ABSTRACT

DONAHUE, M. D. Physiological responses to submaximal workloads on four exercise ergometers. MS in Adult Fitness/Cardiac Rehabilitation, May 2001, 29pp. (J. Porcari)

To allow for accurate exercise prescription, relationships needed to be drawn between four common exercise ergometers often found in a cardiac rehabilitation setting. The StairMaster upright (UP) and recumbent (SR) cycles, NuStep recumbent stepper (NU), and Schwinn Airdyne (AD) were compared against one another with six male and six female volunteers (age 23 ± 3.5 years). Ss completed three submaximal exercise bouts (50, 100, 150 Watts) on each of the four ergometers tested. Each stage was five minutes in duration and VO₂, HR, SBP, DBP, Kcal, and RPE were recorded at the end of each stage. Testing sessions were randomized and performed one week apart. Data were analyzed using a one-way ANOVA. Results showed that the UR cycle elicited the highest VO₂, HR, SBP, Kcal, and RPE compared to the remaining three modes at any given power output. Both the SR cycle and the AD showed the next highest values with most stages revealing equal responses to exercise. Finally, the NU produced the lowest physiological responses to exercise of all four modalities. For exercise prescription purposes, the ergometers that create less of a physiological response at a given workload must be modified in order to attain equal amount of cardiovascular benefits.
PHYSIOLOGICAL RESPONSES TO SUBMAXIMAL WORKLOADS ON FOUR EXERCISE ERGOMETERS

A MANUSCRIPT STYLE THESIS PRESENTED TO THE GRADUATE FACULTY UNIVERSITY OF WISCONSIN-LA CROSSE

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

BY
MARC D. DONAHUE
MAY 2001
Candidate: Marc D. Donahue

We recommend acceptance of this thesis in partial fulfillment of this candidate’s requirements for the degree:

Master of Science in Adult Fitness/Cardiac Rehabilitation

The candidate has successfully completed the thesis final oral defense.

Thesis Committee Chairperson Signature 10/20/00

Thesis Committee Member Signature 10/20/00

Thesis Committee Member Signature 10/20/00

This thesis is approved by the College of Health, Physical Education, Recreation, and Teacher Education.

Associate Dean, College of HPERTE 3/22/01

Director of University Graduate Studies 3/27/01
ACKNOWLEDGEMENTS

I would like to congratulate my fellow classmates on completing a successful year and earning a master’s degree you can be proud of. Your hard work and dedication, along with the help of many other talented individuals, help make the La Crosse Exercise and Health Program continue to grow and flourish.

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INTRODUCTION

The American College of Sports Medicine (ASCM) lists numerous benefits of regular physical activity (1). Today, more than ever, people are realizing these benefits and are continuing to discover new ways of obtaining these goals. With the exercise machine market saturated with many new and inventive ideas for exercising, many times the non-weight bearing ergometers prove to be the most popular. Many cardiac rehabilitation patients find these exercise machines as their ergometers of choice.

The Schwinn Airdyne cycle ergometer has been a popular choice for over two decades. The Airdyne uses air to provide resistance which increases the faster one pedals. StairMaster has introduced both semi-recumbent and upright bicycles to the market. By keying on lower-body muscle movements, these ergometers use magnetically derived resistance to provide adequate exercise sessions. Finally, the NuStep, which is a semi-recumbent stepper, combines adjustable workloads, arm positions, and seat positions intended to give a complete upper and lower body workout.

In recent years, the majority of research done in this field has focused on the differences between the upright and recumbent bicycles. Bonzheim, Franklin, DeWitt, Marks, Goslin, Jarski, and Dann (3) found oxygen consumption (VO2) and heart rate (HR) to be lower in the recumbent versus the upright position at any given power output. Similarly, Walsh-Riddle and Blumenthal (11) found lower heart rates associated with the recumbent position at similar power outputs. Similar results were also found by other
researchers (3,5,6,7,8,10) who attribute the increase in venous return due to horizontal leg position in the recumbent position as the major contributing factor.

Additionally, ratings of perceived exertion (RPE) were the common focus of many researchers. Pauly (7) and Johnson (6), along with Bonzheim et al. (3) and Walsh-Riddle and Blumenthal (11) all found their subjects to perceive exercise easier in the recumbent position compared to the upright position even though the power outputs were similar.

The Schwinn Airdyne has been around for many years, yet only one known study to date has studied the physiological effects (VO₂, HR, blood pressure) while exercising. The NuStep is relatively new to the market and has no known studies published at this time and has a limited research base to draw from. These ergometers are common exercise modalities often found in cardiac rehabilitation settings. For this reason, comparative studies need to be done to observe any differences between HR and VO₂ among the four devices to allow for accurate exercise prescriptions. To date, no study has compared these four common modalities in the same group of subjects. Therefore, the purpose of this study is to examine physiological responses to all four ergometers at a submaximal level.

METHODS AND PROCEDURES

Introduction

Each subject completed three submaximal exercise bouts on four different ergometers. During each test, VO₂, HR, systolic blood pressure (SBP), diastolic blood pressure (DBP), RPE, and energy expenditure (Kcal) were measured.
Subjects were instructed to wear loose fitting clothing and avoid eating large meals three hours before testing began.

**Subject Selection**

The six male and six female subjects who participated in the study were volunteers between the ages of 20 and 33 years. These individuals were required to be moderately active which for this study defined as performing at least 20 minutes of continuous aerobic exercise most days of the week. Subjects were asked to complete a Physical Activity Readiness Questionnaire (PAR-Q) to screen for heart disease and were classified as apparently healthy. Finally, subjects were required to provide informed consent. The research protocol had been approved by the University of Wisconsin—La Crosse Institutional Review Board for the protection of human subjects.

**Methods and Procedures**

All testing took place in the Human Performance Laboratory at the University of Wisconsin—La Crosse. Subjects reported to the laboratory on four separate occasions, at approximately the same time of day and a week apart from the prior test. Upon arrival, subjects had their height, weight, blood pressure and heart rate measured. At each meeting, subjects were given complete instructions on how to use the piece of equipment that was randomly selected and given time to practice and become comfortable with the resistance settings. At the same time, the subjects were then given an explanation of testing protocol and instructions for the RPE scale.

Once accustomed, subjects were then fitted with headgear and a mouthpiece used to collect expired gases and asked to begin. The protocol consisted of three continuous
stages of increasing resistance (50, 100, 150 Watts). Subjects exercised for a total of five minutes then immediately started into the next stage. During the last minute of each stage, blood pressure, heart rate and RPE were measured.

**Instrumentation**

Subjects were randomly tested on each of the following four ergometers: the StairMaster upright and StairMaster semi-recumbent cycles (StairMaster, Kirkland, WA—Models: 3300 CE and 3900 RE), Schwinn Airdyne (Schwinn Cycling & Fitness, Boulder, CO), and NuStep 4000 recumbent stepper (NuStep, Ann Arbor, MI). Heart rate was measured each minute using the Vantage XL Heart Rate Monitor (Polar-CIC Inc., Port Washington, NY) with blood pressures measured using a calibrated mercury sphygmomanometer. Expired air was collected and analyzed using open-circuit spirometry (Q-Plex 1 Cardio-Pulmonary System, Quinton Instrument Company, Seattle, WA). Finally, RPE was recorded each stage using the 6-20 Borg Scale (4).

**Statistical Treatment**

The VO₂ was plotted as a function of submaximal workloads for each set of trials. Common interpolated data points were used to compare the VO₂ across modes and power outputs using repeated measures ANOVA. A Tukey test was used for post-hoc comparisons.

**RESULTS**

This study was conducted to determine the physiological differences between four different exercise ergometers. Subjects were twelve volunteers (6 male, 6 female)
between 20 and 33 years of age. The mean physical characteristics of the twelve subjects are presented in Table 1.

Table 1. Physical characteristics of subjects (N=12)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>23</td>
<td>3.5</td>
<td>20 – 33</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>174.6</td>
<td>10.5</td>
<td>160 – 190</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>70.5</td>
<td>14.3</td>
<td>49.9 – 91.6</td>
</tr>
</tbody>
</table>

Subjects were asked to complete four, randomly ordered submaximal exercise tests on the StairMaster upright (UR) and semi-recumbent (SR) cycles, NuStep recumbent stepper (NU), and Schwinn Airdyne (AD) cycle. All but four subjects were able to complete all of the submaximal tests administered. Of those four subjects who were not able to finish, each completed every test but the last stage (150 Watts) of the UR cycle modality. In each of the four cases, subjects ceased testing due to leg fatigue. Data collected and analyzed on each test included VO₂, HR, SBP, DBP, Kcal, and RPE. The following tables summarize these findings.

Values for VO₂ are presented in Table 2. When compared to UR cycling at 50W, VO₂ values were 24% lower with SR (p < .05) and 31% lower with NU (p < .05). The AD VO₂ values were 13% higher compared to UR, however this margin was not statistically significant (p > .05). These trends changed at both 100W and 150W as the UR became significantly higher (p < .05) than the AD, SR, and NU by peak margins of 11%, 11%, and 43%, respectively.
Table 2. VO₂ (ml/kg/min) responses to SR, UR, NU, and AD ergometers

<table>
<thead>
<tr>
<th>Stage</th>
<th>SR Mean ± SD</th>
<th>UR Mean ± SD</th>
<th>NU Mean ± SD</th>
<th>AD Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 W</td>
<td>11.7 ± 2.3&lt;sup&gt;b,d&lt;/sup&gt;</td>
<td>15.3 ± 3.0</td>
<td>10.6 ± 1.7&lt;sup&gt;b,d&lt;/sup&gt;</td>
<td>16.1 ± 2.6</td>
</tr>
<tr>
<td>100 W</td>
<td>22.3 ± 4.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>27.1 ± 5.0</td>
<td>13.7 ± 2.3&lt;sup&gt;a,b,d&lt;/sup&gt;</td>
<td>23.5 ± 3.7&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>150 W</td>
<td>31.6 ± 6.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>35.3 ± 5.7</td>
<td>20.1 ± 3.5&lt;sup&gt;a,b,d&lt;/sup&gt;</td>
<td>31.6 ± 5.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

a: statistically different than SR  
b: statistically different than UR  
c: statistically different than NU  
d: statistically different than AD

Table 3. HR responses to SR, UR, NU, and AD ergometers

<table>
<thead>
<tr>
<th>Stage</th>
<th>SR Mean ± SD</th>
<th>UR Mean ± SD</th>
<th>NU Mean ± SD</th>
<th>AD Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 W</td>
<td>95 ± 11.9&lt;sup&gt;b,d&lt;/sup&gt;</td>
<td>112 ± 19.1</td>
<td>105 ± 18.8</td>
<td>110 ± 23.3</td>
</tr>
<tr>
<td>100 W</td>
<td>131 ± 21.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>152 ± 23.2</td>
<td>115 ± 19.4&lt;sup&gt;a,b,d&lt;/sup&gt;</td>
<td>139 ± 28.9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>150 W</td>
<td>160 ± 24.5</td>
<td>166 ± 16.1</td>
<td>137 ± 24.4&lt;sup&gt;a,b,d&lt;/sup&gt;</td>
<td>162 ± 28.4</td>
</tr>
</tbody>
</table>

a: statistically different than SR  
b: statistically different than UR  
c: statistically different than NU  
d: statistically different than AD

Submaximal heart rate values are presented in Table 3. These findings indicate significantly lower (p < .05) HR values for SR at 50W compared to UR. At 100W, HR was 9% lower (p < .05) during AD, 14% lower (p < .05) during SR, and 24% lower (p < .05) during NU compared to UR. At 150W, HR values were 18% lower (p < .05) on the NU compared to UR values. The remaining two modalities (SR and AD) were not statistically different compared to UR at the 150W stage (p > .05).
Systolic blood pressure responses are represented in Table 4. Values found at 50W indicate the NU was significantly higher (p < .05) than the remaining three ergometers. At 100W, the UR was significantly higher (p < .05) than SR, NU, and AD by 6%, 8%, and 8%, respectively. This relationship remained constant for the 150W stage as well.

Table 4. SBP responses to SR, UR, NU, and AD ergometers

<table>
<thead>
<tr>
<th>Stage</th>
<th>SR Mean ± SD</th>
<th>UR Mean ± SD</th>
<th>NU Mean ± SD</th>
<th>AD Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 W</td>
<td>124 ± 7.0^ac</td>
<td>131 ± 7.4^c</td>
<td>142 ± 8.4</td>
<td>133 ± 10.5^c</td>
</tr>
<tr>
<td>100 W</td>
<td>153 ± 11.4^b</td>
<td>163 ± 12.7</td>
<td>150 ± 8.7^b</td>
<td>150 ± 12.3^b</td>
</tr>
<tr>
<td>150 W</td>
<td>173 ± 15.4^b</td>
<td>189 ± 13.5</td>
<td>161 ± 10.3^b</td>
<td>165 ± 14.3^b</td>
</tr>
</tbody>
</table>

a: statistically different than SR  
b: statistically different than UR  
c: statistically different than NU  
d: statistically different than AD

Table 5. DBP responses to SR, UR, NU, and AD ergometers

<table>
<thead>
<tr>
<th>Stage</th>
<th>SR Mean ± SD</th>
<th>UR Mean ± SD</th>
<th>NU Mean ± SD</th>
<th>AD Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 W</td>
<td>71 ± 6.4</td>
<td>75 ± 5.4</td>
<td>71 ± 5.7</td>
<td>76 ± 6.2</td>
</tr>
<tr>
<td>100 W</td>
<td>69 ± 7.8^bd</td>
<td>75 ± 5.8</td>
<td>71 ± 5.7^d</td>
<td>77 ± 6.0</td>
</tr>
<tr>
<td>150 W</td>
<td>68 ± 6.9^d</td>
<td>72 ± 6.2</td>
<td>70 ± 5.7^d</td>
<td>77 ± 6.3</td>
</tr>
</tbody>
</table>

a: statistically different than SR  
b: statistically different than UR  
c: statistically different than NU  
d: statistically different than AD
Diastolic blood pressure responses are summarized in Table 5. There were no significant differences in DBP between modalities at 50W. However, at 100W and 150W, AD values were slightly higher than both SR and NU (p < .05).

Values found for Kcal/min are presented in Table 6. When compared to UR at 50W, Kcal values were 22% lower during SR (p < .05) and 30% lower during NU (p < .05). The AD Kcal values were 6% higher compared to UR, however this margin was not statistically significant (p > .05). These trends change at both 100W and 150W as the UR became significantly higher (p < .05) than the AD, SR, and NU by a margin of 13%, 14%, and 45%, respectively.

Table 6. Kcal/min responses to SR, UR, NU, and AD ergometers

<table>
<thead>
<tr>
<th>Stage</th>
<th>SR Mean ± SD</th>
<th>UR Mean ± SD</th>
<th>NU Mean ± SD</th>
<th>AD Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 W</td>
<td>3.99 ± 0.90&lt;sup&gt;b,d&lt;/sup&gt;</td>
<td>5.09 ± 0.71</td>
<td>3.58 ± 0.62&lt;sup&gt;b,d&lt;/sup&gt;</td>
<td>5.44 ± 0.54</td>
</tr>
<tr>
<td>100 W</td>
<td>7.63 ± 0.94&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.18 ± 0.86</td>
<td>4.58 ± 0.58&lt;sup&gt;a,b,d&lt;/sup&gt;</td>
<td>8.03 ± 0.57&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>150 W</td>
<td>10.84 ± 0.96&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.57 ± 1.26</td>
<td>6.89 ± 0.69&lt;sup&gt;a,b,d&lt;/sup&gt;</td>
<td>10.88 ± 0.56&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

a: statistically different than SR
b: statistically different than UR
c: statistically different than NU
d: statistically different than AD
RPE values are presented in Table 7. At 50 W, there was very little apparent
difference in RPE with AD, SR, and NU values just below UR values. However, these
differences were still statistically significant (p < .05). Overall, SR and UR ratings were
significantly higher (p < .05) during the final stage than both NU and AD.

Table 7. RPE responses to SR, UR, NU, and AD ergometers

<table>
<thead>
<tr>
<th>Stage</th>
<th>SR Mean ± SD</th>
<th>UR Mean ± SD</th>
<th>NU Mean ± SD</th>
<th>AD Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 W</td>
<td>8 ± 1.0&lt;sup&gt;b,d&lt;/sup&gt;</td>
<td>9 ± 1.3</td>
<td>7 ± 1.0&lt;sup&gt;a,b,d&lt;/sup&gt;</td>
<td>9 ± 1.4</td>
</tr>
<tr>
<td>100 W</td>
<td>11 ± 1.7</td>
<td>12 ± 1.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>10 ± 1.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11 ± 1.7</td>
</tr>
<tr>
<td>150 W</td>
<td>15 ± 2.5</td>
<td>15 ± 2.2</td>
<td>11 ± 1.9&lt;sup&gt;a,b,d&lt;/sup&gt;</td>
<td>13 ± 2.0&lt;sup&gt;a,b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

a: statistically different than SR
b: statistically different than UR
c: statistically different than NU
d: statistically different than AD

DISCUSSION

This study compared physiological responses (VO₂, HR, SBP, DBP, Kcal, RPE)
to three submaximal workloads (50, 100, 150 Watts) on four different exercise
ergometers (SR, UR, NU, AD). On average, the UR cycle elicited the highest VO₂, HR,
SBP, Kcal, and RPE compared to the remaining three modes at any given workload. In
only two situations (VO₂ and SBP) did any other modality show higher physiological
responses and these both occurred at 50 Watts. Both the SR cycle and the AD showed
the next highest values with most stages revealing equal responses to exercise at any
given workload. Only RPE and DBP demonstrated statistical significance between the
two ergometers with the SR cycle having higher RPE values during the later workloads.
Finally, the NU elicited the lowest physiological responses to exercise of all four modalities. Only for SBP at 50 Watts did the NU supercede any of the other three ergometers.

**Previous Studies on Upright versus Recumbent Cycling**

When comparing UR cycling versus SR cycling, the present study found VO\(_2\) responses in SR cycling significantly lower in all three stages compared with UR cycling. These results are similar to Bonzheim et al. (3), Pauly (7), Johnson (6), and Quinn et al. (8) who all found significantly lower VO\(_2\) levels during SR cycling compared to UR cycling.

HR values were also found to be significantly lower in SR cycling versus UR cycling at 50 and 100 Watts. Similar results were found by Walsh-Riddle and Blumenthal (11) where mildly, hypertensive subjects showed significantly lower HR at 70% and 90% of VO\(_2\)max in the SR position. Similar results were also shared by others (5,6,7,8). However, at 150 Watts, the current study showed this significance disappear as SR cycling values approached UR cycling values. These findings were not consistent with any of the previously mentioned studies.

SBP response also showed a significant interaction when comparing UR cycling and SR cycling at 100 and 150 Watts. Unlike Currie et al. (5) who found lower SBP in the erect position versus the supine position and Quinn et al. (8) who found no differences, SBP responses were significantly higher in the UR ergometer. These results are similar to both Bozheim et al. (3) and Pauly's (7) findings.
Responses in DBP were a little unpredictable in the current study, as significant differences were seen at 100 Watts, but not at 50 or 150 Watts. Generally, DBP either remains the same or decreases slightly in response to aerobic exercise. However, the rate and magnitude of this decrease was not the same for each modality producing significant responses in some workloads and not others.

The physiological changes seen when comparing SR cycling and UR cycling are most likely due to differences in leg positioning. In the SR position, the legs are working in a more horizontal position were venous return is not having to work against the force of gravity. In contrast, UR cycling often results in peddling where blood flow has to work directly against gravity in order to return to the heart. This decrease in venous return forces the heart to contract faster and harder in order to keep up with physiological requirements needed to perform the aerobic task. As a result, physiological factors (VO₂, HR, SBP, Kcal) while in the UR position are higher compared to the same workload and conditions in the SR position.

Finally, RPE examined by both Pauly (7) and Johnson (6) was found to be significantly higher when comparing UR cycling to SR cycling. These finding were not reproducible in the current study where no significant differences were found between the two ergometers at both 100 and 150 Watts. These findings were also shared by Quinn et al. (8) and in contrast to both Bonzheim et al. (3) and Walsh-Riddle and Blumenthal (11).

**Previous Studies on the Schwinn Airdyne**

A study by Zeni et al. (12) is one of the few studies that compares physiological responses (Kcal and HR) at various workloads using a Schwinn Airdyne.
Unlike the current study which used set submaximal workloads (50, 100, 150 Watts), Zeni et al. relied on RPE (11, 13, 15) as a basis to increase workloads. Like the current study, Zeni et al. found an increase in Kcal and HR with an increase in workload (Watts or RPE). However, when comparing like RPE scores, they showed higher rates of energy expenditure and higher HR values compared to the current study. These differences are likely due to an older sample (mean age, 31 years) taken in the Zeni study versus the current study (mean age, 23 years).

In another study that used RPE as a method of gauging workload, Spranger (10) had his subjects exercise at a self-selected intensity for 30 minutes. His results showed a mean RPE on the AD of 12.5 ± 0.72. When comparing RPE responses, the present study found similar results in VO2, HR, and Kcals to Spranger.

Previous Studies on the NuStep Recumbent Stepper

The NU recumbent stepper, being a fairly new piece of equipment, also has a limited research basis behind it. One of the first original studies done on the NU took place at the University of Toledo (2) using 20 healthy, college-aged subjects. They compared predicted METs derived from the NU with actual METs found using open circuit spirometry. The Toledo group found the NU METs were significantly higher (p < .05) than the actual METs with a range of 11-32% difference.

A similar study done by Ratieke (9) compared the NU MET values with actual MET values derived from the AeroSport Portable Analyzer. By testing 50 male and female volunteers with either known cardiac disease or significant risk factors for CAD, Ratieke found the NU MET levels to overpredict the actual measured MET levels by
anywhere from 44-73%. These results found by both Toledo (2) and Ratieke (9) indicate that the Watt levels displayed on the NU console are erroneously high compared to the actual power output at which subjects are working. With this in mind, the lower physiological values found in the current study may be attributed to mechanical error found with the NU console.

Summary

Physiological requirements elicited when testing the four modalities conclude that the UR cycle appears the most demanding, followed equally by the AD and SR, and finally by the NU. Whether the differences are caused by overall body position or mechanical problems, prescribing exercise intensities must be altered accordingly. The ergometers that draw less of a physiological response at a given workload must be modified in order to attain equal amount of cardiovascular benefits.
REFERENCES


APPENDIX A

INFORMED CONSENT FORM
INFORMED CONSENT FOR PHYSIOLOGICAL RESPONSES TO SUBMAXIMAL WORKLOADS IN FOUR EXERCISE ERGOMETERS

I, ____________________________, give my informed consent to participate in a study investigating the physiological responses to energy effects of four indoor exercise machines. I have been informed I will be exercising for five-minute intervals at predetermined, submaximal intensities while on the Stairmaster upright and semi-recumbent cycles, Schwinn Airdyne bicycle, and NuStep stepper. I have been informed this study requires me to exercise on four separate occasions with each session a total of 15 minutes in duration. While exercising, I have been informed I will be wearing a headset and mouthpiece to measure my expired air and a heart rate monitor that will strap across my chest. These instruments have been explained and demonstrated to me.

As with any exercise, the possibility of adverse effects are real but not expected. I have been informed that some acute discomforts may accompany my exercise bouts such as shortness of breath, muscle soreness, and general fatigue. I have been informed that serious complications may occur during exercise (e.g. heart attack), but that the rate in young, apparently healthy individuals is less than 0.3/10,000 tests. If I have any abnormal signs or symptoms that are uncomfortable, I will inform the researcher and terminate my participation at that time without penalty.

I have been informed that results of this study may be published, but am aware that my identity will be kept confidential. I also consent to data being collected and recorded on a report sheet. I have been informed my data will only be referred to number alone. Information obtained from this research will also be available to me upon request.

I consider myself to be in good health and to my knowledge I am not infected with a contagious disease or have any limiting physical condition or disability, especially with regard to my heart, that would preclude my participation in the exercise test described above. Finally, I have been informed that my participation in this study is completely voluntary and may be terminated at any point in the study without consequences.

Questions regarding protection of human subjects may be addressed to Dr. Garth Tymeson, chair UW-La Crosse IRB for the protection of human subjects. Questions about any aspects of this study may be referred to the principal researcher (Marc Donahue, 608-781-4693) and thesis advisor (Dr. John Porcari, ESS Room 141 Mitchell Hall, 608-785-8684).

Signed: ____________________________ Date: ______________

Researcher: ____________________________ Date: ______________
APPENDIX B

RATING OF PERCEIVED EXERTION SCALE
Borg's Rating of Perceived Exertion Scale

6-
7- Very, Very, Light
8-
9- Very Light
10-
11- Fairly Light
12-
13- Somewhat Hard
14-
15- Hard
16-
17- Very Hard
18-
19- Very, Very, Hard
20-

APPENDIX C

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

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

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

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
2. Do you feel pain in your chest when you do physical activity?
3. In the past month, have you had chest pain when you were not doing physical activity?
4. Do you take your balance because of dizziness or do you ever lose consciousness?
5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?
6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
7. Do you know of any other reason why you should not do physical activity?

If you answered YES to one or more questions:

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness assessment. Tell your doctor about the PAR-Q and which questions you answered YES.
- You may be able to do any activity you want—as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you want to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

If you answered NO: NO need to do the PAR-Q questions, you can be rest assured that you can:
- Start becoming much more physically active—begin slowly and build up gradually. This is the safest and easiest way to go.
- Take part in a fitness assessment. This is an excellent way to determine your basic fitness so that you can plan the best way for you to tie.

DELAY BECOMING MUCH MORE ACTIVE:
- If you are not feeling well because of a temporary illness such as a cold or a fever—rest until you feel better.
- If you are or may be pregnant—talk to your doctor before you start becoming much more active.

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

You are encouraged to copy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person under the age of majority, the parent or guardian should answer the questions. This section may be used for legal or administrative purposes.

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

NAME ____________________________

SIGNATURE ____________________________

SIGNATURE OF PARENT/GUARDIAN ____________________________

DATE ____________________________

WITNESS ____________________________

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Société canadienne de physiologie de l'exercice

FIGURE 2-1. PAR-Q form. (Reprinted with permission from the Canadian Society for Exercise Physiology, Inc., 1994.)
APPENDIX D

DATA RECORDING SHEET
Subject Number: 
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Weight: 

**NuStep:**

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APPENDIX E

REVIEW OF RELATED LITERATURE
REVIEW OF RELATED LITERATURE

Introduction

The following review examines the available research on the four ergometers tested in the current study. Many studies are available on the upright and semi-recumbent cycles used throughout the years. However, limited research is available on Schwinn Airdyne and the NuStep semi-recumbent stepper. Like the cycle ergometers, these devices have emerged onto exercise market and continue to grow in popularity. With each ergometer being non-weight bearing and easy to use, each machine will continue to be favored by both young and old.

Submaximal Exercise Responses

Upright versus recumbent cycles

Bonzheim et al. (2) tested 14 men with coronary artery disease on both the upright and recumbent cycle ergometers. They found that oxygen consumption (ml/kg/min) was significantly lower on the semi-recumbent compared to the upright cycle when comparing a submaximal power output of 100 Watts. Pauly (5) and Johnson (4) found similar results and agree with Bonzheim and associates who attributed these differences to the reduction of leg weight and increased muscular efficiency. Quinn et al. (6) also examined oxygen uptake in cardiac patients. They found significantly lower VO2 levels when comparing supine cycle ergometry with both recumbent and upright positions at a workload of 300 kgm/min (50 Watts). Again, these differences were attributed to the better venous return in the supine position.
In a similar study, Walsh-Riddle and Blumenthal (7) examined cardiovascular responses in unmedicated, mildly hypertensive subjects during upright and semi-recumbent cycle ergometry tests. They found significantly lower heart rate responses at rest, and at 70% and 90% VO₂ peak in the semi-recumbent position. These results are in agreement with Pauly (5), Johnson (4), and Bonzheim et al. (2) who also found significantly lower heart rates in the recumbent position. Similar findings were also reported by Currie et al. (3) and Quinn et al. (6) when examining heart rates in a supine position.

Currie et al. (3) studied 43 patients with a known cardiac history and examined hemodynamic patterns during exercise in the erect and supine positions. They found systolic, diastolic, and mean blood pressures to be significantly lower in the erect posture both at rest and at submaximal work levels. In contrast, Quinn et al. (6) found no differences in both systolic and diastolic blood pressure responses in the supine, recumbent, and upright positions. They instructed their subjects leave their hands in a comfortable position to avoid isometric handgripping. Like Quinn et al., Johnson (4) found no significant differences in submaximal systolic and diastolic pressures in men when comparing upright and semi-recumbent positions. Pauly (5), however, found significant differences in systolic pressures only in a female sample. Finally, Bonzheim and associates (2) observed significantly lower blood pressure responses on the recumbent ergometer compared with the upright cycle.

Finally, Pauly (5) and Johnson (4) compared physiologic submaximal responses to upright and semi-recumbent cycling in healthy females and males, respectively. They
each found ratings of perceived exertion (RPE) to be significantly lower in the recumbent position versus the upright position at set workloads. Pauly relates these lower RPE values to more efficient muscle usage during recumbent cycling. In agreement with the findings of Pauly and Johnson are that of Bonzheim et al. (2) and Walsh-Riddle and Blumenthal (7) who both found significantly lower RPE with their patients at each submaximal level tested in the semi-recumbent position. In contrast to the above studies, Quinn et al. (6) found no significant differences in RPE at submaximal workload in the recumbent position.

Schwinn Airdyne

In the lone published study known to have used the Schwinn Airdyne, Zeni, Hoffman, and Clifford (8) compared rates of energy expenditure on six indoor exercise machines at a given rating of perceived exertion (RPE). The six ergometers used included the Schwinn Airdyne, a simulated cross-country skier, a cycle ergometer, a rowing ergometer, a stair stepper, and a treadmill. After a four-week habituation period to familiarize subjects with the RPE scale and machines used, Zeni et al. measure oxygen consumption, heart rate, and blood lactate levels after each stage of exercise. They determined all machines were lower than the treadmill in both energy expenditure and heart rate. Not only did the Airdyne and cycle ergometers elicit lower energy expenditures and heart rates, but also the Airdyne was the lowest in comparison to all machines. Zeni et al. listed reasons such as movement pattern of the exercise and the degree to which eccentric and isometric contractions are involved as factors for differences in metabolic demand between ergometers.
**NuStep Stepper**

As mentioned previously, the stepper by NuStep is a fairly new exercise machine with very little experimental data available. One study conducted at the University of Toledo (1) tested 20 young and apparently healthy adults with fitness levels ranging from moderately-low to moderately-high. They randomly assigned subjects to five, 4-minute stages with intensities ranging from 4.63 to 16.30 METS. At a cadence of 100 steps/min. and workloads ranging from 83.2 to 325.3 watts, heart rates ranged from 109 to 187, and RPE from 8.5 to 18.5. However, no comparisons were made between other ergometers.

**Summary**

As the previous studies indicate, the majority of the researchers are in agreement with each other. However, there still are some inconsistencies in the literature to warrant further review. More and more cardiac rehabilitation centers are using these ergometers not only to provide new and interesting ways to exercise, but also to keep the patient safe with easier monitoring and workload settings. With the emergence of the NuStep semi-recumbent stepper and the popularity of Schwinn’s Airdyne, a study examining the relationships between all four ergometers is essential for correct exercise prescriptions.
REFERENCES


