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The effect of pacing strategy on 2000 m rowing ergometer performance in well-trained male and female rowers

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Abstract

The purpose of this study was to determine whether an even pacing strategy would be more optimal than the traditional fast-starting parabolic (On Water) strategy in a 2000 m rowing ergometer test. Based on the conflicting results in literature for moderate duration racing events, both pacing strategies were hypothesized to produce similar performance results. Thirteen collegiate level (seven male and six female) rowers completed two 2000 m pacing strategies; one Even Paced, and one the On Water strategy. Neither pacing strategy demonstrated differences in performance. This finding was consistent across sexes and experience levels. Males demonstrated a significant correlation between mean power output of the Even Pacing strategy and 6000 m performance (EP $p=0.001$). Females showed significant correlations between both pacing strategies and 6000 m performance, as well as peak power and the On Water (EP $p=0.004$, OW $p=0.002$ and PP $p=0.043$). Nationally identified rowers showed significant correlations with the parabolic On Water strategy and 6000 m performance (OW $p=0.017$). In conclusion it is recommended that either parabolic or even pacing strategies can be used during 2000 m rowing ergometer performances with similar results.

Keywords

Rowing, Pacing, Critical Power, Anaerobic Capacity, High Performance.

Lay Summary

Elite level rowers have consistently used a fast-starting parabolic pacing strategy when racing over 2000 m. However, the current literature is unclear on which pacing strategy is optimal for moderate duration races. An even pacing strategy is highly supported by the literature as being optimal for moderate duration racing events, but has not demonstrated to be utilized in rowing. The aim of this study is to understand if the traditional fast-starting parabolic pacing strategy, or an even pacing strategy, is more optimal for performance in a 2000 m rowing race. The implications of understanding the performance differences of both pacing strategies may offer a more optimal pacing strategy option for rowers, or challenge the current literature as to which pacing strategy is most optimal for moderate duration events. This study may also identify that exercise modality impacts pacing strategy as no current study to the author's knowledge has compared pacing strategies in rowing in a quantitative manner. 13 collegiate level rowers (n=7 male, n=6 female) completed two 2000 m pacing strategies. One pacing strategy utilized a traditional on water pacing strategy, and the other with an even pacing strategy. Average power output for participants was calculated using their critical power, which is the maximal power output at steady state metabolic conditions, and anaerobic capacity that is the work capable to be done above the critical power threshold. Neither pacing strategy demonstrated differences in performance classified by power output. This finding was consistent across sexes and experience levels. However, different subgroups of participants demonstrated individual correlations to other physiological markers. Males demonstrated significant correlations with an even pacing strategy and 6000 m performance (EP $p=0.001$). Females showed significant correlation between both strategies and 6000 m performance, along with a significant correlation between peak power and the on water strategy (EP p=0.004, OW p=0.002 and PP p=0.043). Nationally identified rowers showed significant correlations with the on water strategy and 6000 m performance (OW p=0.017). To conclude, neither pacing strategy appears to be more optimal for a 2000 m rowing race. However, both pacing strategies appear to have individual correlations to physiological markers.

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List of Terms and Abbreviations

ATP = adenosine triphosphate

Cd = effect size

CP = critical power

CrP = creatine phosphate

H^+ = hydrogen ion

J = joules

PO = power output

RPE = rate of perceived exertion

SD = standard deviation

T = time

W’ = anaerobic capacity (work done above critical power)

W = watts

Chapter 1

1. Review of the Literature

1.1 Introduction

Racing sports, including track events, cycling, swimming and rowing, are considered to be “closed loop designs” (Gibson et al., 2001). The objective of these sporting events is that the goal of the competitors is to complete a standard, predetermined distance, in the shortest time possible (Foster et al., 1993; Padilla et al., 2000). During head to head competition, as opposed to a time trialing format, competitors begin the race at the same time. The winner is determined by the marginal fastest time to complete the distance (Foster et al., 1993). The tactics and actions of the race dynamics of competitors are important to success (Wilberg & Pratt, 1988). Dissimilar to the head to head style of racing, time trial competition format requires that competitors compete in isolation, where no reference to the speed of other competitors is known (Foster et al., 1993; Wilberg & Pratt, 1988). The winner of these time trial competitions completes the distance of the event in the shortest time (Coyle, 1999; Foster et al., 1993). Both race styles involve competitors to implement their race dynamics and tactics to be able to completely expend their available energy. This will result in covering the distance in the fastest possible time. This is known as a pacing strategy (Abbiss & Laursen, 2008; Foster et al., 1994). Furthermore, the timing of utilization of this available energy is done in a fashion that enables the competitor to reach their greatest overall average work output during the event (Foster et al., 1993, 1994, 2005).

1.2 Regulation of Pacing

In order for competitors to optimize their physiological limits to produce their greatest possible average work output during the race, there are large amounts of feedback and processing between the brain and periphery that determines the amount of work output the competitor is capable of producing (Gibson et al., 2006). While there are many tactics of work distribution, and theories on optimal pacing strategies for various distances, durations and competitions, all are reliant on the communication between the brain and peripheral physiological systems (Foster et al., 1994; Gibson et al., 2006). Ultimately the most important factor to a competitors pacing strategy is knowledge of the end point of the race (Gibson et al., 2006). This conscious or unconscious knowledge allows competitors to gauge and modify their work output in order to not disrupt the peripheral state of homeostasis so much that damage would occur to the body (Tucker et al., 2004). Pacing is a complex task that involves multiple feedback loops between the peripheral musculature and brain, or within the brain itself (Tucker, 2009). However, the regulation of work output from afferent input to the central nervous system is different based on the exercise task prescribed (Tucker, 2009). In the case of fixed work rate conditions, the central nervous system has no influence in the throttling or regulating of work output. Rather, the only control is the duration until the termination of exercise based on the perceived rise in the rate of perceived exertion in the individual (Tucker et al., 2004). Changes in the physiological state of the peripheral musculature are assessed by the central nervous system through afferent feedback and result in a rise of perceived exertion over time (Noakes et al., 2004; Tucker, 2009). A rise in perceived exertion will lead to exercise termination based on the anticipated amount of safe exercise duration established by the central nervous system's feedback (Gibson et al., 2006; Tucker, 2009). The insights into the rise of perceived exertion with a fixed work output, and the effect on duration of exercise termination are not as applicable for alternative exercise task such as competition, where the work rate of competitors is open and not limited by laboratory conditions. A different model of the feedback loops between the central nervous system and the peripheral musculature has been suggested to identify limitations of work output pacing during open work rate trials and in competition.

These feedback loops for an open work rate trial provide constant assessments in the level of the competitor's conscious perceived exertion, and alter the work output based on anticipatory and feedback components (Tucker, 2009). The difference between the fixed work rate experimental condition and an open paced trial is the influence from previous experience, other competitors (or other forms of motivation), and the knowledge of the remaining duration left (Tucker, 2009). The impact of previous trials, motivation and knowing the remainder of the trial allows the competitor to form a perceived exertion template of which the competitor believes is an appropriate and sustainable exertion level (Noakes et al., 2004). This template rate of perceived exertion (RPE) is formed from past experiences in exercise in combination with the known end point of exercise and is used as a fixture for the conscious RPE to be compared to (Gibson et al., 2006).

During the onset of exercise, a conscious and measurable RPE is formed based on physiological changes that the muscle interpreted through afferent feedback (Tucker, 2009). This RPE is compared to the template RPE based on the amount of duration remaining for the trial and work rate is modified to prevent premature exercise termination or to coincide with the template RPE (Noakes et al., 2004; Tucker et al., 2004). This process then forms a new conscious level of exertion and the feedback process repeats altering the amount of work output based on the updated conscious exertion (Noakes et al., 2004; Tucker, 2009; Tucker et al., 2004).

Conscious RPE relates to the tactics of race dynamics that competitors may use in order to support a pacing strategy in order to maximize their physiological potential in order to put themselves in the best position to win the event (Gibson et al., 2006; Gibson et al., 2001). Moreover, RPE reflects the contributions from the aerobic and anaerobic energy systems. As intensity increases above the lactate threshold the change in pH mirroring the lactate accumulation increases the pain that the competitor will experience, particularly at the working muscle.

A competitor understanding their physiological potential is crucial to energy expenditure coinciding with race dynamics and their pacing strategy. Knowledge of the aerobic and anaerobic pathways of substrate breakdown, and their respective individual capacities, may assist in executing an optimal pacing strategy.

1.3 Energy Systems

The anaerobic energy system is comprised of the alactic and lactic systems. The alactic system involves the breakdown of stored high-energy phosphates (ATP and PCr) existing within the muscle releasing energy for the myosin head to bind with actin and complete muscle contraction. This energy system is dominant within the first 10 seconds of exercise onset as it provides energy to the contracting muscle in the shortest amount of time. Past the initial 10 seconds of exercise, when the alactic anaerobic systems stores are depleting, the anaerobic lactic system breaks down glucose derived from muscle glycogen to pyruvate and/or lactate. When energy demand exceeds the ATP output of oxidative phosphorylation, lactate and its associated metabolic byproducts including H^+, begin to accumulate in the muscle. The anaerobic energy systems, both alactic and lactic, are capable of producing high energy output for short durations until the effects of the H^+ and associated metabolic byproducts of these reactions limit continued ATP regeneration from the anaerobic systems (Astrand & Rodahl, 1986).

The terminal step of the electron transport chain involves the consumption of O_2 and differentiates the aerobic pathway from the anaerobic pathway. The aerobic pathway utilizes both glucose as well as free fatty acids as substrates for energy. While the aerobic pathway is capable of producing greater amounts of energy (ATP) compared to the anaerobic energy system, the rate at which energy is produced through the aerobic system is slower. Unlike the anaerobic system, the aerobic system does not produce fatigue-inducing metabolites, rather the end products of the aerobic system are CO_2 and H_2O, although energy production from this system is limited by glycogen depletion (Astrand & Rodahl, 1986).

1.4 Critical Power and Anaerobic Capacity

Critical Power (CP), measured in watts, is the term to describe the threshold of work output where a steady state is achieved in VO_2 uptake along with fatigue markers such as lactate (Jones et al., 2008; Jones & Vanhatalo, 2017). The rate and capacity of the aerobic energy system suggests that work done below the CP threshold is dominantly supplied by energy from the aerobic energy pathway. The power output at CP is the threshold at which, any increase in power output above this level will result in increasing values of VO_2 and lactate and eventually result in fatigue (Jones et al., 2008; Jones & Vanhatalo, 2017). It needs to be noted however that the CP threshold, while it is measured in watts, is not an absolute value; rather, it is a reflection of a steady metabolic state of the competitor (Barker et al., 2006).

Work done above the threshold of CP will also tax the anaerobic system in order to meet the rate of energy demands by the muscle. This in turn, demands the utilization of anaerobic capacity (Jones et al., 2008, 2010; Jones & Vanhatalo, 2017). Anaerobic capacity can be described as the amount of work capable of being produced above the CP threshold (Burnley et al., 2006; Jones et al., 2010; Jones & Vanhatalo, 2017). As the workload increases above the CP threshold, severe intensity exercise, a non-steady state condition evolves by which pH, phosphocreatine decrease and lactate and VO_2 begin to rise until exercise termination (Jones et al., 2011).

This severe exercise domain encompasses a large number of sporting events that include 2000 m rowing races. For exercising within the severe exercise domain, competitors must appropriately, and strategically, expend their anaerobic capacity, while maximizing their aerobic capacity in order to prevent a premature termination of exercise due to intolerable conditions. Along with the knowledge of the capabilities of the athlete's maximum oxidative capacity (VO_2max) and anaerobic capacity (W'), CP is also critical to maximizing performance potential (Jones et al., 2010; Vanhatalo et al., 2011).

At severe exercise domain intensities, the utilization of the anaerobic capacity appears to be linear, while anaerobic capacity replenishment may be curvilinear and the kinetics of this system are highly individual (Jones & Vanhatalo, 2017). Consequently, pacing strategies will determine the distribution of anaerobic and aerobic capacities over the duration of the event (Foster et al., 1994; Gibson et al., 2006). An infinite number of pacing strategies are possible for athletes to incorporate into competition however, generally speaking, there are four categories of pacing strategy are used including an all-out style, even paced, slow start, and a parabolic style (Abbiss & Laursen, 2008; Gibson et al., 2006). These will be presented in some detail in the following section.

1.5 Pacing Strategies

An all-out pacing strategy demonstrates a distribution of power output (PO) where a competitor begins the event at maximal effort and speed. This maximal effort is maintained for the remainder of the race (Abbiss & Laursen, 2008; Gibson et al., 2006). There will ultimately be a decrease in speed towards the end of the event using an all-out pacing strategy. This all-out start limits the duration during which the competitor is producing submaximal power outputs (Abbiss & Laursen, 2008). All-out pacing strategies seem to be effective in increasing performance for short events less than two minutes in duration, and in 1000 m women's rowing (Abbiss & Laursen, 2008; Bishop et al., 2002; de Koning et al., 1992; De Koning et al., 1999; Fukuba & Whipp, 1999; van Schenau et al., 1994) (women's rowing reference). Looking to track cycling, in the discipline of 1000 m time trial (approximately one minute in duration at the elite level) found a performance increase when adopting an all-out pacing strategy (De Koning et al., 1999). However, the short duration 1000 m track cycling is not similar to the six-minute duration of a rowing event (Gardner et al., 2005; Garland, 2005).

A slow start pacing strategy, also referred to a negative pacing strategy, reflects a continuous increase in work output that increases over the race (Abbiss & Laursen, 2008; Gibson et al., 2006). The benefit of incorporating this pacing style into competition is that the distribution of work output limits the rate of the rise in fatigue inducing metabolites that would lead to premature fatigue that will reduce overall performance (Abbiss & Laursen, 2008; Mattern et al., 2001). This pacing style of "negative splitting" or slow starting also reduces the rate of carbohydrate store depletion by reducing the contribution of the anaerobic glycolytic phosphorylation system, that may become a factor for longer duration events (Abbiss & Laursen, 2008). For example, it has been demonstrated in 20-kilometer cycling time trials for participants to have lower blood lactate values in the beginning nine minutes of the trial (Mattern et al., 2001). Initially high blood lactate levels at the onset of exercise may impair performance for events similar in duration to a 20-kilometer cycling time trial, and lead to a negative performance (Mattern et al., 2001). Likewise, Rodriguez and Veiga advocate that in 10 km swimming, which lasts a duration of approximately two hours, a slow-start pacing strategy is also more beneficial in order to limit the accumulation of lactate and limit the amount of anaerobic energy reserve used during the beginning of the race to avoid early fatigue metabolite accumulation (Rodriguez & Veiga, 2018; Zamparo et al., 2005).

An even pacing strategy is characterized by few deviations from an initial power output set at the beginning of the event, that is maintained through to the finish (Abbiss & Laursen, 2008; Gibson et al., 2006). The even pacing strategy has been regarded as an optimal pacing strategy for events of prolonged duration lasting longer than two minutes, but less than (Abbiss & Laursen, 2008; De Koning et al., 1999; Thompson et al., 2003, 2004). For these longer events, there is less of an overall fraction of time that the competitor spends in the acceleration phase at the beginning of the event (Foster et al., 2004; Foster et al., 1994). Even pacing has been notably the dominant pacing strategy of successful athletes in track cycling (Wilberg & Pratt, 1988). Looking to Canadian track cycling athletes with national and international experience, athletes who are more successful demonstrate an even pacing profile in 3000 meter and 4000 meter events (Wilberg & Pratt, 1988). Sporting events where fluid dynamics contribute to competitor's speed may benefit greater from an even pacing strategy due to the minimal changes to drag force on the body moving through the fluid (Abbiss & Laursen, 2008; Zamparo et al., 2005). In swimming there is great fluid resistance of which the competitors must overcome, and increases in velocity, which in turn increases the amount of drag forces on the athlete and result in increased work output to overcome the hindering forces (De Koning et al., 1999; Van Ingen Schenau et al., 1990; Zamparo et al., 2005). This may lead to impaired performance as the work demands to increase speed may become disproportionate to the energy needed (De Koning et al., 1999; Van Ingen Schenau et al., 1990; Zamparo et al., 2005). Similar effects of the even pacing strategy's benefits are seen in cycling, where aerodynamics contribute greatly to overall velocity of athletes and deviations in speed can result in resistive forces (Swain, 1997). With significant drag fluid forces in rowing as competitors move through the water medium, an even pacing strategy appears to be beneficial to reduce the debilitating drag forces of uneven pacing distribution.

Finally, a parabolic pacing strategy is identified by the competitor decreasing work output or speed after the beginning of the race, but then increasing in speed towards the finish (Abbiss & Laursen, 2008; Gibson et al., 2006). The resulting pattern of work output can be described as a U-shaped, parabolic, or J-shaped (Abbiss & Laursen, 2008; Gibson et al., 2006). The parabolic pacing strategy has been observed to be used within endurance events and has been associated with an anticipatory response to increase work output as the distance remaining decreases (Gibson et al., 2006; Tucker, 2009; Tucker et al., 2004). Particularly at the international rowing level, the parabolic pacing strategy (On Water) appears to be the preferred pacing strategy, regardless of sex or boat class (Garland, 2005). Both the winners and losers at international races follow the parabolic pacing strategy (Garland, 2005). The parabolic pacing strategy is less clear as to the physiological benefit for pacing in such a manner. A possible performance benefit from using a parabolic pacing strategy with its fast start and reduced work load through the middle and the speeded VO_2 uptake through ventilation kinetics at the beginning of the event that increases the oxidative respiration and reduces the amount anaerobic phosphorylation contributions during the beginning of the race or trial (Amann, 2012; Wood et al., 2014).

The duration of a 2000 m rowing race is approximately five to eight minutes depending on sex and boat class (Garland, 2005). Therefore, rowing races seem to fall into a grey area for which the research literature has yet to conclude an optimal pacing strategy. Other pacing strategies appropriate for longer or shorter durations appear to have a certain drawback making them potentially suboptimal for a moderate duration event such as a 2000 m rowing race. Therefore both the parabolic pacing strategy, and an even pacing strategy may be used with similar results. For the duration of a rowing race (greater than 2 min but less than 30 min), the literature supports that an even paced racing strategy would produce optimal performance for competitors (De Koning et al., 1999; Hettinga et al., 2006; Van Ingen Schenau et al., 1990). An even paced strategy does not have the potential issues of other pacing strategies such as the rapid onset of fatigue metabolites of an all-out strategy, nor does it have the potential for a sub-optimal performance that a slow-starting pacing strategy may produce (Bailey et al., 2011; Fukuba & Whipp, 1999). An even pacing strategy has previously been used in other sporting events such as 4000 m track cycling events and is similar to the duration of a 2000 m rowing race. Conversely, Aisbett et al., observed that the optimal pacing strategy for moderate duration (5 min) cycling time trial performance was a fast start strategy, when compared with a slow starting, or even paced strategy (Aisbett et al., 2009). Others have suggested that moderate duration events, such as 2000 m rowing races in which VO_2 max will be achieved, pacing strategy is a small factor in performance so long as anaerobic capacity is completely expended (Bailey et al., 2011).

With the current literature appearing conflicted on which of the even pace or parabolic strategy would be superior, the purpose of this study was to compare an even pacing and the parabolic pacing strategy for a 2000 m rowing ergometer performance. The inconclusive previous literature suggests these two pacing strategies may result in similar performances.

Chapter 2

2.0 Manuscript: The effect of pacing strategy on 2000 m rowing performance in well-trained male and female rowers.

2.1 Introduction

The objective of an Olympic rowing race is to complete the 2000 m distance prior to any competitors. At the international level, depending on the number and sex of the rowers in a particular boat class this 2000 m race is completed in between five and eight min (Garland, 2005). This 2000 m race requires an aerobic energy system contribution of

≈ 87%, and an anaerobic energy system contribution of ≈ 13% (de Campos Mello et al., 2009). This anaerobic contribution results in an increase in PO but produces fatigue-inducing metabolites, including H^+ (Jones et al., 2008). The timing of the contributions from an athlete's aerobic energy system and their anaerobic capacity (W′) is dictated by the particular pacing strategy that is employed over the 2000 m. Their distribution can be expended through positive, negative, even or parabolic pacing strategies over the duration of the race (Abbiss & Laursen, 2008). A positive pacing strategy is defined as a progressive decrease in speed or PO over the duration of the race, whereas a negative pacing strategy is identified as a progressive increase in speed or PO over the duration of the race (Abbiss & Laursen, 2008). The even pacing strategy is characterized by a constant PO throughout, whereas the parabolic strategy (On Water) is characterized by a high PO initial portion, a decrease through the middle of the race and increase in PO again towards the end (Abbiss & Laursen, 2008). The optimal pacing strategy for a 2000 m rowing race will enable the most efficient utilization of the aforementioned aerobic energy system, as well as a complete utilization of their anaerobic capacity (W′) (Foster et al., 1993, 2005).

Olympic rowing races fall in the category of moderate duration races (those events being greater than 2 min, but less than 15 min). Foster et al. suggested that for 2 km cycling races (≈ 2 min) even pacing strategy produced a faster finishing time compared to fast-starting and slow start strategies (Foster et al., 1993). Murray et al. (Murray et al. 2017) has also shown enhanced cycling ergometer performances (6 min) utilizing an even paced versus a fast start strategy. This performance advantage was attributed to a greater utilization of anaerobic capacity during the even pace strategy. This finding is consistent with theoretical support for the benefits of the even pacing strategy for middle duration events (De Koning et al., 1999) (Fukuba & Whipp, 1999). In elite world championship cycling competition, Corbett and Foster et al., noted that track cycling's 4000 m (≈ 4 min) individual pursuit participants utilized this even pacing strategy (Corbett, 2009) (Foster et al., 1994).

Conversely, Aisbett et al., observed that the optimal pacing strategy for moderate duration (5 min) cycling time trial performance was a fast start strategy, when compared with a slow starting, or even paced strategy (Aisbett et al., 2009). Others have suggested that moderate duration events, such as 2000 m rowing races in which VO_2 max will be achieved have suggested that pacing strategy is a small factor in performance so long as anaerobic capacity is completely expended (Bailey et al., 2011). Non-empirical observations have shown elite swimmers performing 400 m (≈ 4 min) in competition have utilized an array of pacing strategies including the fast-start, even and parabolic strategies (Mauger et al., 2012; McGibbon et al., 2018) suggesting that experienced swim coaches and swimmers have not observed any clear advantage to either strategy, besides that of personal preference. It is clear that an optimal pacing strategy for moderate duration performance events is controversial. Currently, the majority of international rowers utilize a parabolic pacing strategy during competition (Garland, 2005). This strategy, however, has not had empirical support as the optimal pacing strategy for a 2000 m rowing performance. The purpose of this study was to compare the parabolic pacing strategy utilized in on water racing, to an even paced strategy in male and female well-trained rowers. The conflicted nature of the literature to date suggests that that the even paced strategy and parabolic strategy for 2000 m rowing races will elicit similar results.

2.2 Methods

2.2.1 Participants

Healthy male (n = 7) and female (n = 6) rowers volunteered to participate in the study. All subjects had competed for an intercollegiate rowing program in Canada, and several subjects (n = 4) had been nationally identified by Rowing Canada Aviron to be a part of the university high performance program (HUB) after achieving an ergometer standard. No subjects were smokers, and no subjects had underlying health conditions that would interfere with physiological variables. The Western University Health Sciences Research Ethics board approved the study (see Appendix).

2.2.2 Experimental Overview

Subjects arrived at their usual training facility and participated in three tests over a four-week period. The initial three-minute all-out test (test 1) was separated from the first 2000 m time trial (test 2) by two weeks, and the second time trial was separated by a one week wash out period from the first (test 3). The Even Paced and parabolic pacing strategy (On Water) time trials were performed in random order. Weekly training volume for all participants remained constant, but was variable between participants (14 hours to 22 hours per week). PO during all tests was recorded for every stroke using the Erg Data app synced wirelessly using Bluetooth to the Concept 2 PM5 monitor. All testing was completed on an indoor rowing machine (model: D; Concept 2; Vermont; USA)

2.2.2.1 Experimental Overview: Three-minute all-out CP test

The first test performed, was a three-minute all-out test that was used to determine critical power (CP) and W′ and subsequently, to calculate the PO (W) for the following 2000m time trials. PM5 monitors were set to complete a three min maximal effort and positioned so that feedback of PO and time remaining were blinded from the participants view. Subjects were instructed to attempt to reach their peak power as quickly as possible and to maintain a maximal effort throughout a three min period. This three min all-out test has been shown to be a valid and reliable measure of CP and W′ in both cycling, running and rowing (Burnley et al., 2006; Cheng et al., 2012). Measurements of CP and W' were utilized to predict the average PO that participants would theoretically be able to maintain for the 2000 m trials, as the sum of these two variables results in the highest possible PO. The predicted mean PO for the Even Paced strategy was calculated using the PO = (W′/t)+CP equation where CP was the final 30 sec averaged PO from the three minute test, and W' was the work completed above this CP threshold measured in joules, and time was 180 sec.

2.2.2.2 Experimental Procedure: 2000m time trials

The participants completed the Even Pace and On Water strategies 2000 m time trials seven days apart in random order. Specific PO (given in 500 m split times) for each 100 m for each pacing strategy was provided to the participants ahead of the time trials. An observer was assigned to every participant during the time trial to ensure that the appropriate PO was performed over each of the initial 1500 m. Over the last 500 m participants were instructed to build to a maximal effort. Verbal encouragement was given to ensure maximal efforts were performed over this last 500 m.

2.2.2.3 Even Pacing Strategy

The strategies were defined as an Even Paced strategy where participants were instructed to produce their target PO by the third to fifth stroke of the time trial, and then to maintain the prescribed PO until the remaining 500m of the time trial. If participants did not reach the prescribed Even Pace strategy PO by the fifth stroke of their test (approximately 10 seconds) the data was excluded from the study.

Participants were instructed to increase their PO, if possible, from 1500 m to 2000 m. If participants were unable to raise their PO in the final 500 m, then they were instructed to produce a maximum effort regardless.

2.2.3 On Water

The On Water strategy was based on the pacing strategies of international rowing races noted by Garland et al. (2005). POs for every 100 m were assigned to participants that would correspond to this strategy. This pacing strategy demanded a fast-start, followed by a parabolic model of PO. The fast-start was equivalent to 103.3% of the participants estimated average PO (Garland, 2005). This fast-start was followed by a slow decrease in PO through this initial 500m of the time trial until reaching 99% of their estimated average PO (Garland, 2005). Following the initial 500 m, participants were instructed to hold 99% of their estimated average PO through the second 500m of the time trial. The third 500 m was performed at 98.3% of their estimated average PO (Garland, 2005). Over the final 500m, participants were instructed to raise their PO to maximal effort and if they were unable to raise the PO to perform a maximal effort regardless.

2.2.4 Data Analysis

Qualitative analysis of the utilization of W′ from the three minute all-out tests and each pacing strategy time trial was performed to determine if the complete utilization of W′ had been achieved. Data was saved to an online cloud and downloaded into CVS file form for analysis.

PO was averaged from all participants for both 2000 m trials and plotted against distance. Stroke by stroke PO data was 10 strokes averaged for graphical display using Origin 9 software.

Participants average power outputs from both pacing strategies were correlated to 6000 m time trial power output. The 6000 m test has a high aerobic energy contribution. Anaerobic capacity, measured from the work done above CP in the three-minute all-out test, and PP were also correlated with both 2000 m pacing trials.

6000 m Test

Participants were instructed to complete a 6000 m time trial in the shortest amount of time possible. Participants were familiar with this standard rowing test and based their PO off of previously completed tests to attempt to complete the distance in the fastest time possible.

Peak Power Test

Participants were instructed to perform 10 s with maximal effort. The highest PO observed was deemed to be their PP. If the participant’s PO continued to rise after the tenth stroke, they were instructed to continue until the PO finally began to decrease.

Both the 6000 m and the PP tests were completed four weeks prior to the start of the testing protocol.

2.2.5 Statistical Analysis

The statistical analysis for the data was completed in Sigma Plot 12.3 and Origin 9. Differences between pacing strategies were compared for mean PO, and anaerobic capacity expenditure. Data was analyzed between both 2000 m time trial conditions using a paired two-tailed t-test. Significance level was set at p<=0.05. Correlations between each 2000 m pacing strategy and 6000 m time trial, peak, sex and W′ were also calculated. The Pearson Correlation was used. Significance for the correlations were also set at p<= 0.05. Effect sizes (Cd) were performed with all comparisons.

2.3 Results

Mean PO over the three-minute all out test can be seen in Figure 1 for both sexes. Sex, weight class, peak power, W′, CP and 6000 m time trial of the rowers are presented in Table 1.

There were no group mean ($p=0.366$, $Cd=0.039$), or sex differences (Male: $p=0.412$ $Cd=0.148$; Female: $p=0.768$ $Cd=0.006$), between the On Water and Even Pacing strategies PO (Table 2 and Figure 2).

No differences in anaerobic capacity expenditure were seen between 2000 m strategies within the overall group ($p=0.907$ $Cd=0.026$) or for male or female participants (Male: $p=0.868$ $Cd=0.068$; Female: $p=0.867$ $Cd=0.027$). Moreover, no group mean anaerobic capacity expenditure differences were observed between the three-minute all out test and the On Water or Even Pacing strategy (Group: On Water $p=0.253$ $Cd=0.481$; Even Pace $p=0.140$ $Cd=0.579$) (Table 1 and Table 2).

There was also no difference between W′ utilized during the three minute all–out test and both pacing strategies (Male: On Water $p=0.726$ $Cd= 0.227$; Even Pace $p=0.740$ $Cd=0.192$). However, female anaerobic capacity expenditure was significantly different between the three-minute all-out test and both 2000 m pacing strategies (Female: On Water p=0.001 Cd= 1.608 Even Pace p=0.001 Cd=1.661) (Table 1 and Table 2).

The combined male and female On Water and the Even Pacing strategies POs showed high correlations to participant's 6000 m performance (Group: On Water r=0.867 p= 0.000125 and Even Pace r=0.900 p=0.000028). Strong correlations were also observed for the mean PO between 2000 m strategies and 6000 m Even Pacing strategies for both male and female participants; however, male On Water 2000 m performance was not significantly correlated with the 6000 m aerobic capacity marker, while both female pacing strategies were significantly correlated (Male: On Water r=0.754, p=0.0502; Even Pace r=0.875, p=0.001. Female: On Water r=0.945 p=0.004; Even Pacer=0.965 p=0.002) (Figure 3).

Combined male and female On Water strategy mean PO approached significance between W′ and the On Water strategy, whereas the correlation between the Even Pacing strategies PO and W′ reached significance (Group: On Water r= 0.537 p=0.058 and Even Pace r= 0.562 p= 0.046). No correlation was observed between 2000 m pacing strategies and W′ of male and female participants (Male: On Water r=-0.079 p=0.866 and Even Pace r=0.051 p=0.914; Female: On Water r= 0.183 p=0.729 and Even r=0.123 p=0.816) (Figure 4).

Group On Water and Even Pacing strategies were highly correlated with peak POs (Group: On Water r=0.771 p=0.002; Even Pace r=0.828 p=0.0005). Male participants pacing strategy POs were weakly correlated with peak POs (Male: On Water r=0.022 p=0.962; Even Pace r=0.332 p=0.467). However, the correlation between female participants peak power and Even Pacing strategy was not significant, but peak power and On Water pacing strategy showed significance (Female: On Water r=0.826 p=0.043; Even Pace r=0.796 p=0.058) (Figure 5).

A significant correlation was observed for the nationally identified group and the varsity group between both pacing strategies, and 6000 m time trial POs (National: On Water r= 0.983, p=0.017 Even Pace r=0.923 p=0.077; Varsity: On Water r= 0.991 p<0.01 Even Pace r=0.988 p<0.01).

Table 1: Participant's individual weight class, experience level, and critical power, anaerobic capacity (W′), peak power and 6000 m (6km) time trial power outputs.

SD=standard deviation
W'=anaerobic capacity
W=watts
J=joules

Participant	Sex	Weight class	Experience Level	Critical Power (W)	W' (J)	Peak Power (W)	6km Time Trial (W)
1	Male	LW	Varsity	297	16991	809	265
2	Male	LW	Hub	328	15438	768	309
3	Male	LW	Varsity	329	11710	807	282
4	Male	LW	Varsity	285	17912	759	251
5	Male	OW	Varsity	328	16374	1208	279
6	Male	OW	Varsity	363	8794	797	309
7	Male	OW	Hub	436	19252	1007	390
Average Male				338	15210	879	298
SD Male				46	3415	155	42
8	Female	LW	Varsity	172	12111	467	171
9	Female	LW	Varsity	183	11247	457	187
10	Female	LW	Varsity	172	8967	490	167
11	Female	OW	Varsity	223	7469	569	209
12	Female	OW	Hub	211	15508	719	213
13	Female	OW	Hub	230	7716	529	223
Average Female				198	10503	539	195
SD Female				24	2814	89	21
Group Average				274	13038	722	250
Group Standard Deviation				79	3930	213	62

Table 2: Individual and mean values of all participants for predicted, 2000 m (2km), On Water and Even Pace times as well as On Water, Even Pace, Anaerobic Capacity (W′) and Even Pace power outputs.

*= Statistically different from three minute all-out test value ($p<0.05$).
SD=standard deviation
W'=anaerobic capacity
W=watts
s= seconds

Participant	Predicted 2km Time (s)	On Water Time (s)	Even Pace Time (s)	On Water (W)	Even Pace (W)	W' (J) (CP test)	On Water W' (J)	Even Pace W'(J)
1	404.8	404.2	411	339	323	16991	18189	12127
2	394	386.9	387.4	387	385	15438	21941	20420
3	397.2	390.1	391.8	377	372	11710	17865	15442
4	408.4	405.1	409	337	327	17912	16836	19364
5	393.2	393.1	406.2	369	334	16374	5038	15686
6	387.6	384.7	384.7	393	393	8794	12240	10338
7	358	369	364.5	446	463	19252	6729	7886
Average Male	391.9	390.4	393.5	378	371	15210	14120	14466
SD Male	15.3	11.4	15.4	39	42	3415	5853	4271
8	484.4	470.8	469.7	215	216	12111	19152	20934
9	477.6	466.6	463.3	221	225	11247	17207	18856
10	490.8	478.6	475.1	204	209	8967	17379	16001
11	454	447.9	448	249	249	7469	10704	10539
12	451.6	437.2	440.5	268	262	15508	24776	22086
13	449.6	444.7	445.4	255	254	7716	11453	11508
Average Female	468	457.6	457	235	236	10503	16779*	16654*
SD Female	17	15.1	13	23	20	2814	4750	4415
Group Average	427	421.5	422.8	309	312	13038	15347	15476
Group Standard Deviation	41.2	36	34.8	76	78	3930	5533	4473

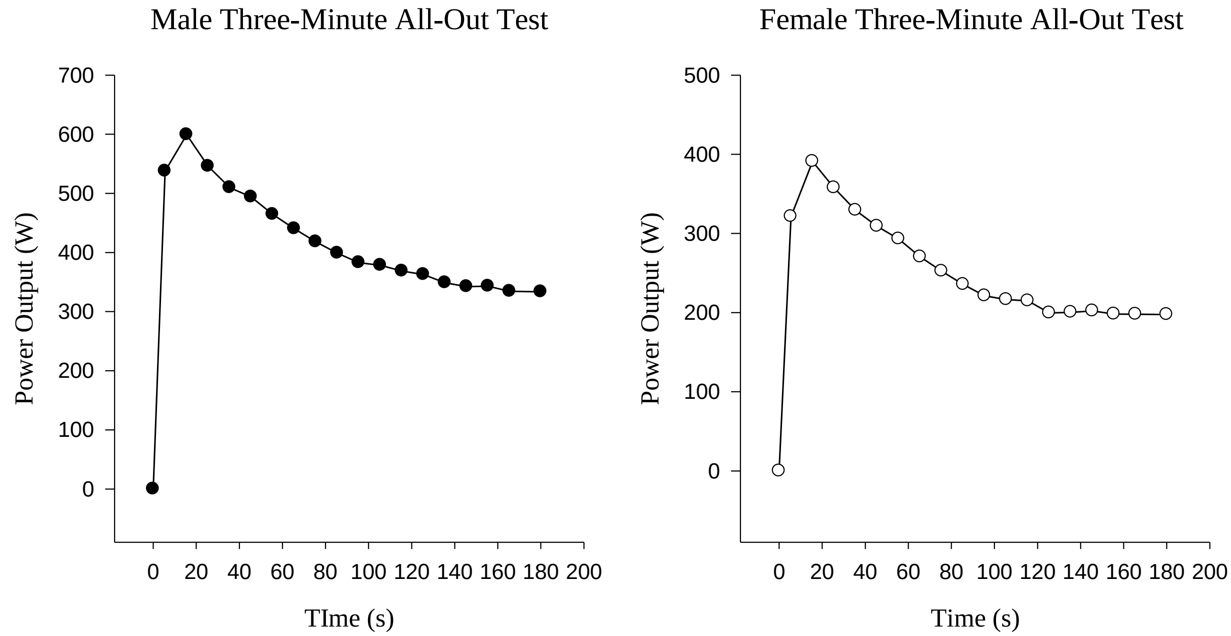

Figure 1. Mean female and male three-minute all-out test POs over time presented in 10 s increments. The expected PO trend of an all-out three-minute test can be seen with participants of both sexes executing an all-out start with PO decreasing until the asymptote of CP is reached in the final 30 seconds of the test.

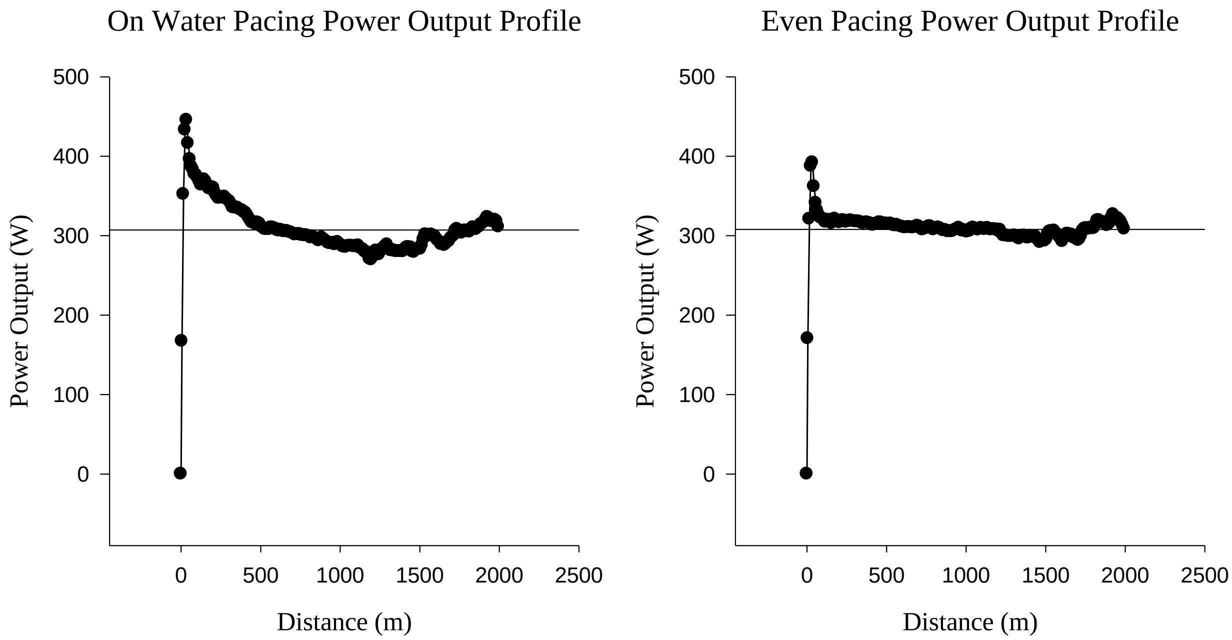

Figure 2. The group's mean PO profile in 10 s increments of both the parabolic and even pacing strategies. The differences in PO over the course of the 2000 m effort can be seen with the dashed horizontal line showing the average PO for each trial. Mean POs were similar between parabolic and Even Pace strategies ($p>0.05$).

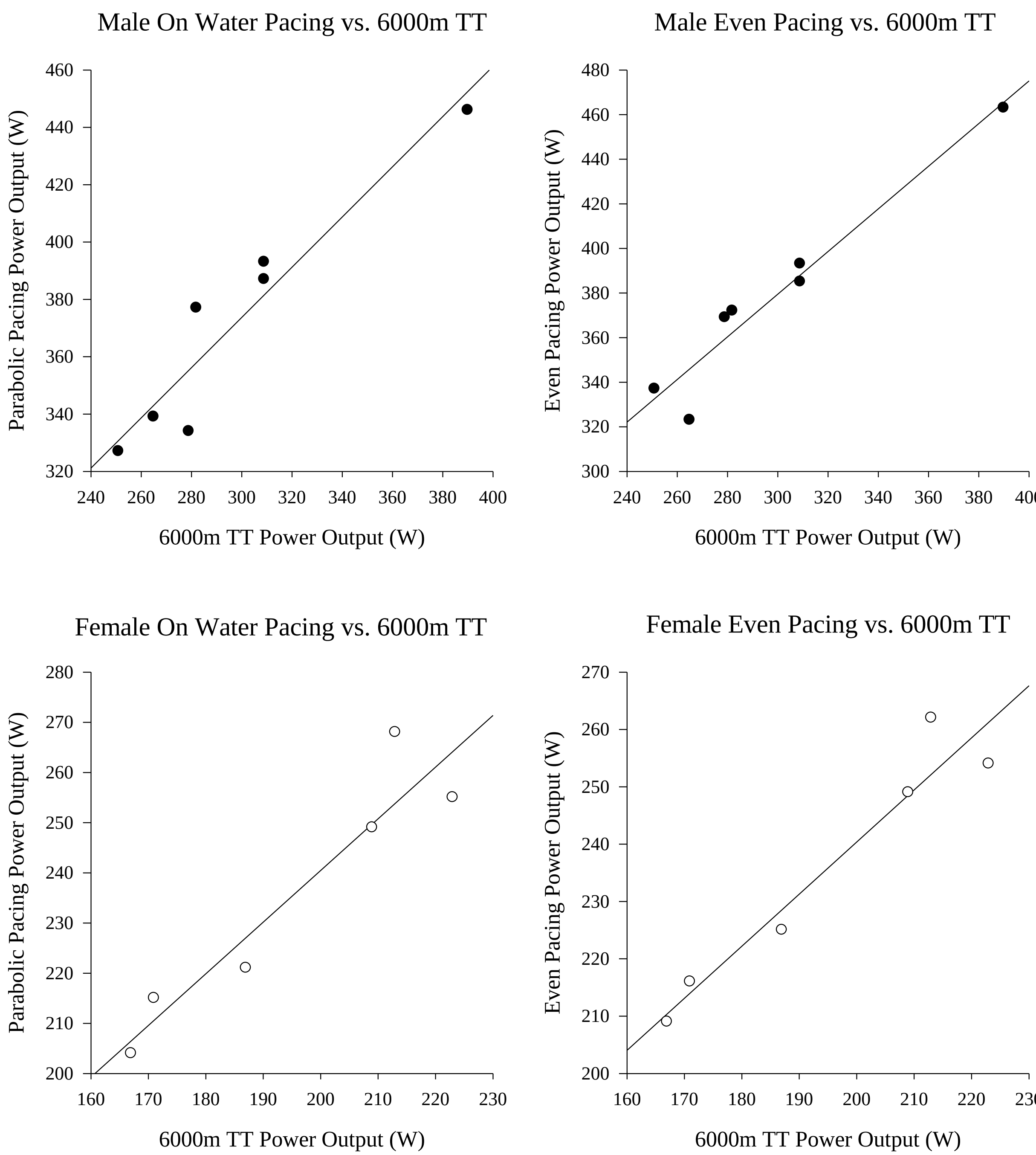

Figure 3. Group POs from both pacing strategies correlated with 6000 m PO can be seen. Both pacing strategies exhibit a significant strong positive correlation to 6000 m PO (On Water r= 0.867. Even Pace r=0.900 p<0.05. Male: On Water r=0.754 p=0.0502 Even Pace r=0.875 p=0.001. Female: On Water r=0.945 p=0.004 Even Pace r=0.965 p=0.002).

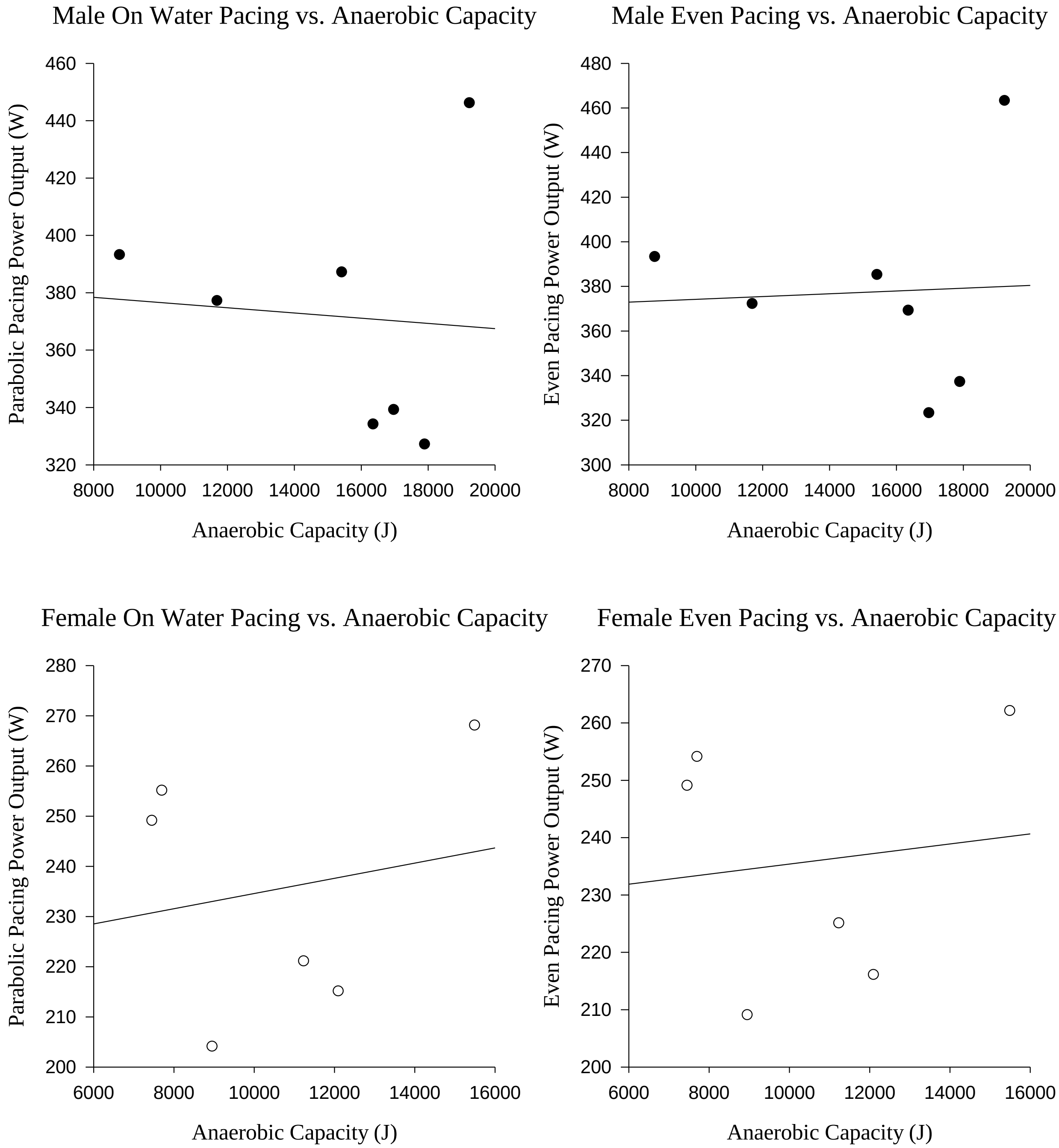

Figure 4. Group POs from both pacing strategies correlated with anaerobic capacity measured from the three-minute all-out test. Both pacing strategies exhibited a moderate positive correlation to anaerobic capacity. The group correlation was not significant in the parabolic pacing strategy but significant for the even pacing strategy (On Water $r=0.058$ $p>0.05$. Even Pace $r=0.046$ $p<0.05$. Male: On Water $r=-0.079$ $p=0.866$ and

Even Pace r=0.051 p=0.914. Female: On Water r= 0.183 p=0.729 and Even Pace r=0.123 p=0.816

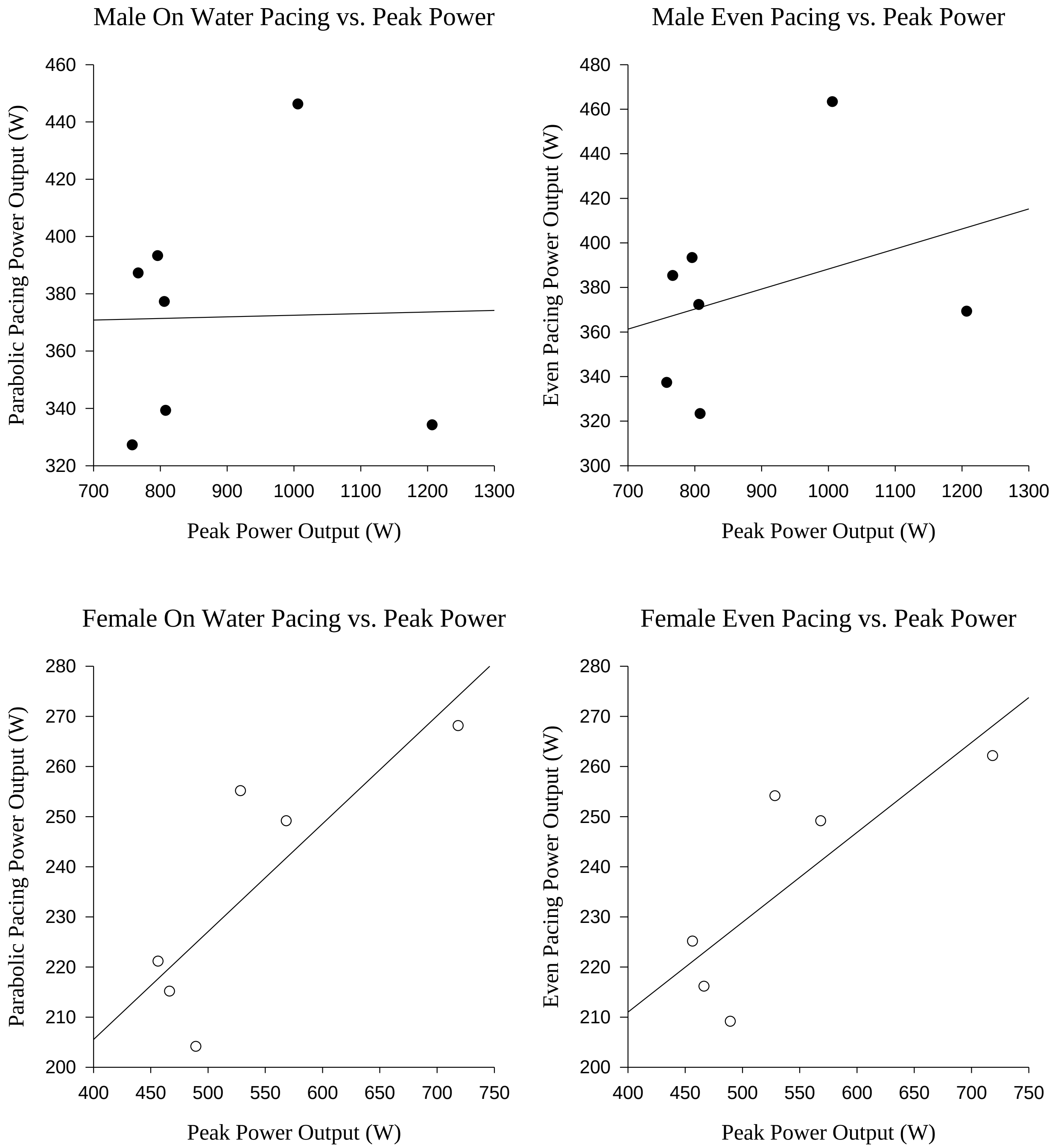

Figure 5. Group POs from both pacing strategies correlated with peak POs. Pacing strategies were strongly and significantly correlated with peak power for females but not for the male On Water strategy (Group: On Water r=0.771 p<0.05 Even Pace r=0.828

$p<0.05$. Male: On Water $r=0.022$ $p=0.962$, Even Pace $r=0.332$ $p=0.467$; Female: On Water $r=0.826$ $p=0.043$ Even Pace $r=0.796$ $p=0.058$).

2.4 Discussion

No current literature has compared pacing strategies in the sport of rowing, or challenged the current traditional fast-starting parabolic strategy used parabolic at an elite level (Garland, 2005). Consequently, the purpose of the present study was to compare the traditional parabolic (On Water) pacing strategy used in rowing races against an Even Pacing strategy performed on a rowing ergometer.

The main findings of the present study show that the On Water pacing strategy utilized by elite rowers elicited similar performances as the Even Pacing strategy over a 2000 m rowing race when performed on a rowing ergometer. Furthermore, no pacing strategy performance differences were observed in either sex or experience level. Supplementary findings of the current study however, showed significant differences between the utilization of W′ between both On Water and Even Pace strategies and the three-minute all-out test in females. Moreover, the predicted times for the 2000 m trial for females, based on their CP and W′ data from the three min all-out tests, were slower than their actual 2000 m On Water and Even Pacing rowing ergometer performance times ($p<0.05$), whereas male predictions and actual performance times were the the same ($p>0.05$).

The mean PO between both pacing strategies in the present study was not significantly different (Table 2). This is contradictory to previous literature that suggests an even pacing strategy is optimal for moderate duration events (De Koning et al., 1999; Foster et al., 1993; Fukuba & Whipp, 1999; Van Ingen Schenau et al., 1990). An even pacing strategy has been suggested to be a compromise between a fast-starting strategy that creates fatigue inducing metabolites early in the exercise bout, and a slow starting strategy which may limit performance as this lost time cannot be recovered (Fukuba & Whipp, 1999). An even pacing strategy has also been supported from theoretical pacing models that have suggested that any deviation from the highest constant PO possible for the duration of the event will result in a suboptimal performance (Fukuba & Whipp, 1999). Also, rowing shell water dynamics suggest that if velocity increases in a linear fashion, the additional fluid drag increases in an exponential fashion that will result in reduction in the change in power to the change in velocity of the rowing shell. It has been suggested that this loss in efficiency should be avoided (Van Ingen Schenau et al., 1990; van Schenau et al., 1994).

Others, however, have observed alternative findings whereby a fast-starting strategy was found to be superior (Aisbett et al., 2009). Still others found no differences in performance between fast start and evenly paced pacing strategies (Bailey et al., 2011). Support for the fast-starting strategy in moderate duration performances has been attributed to the speeding of VO_2 kinetics at the onset of the performance that elicits speeded oxygen uptake kinetics which increases the aerobic energy system contribution (Aisbett et al., 2009) while decreased duration to attain VO_2max (Jones et al., 2008; Wood et al., 2014). This has been suggested, perhaps erroneously, to spare anaerobic capacity for use during the latter stages of the performance (Jones et al., 2008; Wood et al., 2014) since these fast-start strategies have been shown to produce more fatigue inducing metabolites that have resulted in decrements to performance compared to evenly pace strategies (Bailey et al., 2011; Foster et al., 2004). The tradeoff between the speeded oxygen uptake kinetics and the increased fatigue inducing metabolites is unknown, as such, it is difficult to demonstrate that one strategy is superior to the other based on the counter balancing effect of the two energy systems.

Similar to the present study, Bailey et al., (2011) observed no differences in performance, regardless of fast start or even pacing strategies in six-minute cycling trials. The underpinning mechanism suggested for these comparable performances was credited to the attainment of VO_2max coupled with the complete expenditure of W′ (Bailey et al., 2011). This is in agreement with the current study as PO of both strategies were similar and the work ascribed to the anaerobic systems (W′) was also equal (Table 2). It has also been suggested that the performance enhancing effects of a fast-starting strategy which has been highly supported for shorter duration events decreases as duration increases (Bailey et al., 2011; Bishop et al., 2002; Van Ingen Schenau et al., 1990; van Schenau et al., 1994).

In the present study, sex did not affect pacing strategy performance (Table 2). This is in agreement with Lewis et al. who showed that when sex differences in body composition, metabolic and cardiorespiratory responses were controlled, men and women produce similar performances over a 15 mile running race (approximately 115 minutes) (Lewis et al., 1986; Pate et al. 1985). Furthermore, Fawkner et al. observed no male/female differences in VO_2 kinetic responses to high intensity exercise that would effect performance (Fawkner et al., 2002).

Similar to sex, experience level of the participants of the present cohort did not reveal performances differences between the On Water strategy and the Even Pace strategy (Figure 7). This is in conflict to previous 10 km running research, that showed that participants with greater experience and higher performance levels utilize a different pacing strategy, as they ran the initial 400 m at a significantly faster pace compared to their average speed than those with less experience (Lima-Silva et al., 2010). These different pacing strategies have been associated with the much shorter race duration of the high performing runners (Lima-Silva et al., 2010). Moreover, Brown et al. demonstrated that elite, national and sub-elite rowers all execute different pacing strategies both in parabolic and indoor rowing races (Brown et al., 2010). Elite rowers showed lower variations in speed during the 2000 m race, as opposed to national and sub-elite athletes pacing through the middle 1000 m show a significant variation in speed with final 500 m of the race being the fastest (Brown et al., 2010). The ideal elite profile appears to be based on achieving a nearer even paced profile but with a fast start as 100% of rowing race winners have been placed in the top three at the middle of the race (Brown et al., 2010). Large deviations in speed through the middle of the race for national and sub-elite rowers may be attributed to the maintenance of proper technique due to fatigue (Brown et al., 2010). The null differences between pacing strategies of the current study challenge the observations of both Lima-Silva et al. and Brown et al. It is suggested that this difference between the current study and these aforementioned studies may be due to fact that specific pacing strategies instructions were given to the participants in the present study, as well as the Even Pace splits being based on each individual's CP and W′ (e.g. Constant power pace = CP+W'/t). No such pacing prescriptions were given to the Brown et al. rowers. Further, Brown et al., instructed the participants of differing experience levels to self-select their pacing strategies. Therefore, our findings suggest that rowers with both greater and lesser experience are capable of executing both an even pacing strategy and an elite traditional parabolic pacing strategy. Furthermore, it is possible that greater experience may have a role to play when selecting each individual athlete's pacing strategy based on the typical pacing strategies of their competitors, as well as their own preferences and/or comfort level within any given race. For example, does the athlete perform better when leading? Or does the athlete like to "come from behind". In essence, selection of the appropriate pacing strategy may depend on other factors besides the CP and W′ of the athlete. This being said, the present study was limited by its small sample of higher experienced participants. Despite the statistical significance observed between the higher and lower experience level groups, the small population suggests these results should be interpreted with caution and require further investigation with greater sample numbers.

In the present study, the nationally identified group of rowers within this population demonstrated a significant correlation between 6000 m and the On Water pacing strategy PO, but no significant correlation with the Even Pacing strategy (Figure 7). This finding that a fast-starting pacing strategy correlates with rowers of a high performing caliber is in line with that of Lima-Silva et al. who identified that higher performing runners in a 10 km race, utilized a faster starting pacing profile compared to lower performing runners (Lima-Silva et al., 2010). It is suggested that this strategy enables the rowers to keep their fellow competitors in their sights and can respond to accelerations by these opponents in a parallel manner. Moreover, the greater utilization of anaerobic capacity at the start of an even pacing strategy may explain the greater correlation of the Even Pacing strategy 2000 m power output and anaerobic capacity of the rowers. However, as previously mentioned, it is acknowledged that there is a tradeoff between in order to achieve faster VO_2 kinetics at the onset of exercise there also results in a higher utilization of W′ during this same period. Further research is required determine the net sparing of anaerobic capacity with a faster starting strategy.

Supplemental findings of the present study, confirming that which others have shown, include the strong correlation of aerobic capacity (6000 m performance) and peak power (10 stroke maximal effort on the rowing ergometer) to 2000 m performance (Kendall et al., 2011; Russell et al., 1998). It has previously been suggested that peak power (maximal power over 10 strokes on a rowing ergometer) is a strong predictor of 2000 m rowing performance, this present study concurs with this result (Ingham et al., 2002; Riechman et al., 2002). Furthermore, a modest correlation was observed between anaerobic capacity and 2000 m performance in the present study. Previous authors have proposed that this correlation is directly associated with the small but notable, anaerobic contribution (≈ 16%) to 2000 m rowing performance (Kendall et al., 2011; Russell et al., 1998). However, upon separating male and female W′ data it is suggested that there is no correlation between anaerobic capacity and 2000 m rowing power output. These cumulative findings suggest that the product of strength and speed, i.e. the power of the ATP-PCr and anaerobic glycolytic systems, coupled with the capacity of these systems is critical to optimal performances. Our data also suggest that aerobic capacity and power are critical components of 2000 m rowing performance, and should be priorities within a rowing training program, while anaerobic capacity did not reveal itself to be correlated with 2000 m rowing performance and therefore should comprise a much smaller proportion of a training program.

The male On Water pacing strategy did not have a significant correlation with the 6000 m aerobic capacity marker suggesting that other factors (VO_2 max and peak power) may be more important in males for this pacing strategy (Figure 3 and 6). Earlier work has observed sex differences in pacing selection as males have been shown to opt for a fast-starting pacing strategy, whereas females opt for a more even pacing profile in 800 m running and Olympic distance triathlon (Filipas et al., 2018; Le Meur et al., 2009). Whether this is associated with greater peak power in males vs. females would be an area for future research. Losnegard et al., however, suggested that for lower performing male cross-country skiers, an even pacing strategy is recommended to improve performance as technique breakdown during intermitted supra-maximal efforts may have a detrimental affect lower performing athletes more (Losnegard et al., 2016). This finding would seem to be relevant to the current study as the majority of male participants were of varsity, as opposed to elite caliber rowers. Since the On Water pacing strategy was derived from that of elite rowers, the absence of a correlation between the On Water strategy and the 6000 m performance may have been associated with a breakdown in their technique during the On Water performances. Even though the technique degradation with fatigue would not be to the seen to the same extent on an indoor rowing machine compared to rowing in a boat on the water, the effects of fatigue on recruitment pattern and muscle efficiency and coordination may still be present. However, the similar performances between strategies suggest that the breakdown in technique would have been minimal. As the male On Water correlation with 6000 m performance approached statistical significance, it is suggested that the importance of aerobic power is not to be underestimated in this group.

Male/female differences were observed as female peak power was only significantly correlated with the On Water pacing strategy, not the Even Paced one. This may be indicative of higher anaerobic demands of the start in the On Water strategy that would require greater type II fiber recruitment. Earlier research has suggested that females rowers have shown an increased proportion of type II fibers compared to male rowers, which may explain the significant correlation to the On Water strategy in females while no significant differences between pacing strategies are seen in the male population (Hagerman, 1984).

An unexpected finding observed during this study was the disconnect between female participants' anaerobic capacity, as calculated from the three-minute all-out test, and the calculated anaerobic capacity of the female participants during the 2000 m trials (Table 1 and 2). It suggested that the three-minute all-out test either over estimated critical CP, or underestimated W′, or a combination of both in the female rowers in this study. Both pacing strategies, however, demonstrated equal but higher W′ than the three-min all-out test (Tables 1 and 2). This is consistent with Bartram et al. who showed a similar result in elite cyclists from the three-minute all-out test (Bartram et al., 2017). Sexes of the participants were not disclosed in Bartram et al.'s study (Bartram et al., 2017) so comparisons with the current study results are limited. Past literature has suggested that the use of a three-minute all-out test on a rowing ergometer is an appropriate estimate of aerobic capacity and CP in rowers; however, anaerobic capacity from the three-minute all-out test on the rowing ergometer did not correlate with anaerobic capacity estimated from three constant workload trials to exhaustion (Cheng et al., 2012), suggesting that the reduced efficiency of the rowing action, coupled with an increase in type II fiber composition in females may skew the anaerobic capacity determinations from the three-min all-out test. The original research presenting the validity and reliability of the determinations of CP and W′ from the three-minute all-out test, also did not disclose the sex of participants within their study (Burnley et al., 2006).

Within the context of the rowing modality of the present study the three-minute all-out test appears to result in valid values for male CP and anaerobic capacity determinations, as evidenced from the similar predicted and actual 2000 m PO that was observed by the male participants performed on both pacing strategies.

While significant correlations were found between pacing strategy power output and physiological characteristics, the study is limited by the small sample size of the sub groups. The small differences in p-values between pacing strategy correlations and some physiological characteristics while interesting may be created by the low sample sizes of the subgroups. Limited recommendations of pacing strategy sex or experience level of rowers should be given based on this study. The secondary findings looking at subgroups of experience level may especially not be meaningful as the sample included only four participants in the HUB group.

2.5 Conclusion

In conclusion the major finding from this study is that over a 2000 m rowing ergometer performance, the traditional parabolic fast-starting (On Water) pacing strategy and Even Pacing strategy suggested resulted in similar performances on the rowing ergometer. This phenomenon also appears to be independent of a rower's sex or experience level. A supplemental finding of this study was that while the three-minute all-out test was valid for use amongst male participants on a stationary rowing ergometer, the female results revealed discrepancies between the determinations of W′

between both the pacing trials and the three minute all-out test, further research is required in order to determine the validity of the use of a three-minute all-out test on a rowing ergometer with female participants.

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Appendix:

Date: 28 January 2020

To: Dr. Glen Belfry

Project ID: 111088

Study Title: The effect of differing 2 km pacing strategies on energy system contribution and performance in rowing.

Application Type: Continuing Ethics Review (CER) Form

Review Type: Delegated

REB Meeting Date: 11/Jan/2020

Date Approval Issued: 28/Jan/2020

REB Approval Expiry Date: 31/Jan/2021

Dear Dr. Glen Belfry,

The Western University Research Ethics Board has reviewed the application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

Western University REB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The REB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Daniel Wyzynski, Research Ethics Coordinator, on behalf of Dr. Joseph Gilbert, HSREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Curriculum Vitae

Name:

Ryan Clegg

Post-secondary Education:

Western University,

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Degrees:

Western University

2014-2018 B.A

Related Work Experience :

Teaching Assistant Western University 2018-2020