be prepared mentally and physically to perform their best on race day.

During training, rowers practice 2000-meter races both on the water and on land using rowing ergometers. Rowers are typically encouraged by their coaches to treat these practice races as actual races, in order to mentally and physically prepare for the demands of competition. These repeated practice bouts help the athlete become used to the physical stresses of the 2000-meter distance and intensity, while also experiencing the mental stresses. Ideally, practicing these stresses regularly in a variety of conditions allows the athletes to understand how they will respond to the conditions of race day and learn to perform well even in difficult situations. However, there is a lack of research in rowing showing whether athletes are truly experiencing similar physiological and psychological reactions during practice racing and actual racing.

One way to measure physiological response is to monitor heart rate (HR) and ratings of perceived exertion (RPE). There are many other measures of physiology that can be measured, including, but not limited to blood lactate and VO\textsubscript{2} levels, but these can be impractical to monitor
during practice and competition. HR has been shown to be able to predict effort in studies done on other endurance sports: Lambert, Mbambo, and St Clair Gibson (1998) show that running speed and heart rate have a correlation of \( r = 0.99 \), and Jeukendrup and Van Diemen (1998) discuss how athletes use heart rate to monitor training intensity. It has also been used in concert with oxygen uptake when studying running (Billat, Wesfreid, Kapfer, Koralsztein, & Meyer, 2006). Similarly, RPE has been correlated to blood lactate levels in multiple studies (Amtmann, Amtmann, & Spath, 2008; Mendez-Villanueva, Fernandez-Fernandez, Bishop, & Fernandez-Garcia, 2010; Serrano, Salvador, Gonzalez-Bono, Sanchis, & Suay, 2001). HR and RPE have been shown to be useful when used in concert to predict \( \text{VO}_2\text{max} \) and peak \( \text{VO}_2 \) (Lambrick, Faulkner, Rowlands, & Eston, 2009; Eston & Williams, 1988). In all of these cases, HR and RPE as field measures of physiology correlated to lab-based physiological measures.

Athletes must be physically trained for competition, but the mental state of athletes is also important. An athlete may be in peak physical condition, yet be anxious, or lack confidence in their abilities, which can in turn impede performance (Cresswell & Hodge, 2004, Hanin, 1986, Yoshie, Shigemasu, Kudo, & Ohtsuki, 2009). One way to investigate the mental preparedness of athletes is to look at pre-competition anxiety. The Revised Competitive State Anxiety Inventory - 2 (CSAI-2R, Cox, Martens, & Russell, 2003), is used to measure cognitive and somatic anxiety, and self-confidence in athletes. Studies such as that by Edwards and Hardy (1996) on netball teams have used the original CSAI-2 to study how these different components of anxiety manifest in athletes and how they interact to affect performance. In an analysis of multiple studies using the CSAI-2, Craft, Magyar, Becker, and Feltz (2003) showed that of the three measures of state anxiety, self-confidence is the most correlated with performance, especially in team sports. However, the CSAI-2 has some limitations that caused equivocal results across
multiple studies. A revised version was developed by Cox et al. (2003) to resolve these issues by changing the factor structure of the survey and addressing the psychometric weaknesses of the original CSAI-2. This revised version gives a clearer picture of competitive state anxiety and can be used to understand a portion of the psychology of athletes preparing for competition.

There is research looking at the psychological differences in athletes when practicing vs. competing (Frey, Laguna & Ravizza, 2003; Taylor, Gould, & Rolo, 2008), but limited research looking at both the physiological and psychological differences. Mateo, Blasco-Lafarga, Martinez-Navarro, Guzman, and Zabala (2012) studied the link between HR variability and pre-competition anxiety in both practice and competition, but did not include actual and/or perceived physiological effort during competition. It would be useful for coaches to understand how their athletes are approaching practice and competition mentally, as well as how they are performing physically. That insight could give the coach another tool to understand the training effect of their program, and help them make further improvement in the performance of their athletes.

**Purpose of the Study**

Rowers and coaches work on physiological and psychological preparedness during practice in order to achieve peak performance during competition. The purpose of this study is to investigate whether there is a significant correlation between heart rate (HR) and rate of perceived exertion (RPE) in rowing, how athlete perception of pre-race anxiety relates to HR and RPE, and how these variables change between practice and competition.

**Significance of the Study**

Heart rate and RPE are commonly used to gauge physiological response, and have been compared in past studies of other sports. Research has also been conducted on athlete pre-competition anxiety, but there is a lack of research comparing these two areas to one another and
applying them to both practice and competition. Research in this area has the potential to help coaches and athletes understand how mental attitude and physical performance in practice influences performance in competition. It may also guide future attempts to increase confidence and physical effort in both practice and competition.

**Research Questions**

1) Do HR and RPE correlate in rowing?
2) Do on-water and ergometer practice HR and RPE correlate to competition HR and RPE?
3) Do athletes feel different anxiety levels for practice racing vs. competition racing?

**Hypotheses**

1) HR and RPE correlate in rowing.
2) Competition HR and RPE will be higher than indoor ergometer HR and RPE, which will be higher than on-water practice HR and RPE.
3) Competition anxiety levels will be highest, followed by indoor ergometer anxiety levels, with on-water practice anxiety levels being lowest.

**Delimitations**

1) The same four rowers were used for all trials.
2) All participants were under the same physical training plan during the course of the study.
3) The participants were instructed to produce maximum racing effort for all trials.
4) All participants had at least one year of rowing experience at the NCAA Division I level.

**Limitations**

1) The rowers were not always in the same seat or the same boat for all on-water trials, as the head coach makes boat line-ups. Boat speed depends on all rowers in the boat, their physiological and technical abilities, and their psychological state. The subjects may have
been affected in their ability to row at maximal capacity if they were in a boat with less skilled or more/less anxious rowers for a particular trial.

2) Ability to perform at maximum effort is also affected by water and other environmental conditions. Higher winds and rougher water can make rowing more difficult. As the data were collected over several months, conditions varied for each trial.

3) While the subjects were under the same training plan during the course of the study, their nutrition, sleep, and other aspects of physical well-being were not monitored during the study.

4) There is a possibility for reporting errors in the responses given by the subjects for the RPE, CSAI-2R, and STAI-Y values. They were instructed to answer as accurately as possible, but there is always the possibility for inadvertently answering differently from how they actually feel.
Chapter II: Review of Literature

Overview of Rowing

Rowing has been used as a form of locomotion since ancient times, with the first known record of an oar-powered vessel coming from the ancient Egyptians 5000 years ago (Redgrave, 1992). The profession of Waterman has existed in England since at least the mid 16th Century, with the oldest official competition among these rowers beginning in 1715, with the still contested Doggett’s Coat and Badge race (Mallory, 2011). Rowing became the second collegiate sport ever to be contested in 1829 (cricket was the first in 1828) when Oxford and Cambridge came together in competition; rowing as a collegiate sport came early to the United States as well, with the first intercollegiate competition taking place in 1852 between Harvard and Yale (Mallory, 2011).

Races have been contested over a variety of distances over the centuries, with the current standard for international, the National Collegiate Athletic Association (NCAA), and club racing being 2000 meter, and lasting about 6-8 minutes (Smith & Hopkins, 2012). Rowing requires a great deal of preparation; the basic skills are simple but can take years to master with good coaching and hours of practice. Once technique has been learned additional physiological preparation is needed to continue to improve performance (Mallory, 2011). At the elite level, athletes have developed successful technique and have trained very hard physically; at this point mental preparation can often determine the difference between winning and losing (Redgrave, 1992). As in all sports, rowing is a mix of technical, physical, and mental skills.

Racing and Competition Factors

In any competitive athletic event, the athletes need to be able to both meet the demands of their sport and also to perform well under the pressure of competition (Craft, Magyar, Becker,
During a rowing race, the demands the sport places on each athlete mentally include staying focused enough so that their body movement and blade placement are perfectly timed with the other athletes in the boat, while also physiologically using a combination of the aerobic and anaerobic systems (Connolly & Janelle, 2003). Athletes have been shown to hold back at first when they are learning to race, and then they progressively increase effort as they learn strategy and understand how their bodies will react (Foster, Hendrickson, Peyer, Reiner, deKoning, Lucia, Battista, Hettinga, Porcari, & Wright, 2009). More experienced athletes are better able to physically push themselves consistently, and to mentally execute the skills they have practiced over longer periods of time. The more competitive experience a rower has, the better they know their body and how to control their effort during racing (Brown, Delau, & Desgorces, 2010).

Rowing races take place outside on bodies of water, but training occurs both on the water and indoors on rowing ergometers. Brown et al. (2010) showed that these two training environments are managed differently by the athlete due to both performance factors (physical capabilities and skills), and to the fact that on water performance is measured by crew finish order while indoor performance is measured by individual time. Physical effort is similar in both cases, but the required mental skills and areas of focus (i.e., synchronizing movement with the other athletes in the boat) are different.

Connolly and Janelle (2003) looked at associative and dissociative strategies in rowing. Associative strategies include focusing on form and perceiving bodily sensations, while dissociative strategies include daydreaming and focusing on the environment. Connolly and Janelle (2003) found that racing performance for female rowers was best with associative strategies, indicating that when the athletes focused on the act of rowing their performance was
improved. They also found that heart rate (HR) and rate of perceived exertion (RPE) are highest when using associative strategies, even when athletes are told to use the same power in different strategy trials. Mentally focusing on rowing technique during racing increases physiological markers of effort, and improves performance. Similarly, in a study of female gymnasts, heart rate was found to increase when competing as compared to practice (Tsopani, Dallas, & Skordilis, 2011).

**Heart Rate**

**Heart rate monitor accuracy.** Heart rate monitors are a tool commonly used by all levels of athlete to measure and monitor exercise intensity during training. (Terbizan, Dolezal, & Albano, 2002). Heart rate monitoring is one of the most efficient and economical ways available to estimate energy expenditure and physiological effort, especially when measuring multiple subjects or a large group (Keytel, Goedecke, Noakes, Hiiloskorpi, Laukkanen, van der Merwe, & Lambert, 2005). However, heart rate monitors are not always completely accurate. In a study of seven heart rate monitors, Terbizan et al. (2002) found some monitors to be more accurate than others, and found that none of the monitors tested were valid at the highest speed of exercise they tested (160.8 m/min). Others attest to heart rate monitors being accurate to measure heart rate during physical activity, but acknowledge that there is skepticism around the use of heart rate monitors as a training tool specifically when comparing practice to racing (Lambert, Mbambo, & St Clair Gibson, 1998). Lambert et al. (1998) measured runners during training and racing, and found that racing heart rates were higher, concluding that athletes should use caution when monitoring heart rate in racing. More recently, Gamelin, Berthoin, and Bosquet (2006) studied the Polar S810 heart rate monitor, and found it to correlate to ECG measurement of heart rate, concluding that the monitor was a reliable way to measure heart rate.
Nunan, Donovan, Jakovljevic, Hodges, Sandercock, and Brodie (2008) studied the same monitor, and also found it to be reliable and accurate.

**Use of heart rate in testing.** There are many factors that can affect the heart rate of an athlete in practice and competition. Lambert et al. (1998) found that racing causes athlete heart rate to react differently to exercise intensity when compared to practice. In submaximal exercise conditions, heart rate increases as environmental temperature increases, even when ratings of perceived exertion remain constant (Chen, Fan, & Moe, 2002). Also different types of exercise performed at similar physiological levels can cause considerable changes in heart rate (Chen et al., 2002). However, it remains a fact that heart rate is a key indicator of how acute cardiovascular demand is being met (Green, Mclester, Crews, Wickwire, Pritchett, & Lomax, 2005), and indeed may be the best measure of cardiac stress (Jukendrup & Van Diemen, 1998).

It has been shown that there are linear relationships between heart rate, work rate and oxygen consumption (Arts & Kuipers, 1994). Maximal oxygen uptake has been shown in many studies to be one of the most valid measures of physical fitness, is a commonly measured physiological parameter when studying physical effort, and is highly correlated to heart rate (Chen et al., 2002). In cycling, heart rate and power are two commonly used metrics for monitoring training, and Jukendrup and Van Diemen (1998) show that heart rate based training zones are preferable to power based zones because heart rate zones are more stable throughout long periods of time. While training over the course of months, many factors can alter the relationship between submaximal heart rate and workload, yet heart rate is relatively constant (within 2-3 bpm) as compared to power (Keytel et al., 2005). Unlike a training goal such as power that does not reflect environmental conditions like heat and altitude, heart rate will increase in hot temperatures and in cold temperatures, and at higher altitude, indicating that the
athlete is at a high level of physical stress even if the work being produced is less than it would be in a more neutral environment (Muller, Kim, Bellar, Ryan, Seo, Muller, & Glickman, 2012; Jukendrup & Van Diemen, 1998). Heart rate can change based on all types of physical stressors, and indicates how hard the body is working in relative terms while still being well correlated to other physiological measures (Jukendrup & Van Diemen, 1998).

**Rating of Perceived Exertion**

**Correlation to other physiological factors.** Rating of Perceived Exertion (RPE) has been correlated to multiple physiological factors including blood lactate, VO\(_2\)\(_{\text{max}}\), and heart rate. It has been associated with blood lactate in many exercise modalities and across intensities for shorter duration exercise under 30 minutes (Sinclair, Kerr, Spinks, & Leicht, 2007). For longer exercise bouts, such as 60-minute constant cycling, there is a divergence between RPE and lactate after about 30 minutes, and multiple 30-minute bouts in one day also show poor correlation (Green et al., 2005).

The 11-point 0-10 Borg scale has a high intra-test (r = 0.93) and test-retest (r = 0.83-0.94) reliability, and is a reliable measure of physical discomfort (Borg, 1998). Using a 0-10 scale is also more straightforward and clear for a broader population than the 6-20 scale also created by Borg (Borg, 1982). Borg stated “To make the scale easy to use for the lay population and not restricted to those familiar with mathematical or technical terminology, we should use a simple number range, e.g., 0-10” (Borg, 1982, p. 380). RPE is most reliable and compares favorably to other physiological measures of exercise when used with highly fit, young to middle-aged men performing relatively unusual exercise such as swimming (e.g. not walking or running) at high levels of exertion (Chen et al., 2002). At high levels of exertion, athletes are more aware of how their bodies are reacting to physical stress, and can more accurately rate their level of exertion as
compared to other physiological measures (Chen et al., 2002).

RPE has been shown to be a viable physiological measure to use in the field when objective physiological variables such as VO$_2$, lactate or heart rate are difficult or impossible to obtain (Green et al., 2005). It is also recommended to use in concert with these other variables when possible (Green et al., 2005). RPE is also consistently reported regardless of training status, and correlates well with lactate threshold in individuals of all training levels (Green et al., 2005). Heart rate is commonly used with RPE, as combining the two shows changes in workload (heart rate) and changes in metabolic demand (RPE). The RPE scale was even initially validated against heart rate, and heart rate continued to be used for validation as the scale was refined (Borg, 1982). Because heart rate can be influenced by multiple factors including the environment, illness, and diet, RPE is useful to use alongside heart rate to provide useful clinical information (Lambrick, Faulkner, Rowlands, & Eston, 2009). Using the two together provides an efficient, easily employed method to reliably measure physical exertion in the field (Lambrick et al., 2009).

**Measures of Anxiety**

*Arousal* is the term commonly used for the intensity level of behavior on a continuum ranging from comatose to extremely excited, while *anxiety* is the term given to the levels of behavior that lead to stress (Landers & Arent, 2010). In order to compete successfully athletes must learn to control their arousal levels along with the other mental aspects of their sport. Connolly and Tennenbaum (2010) asked athletes about their state of mind during practice and competition, and found that they may describe being fully absorbed, focusing on clear goals, enjoying their sport, and balancing both skill and physical demands. When athletes are not certain they can find this balance and focus, they may report being anxious, and depending on
the type of anxiety performance may be affected (Tsopani et al., 2011). There are a number of physical and mental effects of anxiety including trembling, irregular breathing, sweating, distractibility and muscle tension, all of which can interfere with the athletes’ ability to perform the necessary skills and tasks of their sport (Yoshie et al., 2009). Multiple instruments have been developed to analyze the anxiety of individuals, including the State Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) for overall anxiety measurements, and the Revised Competitive State Anxiety Inventory (CSAI-2R) (Cox et al., 2003).

**State-Trait Anxiety Inventory.** Anxiety is an emotional state that involves feeling nervous, apprehensive and tense (Vitasari, Wahab, Herawan, Othman, & Sinnadurai, 2011). It is a very common human emotion, and people experience anxiety during daily activity. Anxiety is typically broken down into state anxiety and trait anxiety; the STAI measures both and has been tested repeatedly to confirm reliability and validity when used to measure anxiety in research and clinical settings (Vitasari et al., 2011). In creating the STAI, Spielberger et al. (1983) tested over 5,000 subjects, and found test-retest correlations of trait anxiety to range from 0.73 – 0.86 for six different subgroups of college students, whereas state anxiety test-retest correlations much lower (ranging from 0.16-0.54) which is expected as state anxiety reflects the anxiety of the subject at the time of testing. Trait anxiety is considered to be a relatively stable personality trait, which refers to the frequency and intensity of anxiety in an individual over time. Trait anxiety includes feelings of tension, apprehension, and increased autonomic nervous system activity, and people with high trait anxiety tend to see more situations as threatening than people with lower trait anxiety (Barnes, Harp, & Jung, 2002). A rower with high trait anxiety may worry that they are not fast enough to help their team perform well, and not see a way of
improving their speed to a level they feel is appropriate. While trait anxiety is relatively constant, state anxiety changes regularly along with different stressors placed on an individual. If an individual perceives a certain situation as highly stressful or threatening, they will exhibit high state anxiety in that situation. If a situation is low in stress, the individual will have low state anxiety (Barnes et al., 2002). In rowing, state anxiety can depend on the perception of the competition, a team perceived as faster than their own can cause a rower to have higher state anxiety than a team perceived as slower, or if the weather is cold, rainy and windy a rower may feel less confident and more anxious than if it is warm, sunny and calm.

The STAI Form Y is a series of 40 statements that ask the subject to rate how they feel using a 4-point Likert Scale. Twenty statements are related to state anxiety and ask how the subject feels (calm, tense, etc.) at the time of answering with the scale ranging from not at all to very much so, and the other 20 statements are related to trait anxiety and ask how the subject feels (confident, pleasant, etc.) generally and is rated from almost never to almost always (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). There are multiple forms, but Form Y has been shown to have higher internal consistency reliabilities than other forms (Barnes et al. 2002). For Form Y, median alpha coefficients for the trait scale was 0.90, and for the state scale 0.93 (Spielberger et al., 1983). The trait scale has been used to screen individuals to determine how likely they are to experience anxiety, and also can be used to compare anxiety levels between different subjects. It is also generally expected that those individuals with high trait anxiety will generally experience higher and/or more frequent elevations in state anxiety than those with lower trait anxiety (Spielberger, Gorsuch, & Lushene, 1970).

**Anxiety in sports.** The STAI can be used to determine anxiety levels in athletes, as low anxiety and high confidence have both been linked to better performance (Cresswell & Hodge,
Athletes who are confident in their abilities and either experience lower anxiety or are better able to cope with stressful situations are better able to achieve success in their sport (Cresswell & Hodge, 2004). It is common for sport psychology interventions to focus on reducing anxiety. It has also been suggested by Hanin’s (1986) Individual Zones of Optimal Functioning (IZOF) model that there is an optimal level of anxiety that is different for each individual athlete, and learning to identify and achieve that level can also help performance (Wilson, Raglin, & Pritchard, 2000). Every athlete has their own zone of optimal functioning, and it can be determined by administering the STAI or CSAI-2 and asking the athlete to answer the test in terms of their past best performance, then adding and subtracting one-half standard deviation for the test to their score (Hanin, 2000). The range determined by this procedure defines the IZOF for that athlete.

**Competitive State Anxiety Inventory.** There are two forms of the Competitive State Anxiety Inventory (CSAI); the original is the CSAI-2 (Martens, Burton, Vealey, Bump, & Smith, 1990), and the revised version is the CSAI-2R (Cox et al., 2003). The CSAI-2 is one of the most widely used instruments for measuring anxiety in sport psychology research (Yoshie et al., 2009). It was developed based on multidimensional anxiety theory, which assumes that cognitive and somatic anxiety each affect sport performance in different ways (Yoshie et al., 2009). There are three components of sport psychology measured by the CSAI-2: cognitive anxiety, somatic anxiety, and self-confidence.

Cognitive anxiety is the mental component of anxiety, and occurs when the athlete has negative expectations about their performance or a negative self-evaluation. It is generally expected to correlate negatively with performance (Martens et al., 1990). Somatic anxiety is the physical reaction to anxiety, such as sweaty palms or a nervous stomach. It is expected to
correlate in a curvilinear fashion, with low and high levels being associated with poor performance (Martens et al., 1990). Figure 1 shows both cognitive and somatic anxiety as compared to performance. Figure 2 also shows the inverted-U relationship typically associated with somatic anxiety and with arousal in general, with maximal performance occurring at a level of moderate arousal. Arent and Landers (2003) found the optimal levels of arousal for performance to be between 50-70% of heart rate reserve (HRR), though in general terms anxiety can range from comatose to panic attack. Somatic anxiety tends to subside once competition begins, and so is thought to have less of an effect on performance than cognitive anxiety (Martens et al., 1990). Self-confidence is also measured by the CSAI-2, and though it is not a component of anxiety, it was viewed by Martens et al. (1990) as being related to anxiety and performance together. Self-confidence generally has a positive linear relationship with performance.

**Factors affecting anxiety.** There are several factors that affect anxiety in athletes. These include things such as experience level and type of skills involved in the sport. It has been shown that the relationship between anxiety and performance is stronger in elite athletes than non-elite, and also stronger in individual sports (such as gymnastics) than in team sports (such as soccer) (Craft et al., 2003). While an elite or experienced athlete may be more likely to have their performance affected by high anxiety, it has also been shown that experienced rowers are more likely to have higher self-efficacy and lower anxiety than inexperienced rowers, leading to better performance (Magyar, Feltz, & Simpson, 2004). Craft et al. (2003) also found that more experienced athletes are likely to perform better when they have moderate levels of cognitive anxiety, as well as moderate levels of somatic anxiety. They suggest that having some arousal before competing helps these athletes feel ready, though note that these athletes also have high
Figure 1. The relationships between cognitive and somatic anxiety, and athletic performance.

(Wann & Church, 1998).
Figure 2. The inverted-U relationship between arousal and athletic performance. (Landers & Arent, 2010).
levels of self-confidence. Landers and Arent (2010) outline different optimal arousal levels shown by high level athletes in different sports, from “slight arousal” for archery and golf, to “extremely excited” for football blockers and 200-400m sprinters. Others have also found that better performers tend to have higher self-confidence than lower performers, with elite athletes generally having more self-confidence than non-elite athletes (Tsopani et al., 2011).

Believing one will achieve is an important predictor of self-confidence, and it has been shown that when self-confidence is examined alongside cognitive or somatic anxiety it is possible to explain performance variability more accurately (Tsopani et al., 2011). When athletes believe they have some control over their environment, and are able to manage what will happen, they are more likely to believe they can perform well and will have higher levels of self-confidence and self-efficacy (Magyar et al., 2004).

Different sports involve different types of skills; one way of separating these is into open skills and closed skills. Open skills occur in sports with ever-changing dynamics, such as basketball or tennis, where it is not possible to predict exactly what will happen at any given moment. Closed skills occur in sports with a more stable, often self-paced environment, and include sports such as golf, gymnastics, and rowing (Craft et al., 2003). In their analysis of multiple studies using the CSAI-2, Craft et al. (2003) found that for closed skill sports only self-confidence has a significant correlation to performance, whereas open skill sports are more influenced by both anxiety and self-confidence levels.

Athlete view of anxiety. Athletes can see anxiety as something positive that can help their performance and challenge them to work harder, or they can view anxiety as a negative feeling that overwhelms them and causes poor performance (Nicholls, Polman, & Levy, 2010). Those who are able to stay positive in difficult situations and who are focused on goal attainment
and managing challenges generally see anxiety as a positive influence that can help their performance. On the other hand, an athlete who does not feel they have control over how they cope with challenges or whether they can achieve their goals will generally see anxiety as detrimental to their performance (O’Brien, Hanton, & Mellalieu, 2005). Similarly, an athlete with high, resilient self-efficacy beliefs is likely to recover quickly from any setbacks, and also be motivated to exhibit behavior that leads to success (Yoshie et al., 2009).

**Effect of team and individual efficacy on anxiety.** Athletes participating in team sports can have their performance influenced by both self-efficacy and their perception of the collective efficacy of the team (Magyar et al., 2004). When studying the performance of a team, it is necessary to look at data from both the athlete and team level. Analyzing data at just the level of the athlete may lead to the assumption that individual self-confidence carries over to team confidence. The two are similar yet distinct, and when looking at team performance must both be considered (Magyar et al., 2004). Other mood states such as fatigue, anger, and tension are also affected by the factor of team vs. individual sport (Craft et al., 2003).

**Correlation between anxiety, self-confidence, and performance.** It is necessary to consider the measurement of performance success when evaluating the influence of anxiety on athletic outcome. Finish time or place, coach or judge perception, and self-perception are all possible ways to evaluate performance and may correlate differently with anxiety (Craft et al., 2003). Moderate levels of anxiety generally correlate with better performance, and levels of anxiety that are too high or too low lead to poorer performance (Craft et al., 2003). Self-confidence is positive related to better performance regardless of the type of sport, and is strongest in individual sports (Craft et al., 2003). In their study of rhythmic gymnasts, Tsopani et al. (2011) found that there were significant differences in self-confidence between high and low
performers, but saw no significant differences in either cognitive or somatic anxiety in the same groups. However when examining a broad range of studies using the CSAI-2, Craft et al., (2003) found that cognitive anxiety has a consistent, strong relationship to performance as compared to somatic anxiety, and confirmed that cognitive anxiety has a negative linear correlation to performance while somatic anxiety has an inverted-U correlation to performance. Nicholls et al. (2010) had the same conclusion, in addition to noting that there is a significant positive relationship between self-confidence and subjective performance, along with a negative relationship between coping self-efficacy and both cognitive and somatic anxiety. They also saw that neither type of anxiety predicted subjective performance, and go on to state that while cognitive anxiety has a negative linear effect on performance, somatic anxiety tends to have the strongest effect on fine motor skills, and is correlated to them in a quadratic fashion.

Yoshie et al. (2009) used the CSAI-2R to study the performance of musicians, specifically pianists, likening their experience to that of individual athletes. As seen in many athletic studies, they found that self-confidence intensity was strongly positively correlated to performance, and that cognitive anxiety direction positively predicted performance. Even though their population was using fine motor skills during performance, they did not find a significant correlation between somatic anxiety and performance, and attributed this to possible flaws in the somatic anxiety subscale of the CSAI-2R. It has been suggested that cognitive anxiety is more related to performance than is somatic anxiety, and also that the effects on performance of both types of anxiety are more subtle than is the effect of self-confidence (Martens et al., 1990).

**CSAI-2 vs. CSAI-2R.** The CSAI-2 has been in use since 1990, and was developed from the original CSAI published in 1980 (Cox et al., 2003). Although the CSAI-2 is widely used and
well respected, there have been concerns about how it was developed which led to reformulation as the CSAI-2R. One of the primary concerns was the way exploratory factor analysis (EFA), which uses only the common variance among observed variables for analysis, and principal components analysis (PCA), which uses both common and unique variables, were used in development and validation of the CSAI-2 (Cox et al., 2003). In revising the CSAI-2 Cox et al. (2003) instead used a combination of EFA to determine the initial scale properties, and confirmatory factor analysis (CFA) to confirm these scale properties. Cox et al. (2003) state that conducting a CFA with a separate sample allows for determination of whether the factor structure that emerged in initial scale creation remains consistent with other samples. This initial confirmation was not conducted on the CSAI-2, and by using it to revise the CSAI-2 they were able to create a more reliable instrument in the CSAI-2R. The CSAI-2R has been found to be more psychometrically sound than the CSAI-2 in the English version and other languages as well, and Yoshie et al. (2009) also confirmed this in their study.

Anxiety and Heart Rate

Anxiety and heart rate have been linked in multiple studies, though many of these studies measure anxiety and heart rate before an activity or during an activity that is not highly athletic. Watkins, Grossman, Krishnan, and Sherwood (1998) looked at the link between trait anxiety and vagal control of heart rate in healthy subjects by measuring anxiety using the STAI and measuring heart rate and blood pressure in the supine position. They found a direct correlation between anxiety and heart rate; the subjects with higher trait anxiety had significantly higher resting heart rate than those with lower anxiety. Other studies have linked anxiety and heart rate in skydivers (Singley, Hale, & Russell, 2012), astronauts training for high G loads in a centrifuge (Jing, Wu, Liu, Wu, & Miao, 2011), race car driving simulations (Mullen, Faull, Jones, &
Kingston, 2012), and BMX racers (Mateo et al., 2012).

Singley et al. (2012) tested both novice and experienced skydivers for anxiety and heart rate at various times during a jump, from takeoff in the plane to after landing the jump, and found that anxiety scores significantly predicted heart rate, especially at the point just before jumping from the plane. Also, Singley et al. (2012) noted that the jumpers who viewed the jump as a challenge had lower anxiety and heart rate than those who saw jumping as threatening. In their study of astronauts and space travelers undergoing centrifuge training, Wu et al. (2011) were testing the impact of guided imagery on reducing anxiety. They had both an imagery group and a control group, and while imagery did reduce anxiety, both groups showed a significant correlation between anxiety and heart rate just before the training. Mullen et al. (2012) studied subjects who were not racecar drivers in a driving simulation for both practice and “race” conditions. Their subjects were split into groups using different mental focus methods (as they were studying internal and external focus), but both groups showed increased anxiety when competing vs. practicing, as well as increased heart rate and improved performance. Mateo et al. (2012) studied anxiety and heart rate just before practice and competition in BMX racers and found that they were correlated, with both heart rate and anxiety being significantly lower before practice than before competition. These studies indicate good correlations between heart rate and anxiety, although there is a lack of research linking anxiety and performance in more endurance-based sports including rowing.
Chapter III: Methods

Participants

Four female athletes from Eastern Michigan University Women’s Rowing were recruited for testing with the permission of their Head Coach and Team Athletic Trainer. After being informed of the details of the study, all subjects completed an informed consent form in the team ergometer room (indoor testing location) prior to beginning participation. During the study, the subjects were participating in all regularly scheduled practices and competitions, and were tested over the course of the spring competition season. Upon approval of the College of Health and Human Services Human Subjects Review Committee at Eastern Michigan University, these data were used to analyze physiological and psychological performance of rowers in practice and competition.

The tests were conducted as a component of the team’s NCAA regulated supervised practice time, and during regularly scheduled competitions. When testing during practice time, the testing was supervised by a United States Rowing Level III Certified coach, trained in First Aid/CPR, and USRowing safety rules and regulations. When testing during competition, competition officials and safety personnel supervised the subjects on the water. All safety precautions typically taken during rowing practice and competition were in place for this testing. Fatigue is a factor when competing in rowing, and high levels of physical exertion are required of the athletes. The subjects were all trained for this level of exertion, and were not placed under greater physiological stress than what is expected from them in normal training and 2000 meter competition. The subjects all train for rowing two hours per day, six days per week, and have three additional hours of strength and conditioning work. Testing was completed within the training schedule already set by the team Head Coach.
Apparatus and Instruments

Garmin Forerunner 305 (Garmin International Inc., Olathe KS, USA) units with heart rate monitors were used to measure and record heart rate. These units consist of a chest strap heart rate monitor that sends a wireless signal to a wristwatch unit with GPS, heart rate, and other monitoring and recording capabilities. Figure 3 shows a sample of this GPS unit. For ergometer trials, Concept II Model C ergometers (Concept II, Inc., Morrisville VT, USA), as shown in Figure 4, were used. For on-water trials, the subjects were rowing a Hudson Boat Works eight person rowing shell (Hudson Boat Works, London, ON, Canada), as shown in Figure 5. Borg's 11-point Ratings of Perceived Exertion (RPE) scale (Borg, 1982) was used to measure average perceived effort during racing for each subject. The RPE is shown in Figure 6, and is an 11-point category-ratio scale ranging from 0 (no perceived effort at all) to 10 (very, very strong effort).

To determine the influence of anxiety on rowing effort, two psychological instruments were used. At the start of the study, subjects were given a version of the State-Trait Anxiety Inventory for Adults, Forms Y1 and Y2 (STAI-Y; Spielberger et al., 1983) modified for rowing to measure trait anxiety for each subject with regards to their participation in rowing. The STAI-Y is a survey with 40 statements. Twenty statements refer to trait anxiety, and 20 statements refer to state anxiety. For this study, Form Y2 was used, as it refers to trait anxiety, and the STAI was used to determine the general anxiety levels of the subjects. Form Y2 includes statements that describe how people generally feel (e.g. happy, confident), rated using a 4-point Likert scale ranging from “almost never” to “almost always,” and can score from 20 for very low anxiety to 80 for very high anxiety. See Appendix A for the full survey. The general instructions of the STAI-Y were modified to ask how the subjects generally feel when they think
Figure 3. Garmin Forerunner 305 GPS wrist unit with heart rate chest strap. (PavementRunner, 2009).
Figure 4. Concept II Model C rowing ergometer. This type of ergometer was used for ergometer testing trials. (Fitness at Home, 2013).
Figure 5. Crew rowing the Hudson Boat Works eight person rowing shell used for all on-water trials. (Row2k.com, 2014).
<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NOTHING AT ALL</td>
</tr>
<tr>
<td>0.5</td>
<td>VERY, VERY LIGHT</td>
</tr>
<tr>
<td>1</td>
<td>VERY LIGHT</td>
</tr>
<tr>
<td>2</td>
<td>FAIRLY LIGHT</td>
</tr>
<tr>
<td>3</td>
<td>MODERATE</td>
</tr>
<tr>
<td>4</td>
<td>SOMewhat HARD</td>
</tr>
<tr>
<td>5</td>
<td>HARD</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>VERY HARD</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>VERY VERY HARD (MAXIMAL)</td>
</tr>
</tbody>
</table>

*Figure 6. Borg’s 11-point Ratings of Perceived Exertion (RPE) scale. (Borg, 1998)*
about their overall participation in rowing, and one statement was slightly modified to apply more readily to competition. Prior to each race, subjects were given the Revised Competitive State Anxiety Inventory-2 (CSAI-2R) (Cox et al., 2003) to measure pre-competition state anxiety levels. The CSAI-2R is a survey with 17 statements that describes how athletes feel prior to competition, rated using 4-point Likert scale ranging from “not at all” to “very much so.” The CSAI-2R was developed and validated using a large population, including NCAA Division I athletes (Cox et al., 2003). See Appendix B for the full CSAI-2R survey.

Testing Procedure

To address the research questions for this study, a single-group non-experimental design was used. Four NCAA Division I female athletes were tested multiple times in three different 2000 meter racing conditions. Subjects were tested during ergometer racing, during on-water “races” in practice, and during actual races against other teams. The subjects were requested to work at their maximum effort, and this instruction came from coaching staff and was not modified from the team plan for any of the testing.

After volunteering for the study and completing an informed consent form, subjects were measured for height and weight, resting heart rate, and were given a modified STAI-Y2 trait anxiety survey to determine trait anxiety when considering their participation in rowing. This information served as a baseline for each subject to compare to data from the 2000-meter trials.

Because testing was incorporated within already scheduled practice and racing, the three types of trial (ergometer, on-water practice, and race) were mixed, with all three types conducted at multiple times during the racing season. There were different numbers of trials for the different subjects and different types of trial. Some subjects were occasionally unable to race due to illness, and also for a few data sets the heart rate monitors did not collect data properly.
Also, only two ergometer trials were possible in the training schedule as written by the coaching staff. For each type of 2000-meter race, subjects followed the same overall procedure. Subjects were given the CSAI-2R survey 30-45 minutes prior to starting their on-water warm-up (or prior to starting their ergometer warm-up for ergometer based trials). The timing varied slightly for actual competition trials depending on the schedule for the day so as to avoid conflict with planned pre-competition routines. During warm-up and racing, heart rate (HR) data was measured and recorded. As soon as possible after racing, rowers gave an RPE value indicating how hard they felt they were working on average during the race.

The data were exported for statistical evaluation using SPSS 21 (IBM Corporation Armonk NY). Six variables were measured: average heart rate, maximum heart rate, rate of perceived exertion (RPE), somatic anxiety, cognitive anxiety, and self-confidence. As only four subjects were used instead of the planned six or more due to subject willingness and equipment availability, and because only two ergometer trials were possible within the training plan, there were an uneven number of trials for each type for each subject. Therefore, one-way repeated measures ANOVA was used to compare each measured variable across the three test conditions (ergometer 2000 meter, on-water practice 2000 meter, and on-water competition 2000 meter). The data input for this analysis was a random sample of two race and two practice data sets from each subject, along with the two total erg data sets from each subject. These two values were averaged for each condition and each variable, yielding a single value to input into the analysis. For all analyses reported, an alpha level of 0.05 was used to determine statistical significance. The sphericity assumption was assessed with Mauchley’s test of sphericity. In the event of a statistically significant F ratio, all possible pairwise comparisons were conducted. Pearson’s
correlations were performed to examine possible relationships between all variables at each test condition for each subject.
Chapter IV: Results

The age, height, weight, and years of rowing experience for each subject are shown in Table 1. STAI scores for each subject are also shown. Table 2 shows the number of trials for each subject in each condition. Descriptive statistics combining results for all subjects in each of the three testing conditions, race, practice, and ergometer (erg), are shown in Table 3, and Figure 7 shows typical heart rate curves for each of the three test conditions. Table 4 shows the descriptive statistics for all conditions combined, and descriptive statistics combining data from all types of trials for each subject are shown in Table 5. Table 6 shows a summary of F ratios and associated significance probability for each analysis.

The only variable that shows a significant difference between types of trial is maximum heart rate. A pairwise comparison of maximum heart rate data shows that there is a significant difference between erg and practice. Practice and race maximum heart rate are not statistically different. Table 7 shows the pairwise comparison for maximum heart rate. No other variable showed a significant difference in any portion of the general linear model.

Two-tailed Pearson correlations were conducted for each subject individually. A chart summarizing which subjects showed correlations between which variables is shown in Figure 8. Subject 1 showed a strong positive correlation between somatic anxiety and RPE ($r = 0.600$, $p < 0.01$), and also positive correlations between somatic anxiety and cognitive anxiety ($r = 0.473$, $p < 0.05$), and between somatic anxiety and maximum heart rate ($r = 0.469$, $p < 0.05$). She also showed a negative correlation between cognitive anxiety and self-confidence ($r = -0.588$, $p < 0.05$).

Subject 2 showed a strong positive correlation between somatic anxiety and maximum heart rate ($r = 0.634$, $p < 0.01$), and also a positive correlation between somatic anxiety and
Table 1

*Descriptive Statistics and STAI Scores for All Subjects*

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Years of Rowing</th>
<th>STAI Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject 1</td>
<td>21</td>
<td>168.9</td>
<td>59.1</td>
<td>4</td>
<td>37</td>
</tr>
<tr>
<td>Subject 2</td>
<td>19</td>
<td>177.8</td>
<td>75.9</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>Subject 3</td>
<td>19</td>
<td>171.5</td>
<td>101.4</td>
<td>2</td>
<td>31</td>
</tr>
<tr>
<td>Subject 4</td>
<td>21</td>
<td>182.9</td>
<td>104.5</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>20 ± 1</td>
<td>175.3 ± 5.46</td>
<td>85.2 ± 18.73</td>
<td>2.5 ± 0.87</td>
<td>34.5 ± 4.15</td>
</tr>
</tbody>
</table>
Table 2

*Number of Trials of Each Type for Each Subject*

<table>
<thead>
<tr>
<th></th>
<th>Race</th>
<th>Practice</th>
<th>Erg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject 1</td>
<td>8</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Subject 2</td>
<td>7</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Subject 3</td>
<td>6</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Subject 4</td>
<td>8</td>
<td>7</td>
<td>2</td>
</tr>
</tbody>
</table>
### Table 3

**Descriptive Statistics for All Testing Conditions**

<table>
<thead>
<tr>
<th></th>
<th>Race Condition (N=29)</th>
<th>Practice Condition (N=29)</th>
<th>Erg Condition (N=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Confidence Interval (95%)</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Somatic Anxiety</td>
<td>11.33 ± 1.83</td>
<td>10.63 12.03</td>
<td>10.15 ± 0.58</td>
</tr>
<tr>
<td></td>
<td>Lower Upper</td>
<td>Lower Upper</td>
<td>Lower Upper</td>
</tr>
<tr>
<td>Cognitive Anxiety</td>
<td>17.03 ± 3.69</td>
<td>15.63 18.44</td>
<td>14.38 ± 3.49</td>
</tr>
<tr>
<td></td>
<td>Lower Upper</td>
<td>Lower Upper</td>
<td>Lower Upper</td>
</tr>
<tr>
<td>Self Confidence</td>
<td>30.97 ± 4.92</td>
<td>29.10 32.84</td>
<td>30.90 ± 5.97</td>
</tr>
<tr>
<td></td>
<td>Lower Upper</td>
<td>Lower Upper</td>
<td>Lower Upper</td>
</tr>
<tr>
<td>RPE</td>
<td>8.09 ± 0.66</td>
<td>7.84 8.34</td>
<td>7.91 ± 0.94</td>
</tr>
<tr>
<td></td>
<td>Lower Upper</td>
<td>Lower Upper</td>
<td>Lower Upper</td>
</tr>
<tr>
<td>Average Heart Rate</td>
<td>178.39 ± 5.51</td>
<td>176.29 180.49</td>
<td>173.84 ± 7.15</td>
</tr>
<tr>
<td></td>
<td>Lower Upper</td>
<td>Lower Upper</td>
<td>Lower Upper</td>
</tr>
<tr>
<td>Maximum Heart Rate</td>
<td>187.59 ± 4.74</td>
<td>185.78 189.39</td>
<td>186.07 ± 3.60</td>
</tr>
<tr>
<td></td>
<td>Lower Upper</td>
<td>Lower Upper</td>
<td>Lower Upper</td>
</tr>
</tbody>
</table>
Figure 7. Sample heart rate curves for each trial condition.
### Table 4

*Descriptive Statistics for all Trials Combined*

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>95% Confidence Interval</th>
<th>All Conditions (N=66)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Somatic Anxiety</td>
<td>11.15 ± 2.33</td>
<td>10.5752 - 11.7192</td>
<td></td>
</tr>
<tr>
<td>Cognitive Anxiety</td>
<td>15.73 ± 3.88</td>
<td>14.7722 - 16.6823</td>
<td></td>
</tr>
<tr>
<td>Self Confidence</td>
<td>30.82 ± 5.58</td>
<td>29.4465 - 32.1899</td>
<td></td>
</tr>
<tr>
<td>RPE</td>
<td>8.29 ± 0.84</td>
<td>7.877 - 8.2897</td>
<td></td>
</tr>
<tr>
<td>Average Heart Rate</td>
<td>175.45 ± 7.63</td>
<td>173.5703 - 177.322</td>
<td></td>
</tr>
<tr>
<td>Maximum Heart Rate</td>
<td>187.52 ± 4.41</td>
<td>186.43 - 188.6003</td>
<td></td>
</tr>
</tbody>
</table>
Table 5

*Descriptive Statistics for Each Subject, All Conditions*

<table>
<thead>
<tr>
<th></th>
<th>Subject 1 (N=18)</th>
<th></th>
<th>Subject 2 (N=16)</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Confidence Interval (95%)</td>
<td>Mean ± SD</td>
<td>Confidence Interval (95%)</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Somatic Anxiety</td>
<td>12.22 ± 3.47</td>
<td>10.4954</td>
<td>13.949</td>
<td>11.70 ± 2.23</td>
</tr>
<tr>
<td>Self Confidence</td>
<td>33.44 ± 3.81</td>
<td>31.551</td>
<td>35.3378</td>
<td>29.13 ± 1.93</td>
</tr>
<tr>
<td>RPE</td>
<td>7.81 ± 0.93</td>
<td>7.3452</td>
<td>8.2659</td>
<td>7.59 ± 0.52</td>
</tr>
<tr>
<td>Average Heart Rate</td>
<td>170.35 ± 6.45</td>
<td>167.1475</td>
<td>173.5577</td>
<td>180.28 ± 5.47</td>
</tr>
<tr>
<td>Maximum Heart Rate</td>
<td>185.61 ± 5.47</td>
<td>182.892</td>
<td>188.3303</td>
<td>187.94 ± 3.38</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Subject 3 (N=15)</th>
<th></th>
<th>Subject 4 (N=17)</th>
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<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Confidence Interval (95%)</td>
<td>Mean ± SD</td>
<td>Confidence Interval (95%)</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Somatic Anxiety</td>
<td>10.29 ± 0.59</td>
<td>9.9582</td>
<td>10.6133</td>
<td>10.25 ± 1.04</td>
</tr>
<tr>
<td>Self Confidence</td>
<td>23.73 ± 2.25</td>
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<td>24.9799</td>
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<tr>
<td>RPE</td>
<td>8.5 ± 0.71</td>
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<td>8.8916</td>
<td>8.47 ± 0.78</td>
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<tr>
<td>Average Heart Rate</td>
<td>176.93 ± 9.01</td>
<td>171.9379</td>
<td>181.918</td>
<td>174.98 ± 6.20</td>
</tr>
<tr>
<td>Maximum Heart Rate</td>
<td>189.20 ± 4.20</td>
<td>186.8768</td>
<td>191.5232</td>
<td>187.65 ± 3.79</td>
</tr>
</tbody>
</table>
Table 6

*F Ratios and Significance From General Linear Models Comparing Testing Conditions for All Values*

<table>
<thead>
<tr>
<th></th>
<th>Somatic Anxiety</th>
<th>Cognitive Anxiety</th>
<th>Self Confidence</th>
<th>RPE</th>
<th>Average HR</th>
<th>Maximum HR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Within-Subjects</td>
<td>Within-Subjects</td>
<td>Within-Subjects</td>
<td>Within-Subjects</td>
<td>Within-Subjects</td>
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<tr>
<td>Effects</td>
<td>Effects</td>
<td>Effects</td>
<td>Effects</td>
<td>Effects</td>
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<td>F Value</td>
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<td>1.749</td>
<td>1.28</td>
<td>1.444</td>
<td>1.111</td>
<td>5.763</td>
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<tr>
<td>Significance</td>
<td>0.158</td>
<td>0.252</td>
<td>0.344</td>
<td>0.308</td>
<td>0.389</td>
<td>0.04</td>
</tr>
</tbody>
</table>
Table 7

*Pairwise Comparison for Maximum Heart Rate in All Conditions.*

<table>
<thead>
<tr>
<th>(I) MaxHR</th>
<th>(J) MaxHR</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval for Difference&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>-6.250</td>
<td>3.295</td>
<td>.462</td>
<td>-22.251, 9.751</td>
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<tr>
<td></td>
<td>3</td>
<td>1.875</td>
<td>2.536</td>
<td>1.000</td>
<td>-10.442, 14.192</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>6.250</td>
<td>3.295</td>
<td>.462</td>
<td>-9.751, 22.251</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>8.125&lt;sup&gt;*&lt;/sup&gt;</td>
<td>1.248</td>
<td>.022</td>
<td>2.064, 14.186</td>
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<tr>
<td>3</td>
<td>1</td>
<td>-1.875</td>
<td>2.536</td>
<td>1.000</td>
<td>-14.192, 10.442</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-8.125&lt;sup&gt;*&lt;/sup&gt;</td>
<td>1.248</td>
<td>.022</td>
<td>-14.186, -2.064</td>
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</tbody>
</table>

Based on estimated marginal means
* The mean difference is significant at the
  b. Adjustment for multiple comparisons: Bonferroni.

*Note:* Measure 1 is the race condition, measure 2 is the erg condition, and measure 3 is the practice condition.
<table>
<thead>
<tr>
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<th>Somatic Anxiety</th>
<th>Cognitive Anxiety</th>
<th>Self-Confidence</th>
<th>RPE</th>
<th>Average HR</th>
<th>Maximum HR</th>
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<tr>
<td>Cognitive Anxiety</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+2</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Self-Confidence</td>
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<td>-2</td>
<td>-3</td>
<td>-4</td>
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<tr>
<td>RPE</td>
<td>++1</td>
<td></td>
<td>+3</td>
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<tr>
<td>Average HR</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum HR</td>
<td>+1</td>
<td></td>
<td></td>
<td></td>
<td>++3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>++2</td>
<td></td>
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</tbody>
</table>

*Figure 8.* Correlation summary for each subject, all trials combined. Number indicates subject number, “-” and “+” indicate negative and positive correlation with an alpha level of 0.05, “—” and “++” indicate negative and positive correlation with an alpha level of 0.01.
cognitive anxiety ($r = 0.484, p < 0.05$). She also showed negative correlations between cognitive anxiety and self-confidence ($r = -0.506, p < 0.05$), and between self-confidence and RPE ($r = -0.485, p < 0.05$).

Subject 3 showed a strong negative correlation between cognitive anxiety and self-confidence ($r = -0.795, p < 0.01$), and also a strong positive correlation between average and maximum heart rates ($r = 0.864, p < 0.01$). She also showed a positive correlation between cognitive anxiety and RPE ($r = 0.587, p < 0.05$), and a negative correlation between self-confidence and RPE ($r = -0.491, p < 0.05$).

Subject 4 only showed one correlation, and it is a strong negative correlation between cognitive anxiety and self-confidence ($r = -0.748, p < 0.01$).
Chapter V: Discussion

The purpose of this study was to examine relationships between pre-race psychological measures of a rower and in-race physiological measures of performance. It was hypothesized that heart rate and RPE would correlate, as they have been shown to in studies of a variety of other sports. It was also hypothesized that all measures, psychological and physiological, would be highest in a race situation, followed by ergometer testing and finally that the measures would be lowest for on-water race simulation during regular team practice.

From the results, when comparing heart rate and RPE for each subject, there was no correlation. This could be due to the small sample size of only four subjects, however no subject showed correlation. Another possible reason could be that the range of RPE values given in the full study were from seven to ten, or from “very hard” to “maximal” on the Borg scale. In addition, all heart rate values were fairly high; maximal heart rate for each subject was not determined, but as can be seen in Table 4, the mean average heart rate was 175.45, and the mean maximum heart rate was 187.52 for all data sets. Using the equation for maximum heart rate developed by Tanaka, Monahan, & Seals (2001), the expected maximum heart rate for a 20 year old would be 194bpm. This implies that the subjects were working at intensities close to maximal both on average during a 2000-meter trial, and for their maximum rate reached on the trials. Since both RPE and heart rate were high, the data is scattered in the upper reaches of both scales, and it is not surprising that there may not be any strong correlations. Because a 2000 meter race is a maximal effort for approximately six to eight minutes, the subjects were expected to work hard, and the results show that they did.

All of the variables were compared across trial types, and only maximum heart rate showed a significant difference. Erging maximum heart rate was significantly higher than
practice maximum heart rate. A possible explanation for this is that in erging it is common for rowers to “sprint” the final portion or a race. In a boat it is necessary to use some energy on proper technique and to stay synchronized with the other athletes to keep the boat stable and moving efficiently. The erg however is very stable, and no synchronization with others is necessary, allowing the athlete to use all possible energy to produce as much power per stroke as they can. This would allow for as strong of a sprint as the athlete is willing to produce, and could allow the heart rate to reach near maximal values. All four subjects showed the highest maximal heart rates during erging, and all maximal values for erging were at the end, or sprint, portion of the tests. Also, the results showed that statistically, race and practice maximum heart rates were the same. There was a larger variability in the race results, so for some trials there was a higher maximum heart rate than for practice races. This is expected, as a race situation is more intense than practice. This relates to the subjects needing to use some energy to focus on their technique and synchronization in the boat during race and practice trials, and also shows they were working to a similar maximal level for both types of on-water trial. It is possible that if the data from racing conditions were less variable that a significant difference may be present between racing and erging as well. The high maximum heart rate seen in erging vs. practice is likely a combination of being able to use more energy on physiological output in erging, and on-water practice not being as intense as on-water racing.

In addition to analyzing the data to answer the research questions for this study, correlations between all measures were calculated for each subject. This resulted in some interesting findings. All subjects showed a negative correlation between cognitive anxiety and self-confidence. This is somewhat expected, as when an athlete has high self-confidence that they will perform well, they are likely to have low anxiety because they believe in their abilities.
Two of the subjects showed a positive correlation between somatic anxiety and maximum heart rate, with one of those subjects showing a strong correlation. This could be coincidental, as both of these subjects reported very low somatic anxiety on all trials, and reached high maximum heart rates. It is interesting though that it only holds true for two of the four subjects. Further testing with additional subjects would help to show whether this is coincidental or not. These same two subjects showed a positive correlation between cognitive and somatic anxiety, possibly indicating that for these subjects their thoughts about, and physical reactions to anxiety are closely linked.

There is a negative correlation between self-confidence and RPE in two of the subjects. This is somewhat unexpected. Overall the subjects had fairly high self confidence, in fact the total mean for all trials was $30.82 \pm 5.58$, and was compared to the value of $23.9 \pm 6.1$ in the original CSAI-2R formulation study by Cox et al. (2003) using Welch’s t test and a Confidence Interval of 95%. Based on this comparison, the subjects in this study had higher self-confidence than the intercollegiate athletes tested by Cox et al. (2003) when developing the CSAI-2R, and the athletes in the current study had consistent levels of self-confidence throughout all trials. In addition they had high RPE values due to the intense nature of the trials as has been discussed previously. It is possible that these two subjects had lower self-confidence than the other subjects, and that their RPE values were higher, resulting in the negative correlation. It is difficult to speculate from the available data, but this is a result that could warrant more research to see if it holds true across more subjects, or perhaps to look more closely at the psychological profiles of these particular subjects to understand whether this is a coincidence or if there is more to be learned that may help their performance.
There were a few other results that held true for just one subject. One subject showed a strong positive correlation between somatic anxiety and RPE, and another showed a strong positive correlation between average and maximum heart rate and a positive correlation between cognitive anxiety and RPE. The subject with a strong correlation between somatic anxiety and RPE could be more driven to work hard when anxious, perhaps indicating that her ideal pre-competition anxiety level might be higher than average. The subject with a strong correlation between average and maximum heart rate may be working even closer to her maximum than the others, or she may also be more conservative and consistent, and less comfortable or willing to push her limits. She also had a positive correlation between cognitive anxiety and RPE, which could also indicate that her ideal pre-competition anxiety level may be on the higher side. These results would be interesting to investigate further, both to see if they hold true for more athletes and more trials, and to understand how these specific subjects are approaching racing and how changes in coaching may improve their performance.

Additional subjects would definitely increase the statistical significance of the data, and would possibly provide more information to help answer the research questions of this study. Conducting the same number of trials for each trial type is also important, but conducting more ergometer trials during just one season is difficult, as coaches do not often plan for multiple “erg tests.” Athletes tend to see these tests as very stressful and feel they require a lot of physical and mental preparation. However, conducting more tests over a longer period of time could allow for the introduction of more variability, as training effects, both physiological and psychological, will be present if the study is long.
Chapter VI: Conclusions and Recommendations

The hypotheses for this study were not well supported. The only research question that can be even partially answered with significant data is how practice and erg heart rate and RPE compare to racing. However, only erg maximum heart rate was significantly higher than practice maximum heart rate, which does not give any indication of comparison to RPE, and does not indicate a comparison to race results. The largest conclusion to be made from this study is that more subjects and an equal number of trials for each subject and each trial type are necessary for further analysis. The study did yield some interesting results when each subject is examined separately for correlations between the test variables, and these could be studied further to understand these individual subjects or to see if the same trends hold true for multiple subjects. However these correlations were only for all data collected, and were not compared across different trial types due to the different number of trials for each type, particularly the low number of trials for erging.

This study was designed as a case study to perform an initial analysis of relationships between physiological and psychological factors in rowing training and racing. Further studies should include a larger number of subjects, and an equal number of trials for each type. Additionally, further studies could investigate different aspects of these relationships. Are there differences across multiple intercollegiate programs? Are there differences between high school, collegiate, and master’s level athletes? Are there differences in erging and on-water conditions when more data are available? The data provided here give a beginning guide to coaches on which parameters have some correlation in rowers, and provide guidance for further investigations.
References


APPENDICES
Appendix A

STAI-Y2 Modified for Rowing

Name____________________

A number of statements which people have used to describe themselves are given below. Read each statement and then blacken in the appropriate circle to the right of the statement to indicate you generally feel when you think about your overall participation in rowing.

1 2 3 4
Almost Never Sometimes Often Almost Always

1. I feel pleasant. ____
2. I feel nervous and restless. ______
3. I feel satisfied with myself. ______
4. I wish I could be as happy as others seem to be. ______
5. I feel like a failure. ______
6. I feel rested. ______
7. I am “calm, cool, and collected”. ______
8. I feel that difficulties are piling up so that I cannot overcome them. ______
9. I worry too much over something that really doesn’t matter. ______
10. I am happy. ______
11. I have disturbing thoughts. ______
12. I lack self-confidence. ______
13. I feel secure. ______
14. I make decisions easily. ______
15. I feel inadequate. ______
16. I am content. ______
17. Some unimportant thought runs through my mind and bothers me. ______
18. I take disappointments so keenly that I can’t put them out of my mind. ______
19. I am a steady person. ______
20. I get in a state of tension or turmoil as I think over my recent concerns. ______
Appendix B
CSAI-2R Survey

Name_________________ Date__________ Type of 2k (erg/practice/race)__________

Directions: A number of statements that athletes have used to describe their feelings before
competition are given below. Read each statement and then circle the appropriate number to the
right of the statement to indicate how you feel right now – at this moment. There are no right or
wrong answers. Do not spend too much time on any one statement, but choose the answer which
describes your feelings right now. Use the scale below for your answers:

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all</td>
<td>Somewhat</td>
<td>Moderately</td>
<td>Very much so</td>
</tr>
</tbody>
</table>

1. I feel jittery. ____
2. I am concerned that I may not do as well in this competition as I could. _____
4) I feel self-confident. _____
5) My body feels tense. _____
6) I am concerned about losing. _____
7) I feel tense in my stomach. _____
8) I’m confident I can meet the challenge. _____
9) I am concerned about choking under pressure. _____
10) My heart is racing. _____
10. I’m confident about performing well. _____
11. I’m concerned about performing poorly. _____
12. I feel my stomach sinking. _____
13. I’m confident because I mentally picture myself reaching my goal. _____
14. I’m concerned that others will be disappointed with my performance. _____
15. My hands are clammy. _____
16. I’m confident of coming through under pressure. _____
17. My body feels tight. _____

Other Comments: