THE ECONOMY OF ROWING AT SELECTED STROKE RATES ON A CONCEPT II INDOOR ROWING ERGOMETER
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My thanks go to my dissertation supervisor Michael Hughes, for all of his hard work and support over the past year. Also to the laboratory technicians, Danny Newcombe and Mike Stembridge, for their effort in training me on use of equipment, and making available time when I needed their help. Thanks also to the subjects who gave up valuable time to volunteer to take part in the study.
ABSTRACT

In cycling, the affect of cadence on oxygen consumption (\(\dot{V}O_2\)) has been widely studied. However, in rowing, research is scant. This investigation therefore aimed to establish whether stroke rate affected the economy of rowing.

Male (n = 6) and female (n = 2) club level rowers (Mean ± SD: Age: 22.1 ± 3.4 yrs; Height: 178.1 ±7.9 cm; Mass: 74.3 ±10.3 kg; \(\dot{V}O_{2\,\text{max}}\): 4.2 ±0.7 L·min\(^{-1}\)) volunteered to undertake an incremental test on a concept II rowing ergometer to establish \(\dot{V}O_{2\,\text{max}}\). Subjects then returned and performed three four-minute bouts of rowing, at 70% of \(\dot{V}O_{2\,\text{max}}\) at a self-selected stroke rate (18.6 ± 1.5 s·min\(^{-1}\)), 20% higher than self-selected stroke rate (22.3 ±1.5 s·min\(^{-1}\)) and 20% lower than self-selected stroke rate (15.0± 1.3 s·min\(^{-1}\)). Measurements of \(\dot{V}O_2\), \(\dot{V}CO_2\), R value and VE were collected and heart rate (HR) recorded for both tests. Rating of perceived exertion (RPE) was also collected for the second test.

A change in stroke rate did not affect economy (\(P = .074\)). HR was significantly different (\(P = .001\)) and was lowest at self-selected stroke rate. RPE was statistically different (\(P = .007\)), with lowest values found for self-selected stroke rate.

Stroke rate did not significantly affect economy, however this could be due to the small variation in stroke rates used in the study. A change in stroke rate affects HR more than \(\dot{V}O_2\). This could lead to difficulties in training prescription, as a change in stroke rate would lead to a change in HR but not necessarily \(\dot{V}O_2\). Rowers should choose a stroke rate they perceive to be easiest. Further investigation is required to establish whether economy is affected by a larger variation of stroke rate, and whether this is important in rowing.
1.0 INTRODUCTION

1.1 ROWING

Rowing over 2000 m takes between six and seven minutes, depending on the type of boat and number of rowers present, and requires maximum effort (Steinacker et al., 1986) relying heavily on the aerobic energy system to provide the required energy (Cosgrove et al., 1999; Hagerman et al., 1978; Mickelson and Hagerman, 1982). A 2000 m rowing race stresses the aerobic, anaerobic lactic and alactic capacities to their maximum (Steinacker, 1993). Pripstein et al. (1999) studied 16 female rowers undertaking a 2000 m rowing test on a concept II rowing ergometer. It was reported that the anaerobic energy system contributed 12% to the total energy requirement of the work. Hagerman et al. (1978) conducted a study involving 310 competitive oarsmen however showed that the aerobic contribution was 70% whilst anaerobic was 30%.

During racing, average stroke rates reach up to 35-40 strokes per minute (s·min⁻¹) for Olympic athletes (Kleshnev, 2005). However, as much of rowing training is performed at low intensity with blood lactate values of around 1.4 mmol⁻¹ (Steinacker et al., 1998), stroke rates utilised are far lower, between 18 and 22 s·min⁻¹. When racing, crews tend to sprint the first 500 m to gain a lead, and then settle into a more sustainable rhythm. Crews that medaled at the Sydney Olympic Games were 2.4% faster in the first 500m, 1.2-1.3% slower in the second and third 500 m, and 0.2% faster in the final 500 m compared to their average velocity (Kleshnev, 2001).

1.2 VO₂max

The ability to maximally consume oxygen (VO₂max), is of great importance, and has been found to be one of the greatest single predictors of 2000 m rowing performance (Cosgrove et al., 1999; Gillies and Bell, 2000; Perkins and Pivarnik, 2003; Kramer et al., 1994). Olympic oarsmen have been found to have VO₂max values of over 6.5 L·min⁻¹ (Hagerman et al., 1978). Other factors; such as lean body
mass (Cosgrove et al., 1999; Slater et al., 2005) and strength (Gillies and Bell, 2000) have also been reported to predict rowing performance.

During a 2000 m time trial on a rowing ergometer, athletes have been found to use up to 98% of \( \text{VO}_{2\text{max}} \) (Hagerman et al., 1978) and up to 98% of age predicted maximum heart rate (Perkins and Pivarnik, 2003). \( \text{VO}_{2\text{max}} \) is therefore of great importance and has been shown to account for 75% in variation of performance (Kramer et al., 1994).

### 1.3 ECONOMY

Economy can be defined as the volume of oxygen consumed by the working muscles at a given steady state workload (Cosgrove et al., 1999). Rowing performance is affected by the economy of the athlete, and variation is observed between performers (Perkins and Pivarnik, 2003). Few studies have investigated the economy of rowing. Maclennan et al. (1994) investigated the effect of entrained breathing on economy, however used non-rowers. This may have limited the results as the subjects had not performed any previous rowing training, thus they would not have been used to rowing movements and poor technique may have been adopted. Jensen et al. (1996) performed a study involving male university rowers \((n = 28)\), investigating the efficiency during near maximal rowing in a water tank. The authors found that the study was unable to correlate gross efficiency with any other measures taken. This included height, mass, \( \text{VO}_{2\text{max}} \) (expressed in relative, ml·kg\(^{-1}\)·min\(^{-1}\), or absolute L·min\(^{-1}\) terms), combined leg strength, time to complete 2000 m and maximal lactate during a \( \text{VO}_{2\text{max}} \) test.

The economy of rowing is a combination of not only physiological economy, oxygen consumption for a given power output, but also biomechanical efficiency, the efficiency of movement of the body, and mechanical efficiency, efficiency of the boat and the blades for example (Kleshnev, 1999).
1.3.1 Cycling Economy

In other sports there has been a great deal of research investigating economy, such as cycling (Chavarren and Calbet, 1999; Coast et al., 1986; Coyle et al., 1992) and running (Conley & Krahenbuhl, 1980; Morgan et al., 1989; Jones & Carter 2000; Horowitz et al., 1994), highlighting the importance of economy in athletic performance. In cycling, the most economical cadence has been found to increase with increasing workload (Foss and Hallen, 2004; Coast et al., 1986). Coast et al. (1986) found that at optimum cadence, oxygen consumption ($\dot{V}O_2$) averaged 86% of maximum, whilst at the least efficient cadence of 40 or 120 revolutions per minute (rpm), depending on the variation of subjects, $\dot{V}O_2$ averaged 90% of maximum, and resulted in greater blood lactate levels.

At low pedal frequencies (or low cadence), one of the reasons for increased lactate accumulation could be due to decreased blood flow to the legs (Gotshall et al., 1996). High standard cyclists tend to pedal at a higher cadence, between 90 and 105 rpm, far higher than the most economical (Lucia et al., 2004; Chavarren and Calbet, 1999; Marsh and Martin, 1997). This may be due to adaptations taking place during training so that the athletes are better able to meet the demands of 90-105 rpm (Marsh and Martin, 1997).

1.4 MUSCLE FIBRE TYPE

Coyle et al. (1992) showed that type I muscle fibres are more efficient than type II fibres. This was as a result of athletes with a high percentage of type I fibres eliciting a lower $\dot{V}O_2$ for the same power output than those with a high number of type II fibres. Type II muscle fibres maximally contract between three to five times faster than type I fibres (Fitts et al., 1989), which contract at between 1 and 5 fibre lengths per second at peak efficiency (Fitts et al., 1989). It has been noted that whilst cycling at 80 rpm, as used in many studies (Horowitz et al., 1994; Coyle et al., 1992; O'Toole et al., 1989; Coyle et al., 1991), the vastus lateralis contracts at about 1 to 1.5 fibre lengths per second (Coyle et al., 1992; Fitts et al., 1989). This could
account for a difference in economy due to those with a high percentage of type I muscle fibres contracting a larger percentage of muscle fibres closer to the velocity for peak efficiency of type I fibres, than those with a higher percentage of type II fibres (Horowitz et al., 1994). This area has not been greatly studied in rowing, and would require more research to examine whether this would be observed to the same extent as it has in cycling.
CHAPTER III – METHODOLOGY
3.0 METHODOLOGY

3.1 SUBJECT RECRUITMENT

After ethical approval being granted from the University Research Ethics Committee, eight subjects, consisting of two male heavyweight, four male lightweight, one female heavyweight and one lightweight rowers were recruited from Rhwyfo Cymru rowing club, based in Cardiff. The coach was initially approached and asked whether he would allow his athletes to take part in the study, if they felt so inclined. The outline of the study, and what would be involved of the participants was clearly described to allow the coach to make an informed decision. Following permission being granted by the coach, athletes were approached and asked whether they would like to take part in the study. If an interest was shown, an information sheet (attached in Appendix A) was given to them, for extra information, and taken away for a final decision to be made. If the athlete did not show an interest, then they were thanked for their time and were not approached again. For those who did want to take part in the study, details were taken, such as training, study and work commitments, in an attempt to find a time suitable for the subjects to be participants in the study, which did not interfere with these commitments. Subjects were required to attend the laboratory on two occasions, separated by at least two days and a maximum of seven days to ensure subjects were not fatigued from the original incremental test.

3.2 PILOT STUDY

Two subjects (one male and one female) participated in a pilot study in order to make sure that the test procedure was effective. Informed consent was obtained and a PAR-Q was completed by the test subjects. Height (Holtain fixed stadiometer, Holtain Ltd, Pembrokeshire, UK) and mass (SECA 770 digital weighing scales, SECA, Hamburg, Germany) were recorded and the ergometer’s drag factor (136 for males, 128 for females) was set up ready for the test. The subjects then completed a continuous incremental test on the rowing ergometer (Concept II Model C, Vermont,
USA) until volitional exhaustion. The test consisted of 3 min stages starting at a power output of 200 W for males and 130 W for females, increasing the power output by 30 W after each stage. During the test heart rate data was recorded every 5 s and gas analysis was carried out. Following the test the subjects were encouraged to perform a warm down and remained under supervision for 20 min to ensure the participants safety. It was noted for the male subject that a power output of 200 W elicited a value of above 70%. It was decided to amend the initial stage to 190 W, rather than 200 W, in order that subjects would work at a \( \text{VO}_2 \) lower than 70% of \( \text{VO}_2\text{max} \) during the first stage. The procedure for the female subject was deemed sufficient and no changes to the procedure were made. On the basis of the initial stage being lowered by 10 W for heavyweight males, the initial stage for lightweight males was also lowered by 10 W, from 190 W to 180 W. This was to ensure that lightweight males would exercise at a similar % of \( \text{VO}_2\text{max} \) as the heavyweight males during the first stage.

3.3 CONTINUOUS INCREMENTAL ROWING TEST

Once an 'adequate' informed consent form (attached in Appendix A) was completed, and received by the principal investigator, a PAR-Q (attached in Appendix B) was also completed to ensure the participants were healthy to take part in the study. Anthropometric data was collected including mass and height. Date of birth of the subjects was also recorded, best time for completing 2000 m on a rowing ergometer and the date for this time.

A continuous incremental rowing test on a concept II model C indoor rowing ergometer was completed by all subjects during the initial visit to the laboratory. The test aimed to last between 14 and 20 minutes in order to establish \( \text{VO}_2\text{max} \). The ergometer’s drag factor was set to 136 for heavyweight males, 134 for lightweight males, 128 for heavyweight females and 125 for lightweight females, and shoe heights were moved for each participant’s individual requirements. The drag factors used were based upon those used by athletes when completing ergo tests for the
Great Britain rowing team. Drag factor was lowered by 2 for heavyweight males and females as these athletes were below the standard of those athletes trialing for the Great Britain rowing team, and do not usually train at that drag factor. Subjects were instructed to row at a self-selected cadence throughout the test. They were also informed that it would be a maximal intensity test and that they may feel discomfort, however, no different to what they would often feel during intense training. Subjects were also informed to continue until they could not physically continue, or until the investigator instructed them to stop.

Heavyweight males initially rowed at 190 W, a 500 m split time of 2 min 3 s, lightweight males at 180 W, a split of 2 min 5 s, heavyweight females at 130 W, a split of 2 min 20 s and lightweight females at 115 W a split of 2 min 25 s. Subjects then reduced the split by 30 W, which equated to around 5 s every three minutes, until volitional exhaustion, or until the investigator instructed them to stop. Power output (W) was converted into 500 m split time (min: sec) as it was decided that it would be far easier for subjects to row at a pace, rather than at a power output, as subjects were far more used to rowing at a selected pace than power output in training.

Once the test had been completed, subjects were encouraged to perform a warm down and were supervised for at least 20 minutes to ensure the subject’s safety. During the test heart rate was recorded every 5 s using a polar heart rate monitor (Polar S610 monitor, Polar electro, Finland) and expired gas was analysed using online gas analysis (Oxycon Pro, Jaeger, Warwick, UK) in order to quantify whether subjects had reached \( \dot{V}O_2 \text{max} \). The test was deemed to have ended once subjects were unable to maintain a split within 2 s of the required pace and had met at least two of the following; a heart rate value of within 10 beats of age predicted maximum, an R value of 1.15 or above and an increase in \( \dot{V}O_2 \) of no more than two ml.kg\(^{-1}\).min\(^{-1}\) in two minutes.
A graph was then plotted with the mean power output of each stage against $\dot{V}O_2$ and 70% of $\dot{V}O_{2\text{max}}$ was then calculated and plotted on the graph to determine the power output that would elicit 70% of $\dot{V}O_{2\text{max}}$ (shown in Appendix C). The power output was then converted back into a 500 m split time and rounded to the nearest second. This split was then to be held during the subsequent economy tests. The recorded data, including heart rate data and gas analysis data, were averaged over a thirty second period to find the mean value. For example, $\dot{V}O_2$ data was averaged over thirty seconds during the time period of 2 min 30 s to 3 min 0 s to give a $\dot{V}O_2$ value for three minutes into the test.

### 3.4 ECONOMY TEST

Subjects returned to the laboratory one further time, after at least two, and a maximum of seven days following the initial testing. The ergometer’s drag factor was once again set to the required levels, as previously stated, and shoe heights were varied for each subject. Subjects were instructed on how to use the BORG rating of perceived exertion scale (Borg, 1998) and familiarised themselves with the scale (attached in Appendix D). The test comprised of rowing at the selected split time (velocity at 70% of $\dot{V}O_{2\text{max}}$) calculated from the incremental rowing test, for four minutes at a self-selected stroke rate. Four minutes was selected as the duration as this allowed steady state to be reached, by about three minutes, before the time at which heart rate and gas analysis values were calculated. During the test heart rate was recorded every 5 s and expired gas was analysed throughout. Once the test was completed, subjects were required to select a RPE value from the BORG scale.

Subjects then rested for five minutes before completing the second test, and another five minutes before completing the third and final test. The protocol was the same as the previous test, however using a different stroke rate (Table 1). The stroke rates for the second and third test were calculated by adding or subtracting 20% to or from the stroke rating held in the first test. For example, if a stroke rate of 20 s·min$^{-1}$ was held during the initial test, the stroke rating in the second test would be 24 s·min$^{-1}$
(20 s.min\(^{-1}\) + 20% = 24 s.min\(^{-1}\)). The third test for this subject would involve rowing at 16 s.min\(^{-1}\) (20 s.min\(^{-1}\) - 20% = 16 s.min\(^{-1}\)). These were labeled 1 for initial stroke rating, 2 for initial rating plus 20%, or 3 for initial stroke rating -20%. The order of tests was varied to ensure that this did not bias the results (Table 1).

**Table 1.** Stroke rates held in each test by each subject. Stroke rate 1 refers to self-selected stroke rate, 2 refers to 20% higher than self-selected stroke rate and 3 refers to 20% lower than self-selected stroke rate.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Stroke rate held in Test 1</th>
<th>Stroke rate held in Test 2</th>
<th>Stroke rate held in Test 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>3</td>
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<tr>
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<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Once the three tests had been completed, subjects were encouraged to take time to perform a warm down lasting five to ten minutes, and perform stretching to minimise the effect that the testing may have had on later training.
3.5 DATA ANALYSIS

During the incremental rowing test and the economy test, all gas and heart rate data was averaged over the final thirty seconds of each stage. Heart rate was converted into, and expressed as a percentage of age predicted heart rate max (HRmax = 220 – age) due to the wide age range of the subjects (19 – 30 years). VO2max was considered to be the highest VO2 value recorded over a thirty second period at any point during the incremental rowing test. Data was then entered into a Microsoft Excel spreadsheet, before being processed by SPSS. A one-way ANOVA with repeated measures was carried out using the Bonferroni level of confidence.

3.6 ETHICAL ISSUES

This study did not involve subjects under 18 and all subjects prior to data collection gave informed consent and completed an adequate PAR-Q. Subjects were informed that they might feel dizzy, out of breath, nauseous and pain from lactate during or after the test to reduce any shock that may occur from being unaware. However, no more discomfort than usually experienced during a high intensity rowing training session was experienced. Subjects were only tested in the laboratory when they had free time available for such activities, and not during lecture or work time. Data was kept confidential and was only discussed between the supervisor and researcher.
CHAPTER IV –

RESULTS
4.0 RESULTS

Physical characteristics of the subjects including mass, height, age, personal best time for completing 2000 m on a Concept II rowing ergometer and \( \dot{V}O_2 \text{max} \) are shown in Table 2.

Table 2. Mean and standard deviation of mass (kg), height (cm), age (years), personal best time for 2000 m time trial (secs), and \( \dot{V}O_2 \text{max} \) (L-min\(^{-1}\)) of the 8 subjects

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (kg)</td>
<td>74.3 (±10.3)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>178.1 (±7.9)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>22.1 (±3.4)</td>
</tr>
<tr>
<td>2000 m time (sec)</td>
<td>408.4 (±29.4)</td>
</tr>
<tr>
<td>( \dot{V}O_2 \text{max} ) (L-min(^{-1}))</td>
<td>4.2 (±0.7)</td>
</tr>
</tbody>
</table>

The rates held in the economy test are shown below in Table 3. Self-selected stroke rate had a mean value of 18.6 s-min\(^{-1}\), s = 1.5, mean stroke rate held for low stroke rate (self selected – 20%) was 15.0 s-min\(^{-1}\), s = 1.3, and in the high trial (self selected +20%) mean stroke rate was 22.3 s-min\(^{-1}\), s = 1.5. Power output in the three trials is also shown in table 3. The mean required power output for all subjects was 166.25 W, s = 23.2, in each trial.
Table 3. Mean and standard deviation values of stroke rate (s·min⁻¹), and power output (W) across the three trials for all subjects

<table>
<thead>
<tr>
<th>Trial</th>
<th>Rate (s·min⁻¹)</th>
<th>Power output (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (-20%)</td>
<td>15.0 (±1.3)</td>
<td>166.4 (±23.2)</td>
</tr>
<tr>
<td>Self selected</td>
<td>18.6 (±1.5)</td>
<td>166.2 (±23.9)</td>
</tr>
<tr>
<td>High (+20)</td>
<td>22.3 (±1.5)</td>
<td>166.1 (±23.8)</td>
</tr>
</tbody>
</table>

Figure 1 shows the mean absolute oxygen consumption in L·min⁻¹ of the subjects during the three trials. Although there is no significant difference ($P = .085$) between $\dot{V}O_2$ at different stroke rates, a trend is shown. As stroke rate increases, oxygen consumption decreases, being lowest at the higher stroke rate.

Figure 1. Mean $\dot{V}O_2$ (L·min⁻¹) across the three trials (mean stroke rate of 15.0, 18.6, and 22.3 s·min⁻¹)
Figure two shows the mean economy ($W \cdot L^{-1} \cdot \text{min}^{-1}$) of the subjects over the three trials. Difference in economy, although not statistically significant ($P = .074$), showed a trend that increased from the lowest stroke rate, to the self-selected stroke rate, and was greatest for the highest stroke rate.

![Diagram showing mean economy across three trials](image)

**Figure 2.** Mean economy ($W \cdot L^{-1} \cdot \text{min}^{-1}$) across the three trials (mean stroke rating of 15, 18, 22 s$^{-1}$)

Figure three illustrates the mean percentage of age predicted heart rate maximum of the subjects over the three trials. Heart rate was lowest for self-selected stroke rate and rose for both low and high stroke rates. A significant difference between heart rate was found ($P = .001$), with differences between self-selected and low stroke rate ($P = .005$), and between high and low stroke rates ($P = .049$).
Figure 3. Mean percentage of age predicted maximum heart rate (%HRmax) across the three trials (mean stroke rate of 15, 18 and 22 s·min\(^{-1}\)).

Figure 4 shows the mean rating of perceived exertion (BORG rating of perceived exertion) of the subjects across the three trials. A statistical difference \((P = .007)\) was found between the different stroke rates, with differences found between self-selected and low stroke rates \((P = .001)\). At self-selected stroke rate mean RPE was lowest at 9.5, at high stroke rate RPE was 9.8 and at low stroke rate RPE was highest at 11.1.
Figure 4. Mean rating of perceived exertion (RPE) across the three trials (mean stroke rate of 15, 18 and 22 s·min⁻¹)

Table 4 shows the measured mean expired volume (VE) for all subjects across the three trials. There was no significant difference between VE at different stroke rates ($P = .278$), however was lowest for self-selected stroke rate (70.5 L·min⁻¹), and higher for both high (72.8 L·min⁻¹), and low (73.5 L·min⁻¹) stroke rate.

**Table 4.** Mean and standard deviation values of expired volume (VE) (L·min⁻¹) for all subjects across the three trials

<table>
<thead>
<tr>
<th>Trial</th>
<th>VE (L·min⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (Self-selected – 20%)</td>
<td>73.5 (±14.0)</td>
</tr>
<tr>
<td>Self-selected</td>
<td>70.5 (±12.4)</td>
</tr>
<tr>
<td>High (Self-selected +20%)</td>
<td>72.8 (±13.6)</td>
</tr>
</tbody>
</table>
R values for all subjects across the three trials are shown in Table 5. Difference in R value between the three trials was not statistically significant ($P = .055$). R value was lowest at 0.850 at the self-selected stroke rate, and rose to 0.882 for both the increased and decreased stroke rates.

**Table 5.** Mean and standard deviation values of R values recorded for all subjects across the three trials

<table>
<thead>
<tr>
<th>Trial</th>
<th>R value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (Self-selected – 20%)</td>
<td>0.882 (±0.03)</td>
</tr>
<tr>
<td>Self-selected</td>
<td>0.850 (±0.05)</td>
</tr>
<tr>
<td>High (Self-selected +20%)</td>
<td>0.882 (±0.03)</td>
</tr>
</tbody>
</table>
REFERENCE LIST


Lucia, A., San Juan, A.F., Montilla, M., Canete, S., Santella, A., Earnest, C., and Perez, M., (2004). In professional road cyclists, low pedalling cadences are less efficient. *Medicine & science in sports and exercise, 36*(6), 1048-1054.


APPENDICES
APPENDIX A

The information sheet provided to all subjects before the onset of the study. This sheet was also provided with the PAR-Q form (Appendix B) upon the subject’s first visit to the laboratory to provide information for informed consent to be given.

The economy and efficiency of rowing at selected stroke rates on an indoor rowing ergometer

Thank you for showing an interest in taking part in this study. Firstly, I would like to inform you that participation in this study is at your own will, and you have the option to cease participation at any point without any consequences. If you have any questions, please don’t hesitate to contact me via the contact details provided at the end of this information sheet. All information will be treated with the strictest confidence and names of participants will not be included in any write up.

There has been very little research on the efficiency of rowing from a physiological point of view. Maclellan (1994) conducted a study however used subjects who had no rowing experience whilst Jensen et al (1996) used a water tank. There has been even less research into changing stroke rates and its effect on economy. This study aims to therefore investigate this and provide a basis for future research.

Your involvement will consist of visiting the physiology laboratory at UWIC, Cyncoed campus, on two separate occasions separated by at least two days and at maximum seven days to allow for adequate recovery.
Upon the first visit, participants will be required to perform an incremental rowing test to exhaustion. This will last between 14 and 20 minutes and will push your body to its maximum in order to elicit a $\text{VO}_{2\max}$ value (the maximum amount of oxygen that can be consumed by the body). Male subjects will initially row at 2:00 pace for 3 minutes and will then lower the pace by 5 seconds every three minutes until you can no longer continue. Female subjects will do the same however will start at 2:15 pace. As all participants are experienced oarsmen/women this should not be too different from a hard ergometer session, often carried out during training.

The second visit will consist of three sub maximal tests. These tests will be five minutes in duration and you will be required to perform these tests holding a selected 500 m split time, and a cadence, which will vary with each test. This will be easier than the initial testing however will still be physically demanding. Between the three tests you will have 5 minutes to rest, hydrate and recover before the following test.

During the tests you may feel fatigued, dizzy or nauseous however no more than you are used to with your daily training schedule. To minimize the effects however several procedures have been put in place. Once the subject reaches near maximum heart rate, or $\text{VO}_2$ plateau, the test will be stopped to ensure subjects do not exercise to dangerously high levels. Subjects will also be encouraged to perform a warm down following the procedures and will be supervised for at least 20 minutes following the completion of testing.
Whilst exercising you will be required to wear a polar heart rate monitor, and breathe through a mouthpiece, which can be uncomfortable, in order to analyse expired gas. Subjects will not be referred to in data by name. A number will be assigned to each subject to maintain anonymity. Data will be kept on a computer requiring a password to gain access to keep all information secure.

**Contact details**

Laurence Birdsey

Mobile: 07795 571080

Email: l.birdsey@uwic.ac.uk

Before taking part in the test you will need to complete the following information and bring this with you to testing. If you do not wish to take part then I thank you for your interest, and you obviously need not to complete the following.

Name:

Date of birth:

Telephone number:

Local address:
APPENDIX B

A copy of the PAR-Q form used in the study. All subjects completed a PAR-Q before taking part in the study.

Physical Activity Readiness Questionnaire (PAR-Q)

Participants
name..........................................................................................................................

Please circle the answers to the following questions:

1  Do you have asthma or any breathing problems? Yes / No
2  Has your doctor ever said you have heart trouble? Yes / No
3  Do you frequently suffer from pains in the chest? Yes / No
4  Do you often feel faint or have spells of severe dizziness? Yes / No
5  Has a doctor ever said your blood pressure was too high? Yes / No
6  Has a doctor ever said that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise? Yes / No

7.  Is there a good physical reason not mentioned here why you should not take part in a fitness test? Yes / No
8.  Are you unaccustomed to vigorous exercise? Yes / No

If you have answered yes to any of these questions, please add details below. Similarly, if there are any situations which will prevent you from exercising write them here (or let me know if they arise through the experiment).
If your situation changes regarding your responses to these questions, please notify the Researcher

Signed (participant)…………………………………………………………..

Signed (investigator)…………………………………………………………..

Date………………………………………………………………………………

INFORMED CONSENT

I have read and fully understood the request to be a subject of this research. I understand what I have to do. I understand the risks involved, and the measures in place in the event of accident. I understand that participation is entirely voluntary, and that withdrawal is possible at any time. I understand the measures that will be taken to uphold confidentiality as far as possible.

I agree to participate.

Signature ......................................... Date ..........................
The method of calculating the power output for the economy test is shown in Appendix C. 70% of $\text{VO}_2\text{max}$ was calculated from the data from the incremental rowing test. A line was then plotted on the graph from that point, intersecting the $\text{VO}_2$ line horizontally. At the point of intersection, another line was plotted vertically to establish the power output at which 70% of $\text{VO}_2\text{max}$ occurs.
APPENDIX D

The BORG 6-20 scale for Rating of Perceived Exertion used in this study.

Rating of Perceived Exertion

6 – No exertion at all

7
   – Extremely light

8

9 – Very light

10

11 – Light

12

13 – Somewhat hard

14

15 – Hard (heavy)

16

17 – Very hard

18

19 – Extremely hard

20 – Maximal exertion

While exercising we want you to rate your perception of effort. That is how heavy and strenuous the exercise feels to you. The perception of effort depends on muscle effort as well as your feeling of breathlessness.
Try not to overestimate or underestimate your perception and take into account whole body sensation, not just the feeling in your legs or chest.

Adapted from BORG RPE scale (Borg, 1998).