ABSTRACT

PAULY, M.A. A comparison of the submaximal and maximal responses to upright versus semi-recumbent cycling in females. MS in Adult Fitness/Cardiac Rehabilitation, December 1999, 36pp. (J. Porcari)

To compare the submaximal and maximal responses to StairMaster Upright (UP) and Semi-recumbent (SR) cycle ergometry, 15 female Ss (age 23.5 ± 4.03 years) performed a maximal exercise test on each ergometer. A continuous, incremental protocol was performed on each modality. Testing sessions were randomized and performed 1 week apart. Data were analyzed using repeated measures ANOVA. Heart rate, VO_2, BP, RPE, RER, and Kcal were measured at the end of each 2-min stage and at maximal exercise. At absolute submaximal workloads it was found that VO_2, HR, SBP, RPE, RER, and Kcal were significantly ($p < .05$) higher during UP compared to SR cycling. No significant difference ($p > .05$) was reported in DBP between modalities. At maximal exertion it was found that subjects were able to attain higher Kcal, HR, and VO_2 values during UP compared to SR cycling. Although lower values were obtained during SR cycling, the workload was significantly higher (213 vs 179 watts) and the duration was significantly longer (11.8 vs 9.5 min). For exercise prescription the cardiorespiratory responses will be lower during SR cycling at any given workload, thus use of the SR cycle would require an individual to work at a higher workload to achieve the same cardiovascular benefits as with use of the UP cycle.

A COMPARISON OF THE SUBMAXIMAL AND MAXIMAL RESPONSES TO UPRIGHT VERSUS SEMI-RECUMBENT CYCLING IN FEMALES

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

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DECEMBER 1999

COLLEGE OF HEALTH, PHYSICAL EDUCATION, AND RECREATION

UNIVERSITY OF WISCONSIN-LA CROSSE

THESIS FINAL ORAL DEFENSE FORM

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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.

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ACKNOWLEDGEMENTS

First and foremost I would like to thank Dr. John Porcari, for introducing this project to me. Much patience, time, and guidance were put into this project on his part. He withstood some constant pressure from me to keep this thesis rolling.

I would also like to thank Dr. Larry Terry and Dr. Peg Maher for serving as my thesis committee members. Their time and input were greatly appreciated throughout this project. Another thanks goes out to Dr. Abdul Elfessi who helped tremendously with my statistical data.

I would like to thank my family for everything they have done for me. My parents Julian and Karen, my sister and brother-in-law, Lisa and Donny, and my new niece, Megan, have shown me constant love and support throughout my life. During this project not only have they given me advice, but they have always kept things in perspective for me.

Lastly I would like to thank my classmate, Chuck Johnson, who I have worked with on this thesis from the beginning. Working with him has kept me on the right path and his humor and sarcasm has made all those stressful times that much easier to handle.

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INTRODUCTION

One of the newer pieces of equipment in the home exercise market is the semi-recumbent (SR) cycle. These cycles are becoming popular for a number of reasons. First, because the back is supported, they offer more comfort for individuals with low back pain or orthopedic problems. Second, the seat position of the SR makes it easy for individuals to get into and rise from. Third, the SR cycle may benefit individuals with a low level of fitness since those individuals typically begin at lower workloads. A question that remains relates to which cycle gives the best workout. Many people have the perception that the semi-recumbent cycle is "easier" than the upright cycle.

To date there have been five studies that have compared the physiological responses to cycling exercise in the upright, semi-recumbent, and supine positions. Although some studies compared the same two modalities and tested the same variables, the results were contradictory. Quinn, Smith, Yroman, Kertzer, and Olney (6) studied heart rate (HR), blood pressure (BP), rating of perceived exertion (RPE), and oxygen uptake (VO_2) at a submaximal workload of 300 kgm. They reported no difference in heart rate between use of the upright and the semi-recumbent cycles. This was in contrast to studies conducted by Bonzheim et al. (2) and Walsh-Riddle and Blumenthal (7) who reported lower heart rates during recumbent versus upright cycling at a submaximal workload of 100 watts and 75 and 90% VO_{2peak}, respectively. In addition to lower heart rates, Bonzheim et al. also reported a lower VO_2 during SR cycling at a submaximal workload of 100 watts.

Several studies have compared blood pressure responses between modalities when working at submaximal workloads. Quinn and associates (6) found no significant differences in BP between the upright and the recumbent positions. However, Bonzheim et al. (2) found systolic blood pressure (SBP) to be significantly lower during recumbent cycling than during upright cycling at a workload of 100 watts. In yet another study, Proctor et al. (5) found SBP to be significantly elevated during recumbent cycling when compared to upright or supine cycling at the submaximal workloads. Studies conducted by Quinn and associates (6) and Bonzheim et al. (2) looked at the relationship between HR and VO_2. Both studies agree that the relationship is linear.

Heart rate and VO_2 were also compared at the maximal level. A study conducted by Bonzheim and associates (2) and Quinn et al. (6) showed no significant differences in HR and VO_2 at maximal levels of exertion between cycles. These findings are in contrast to a study conducted by Walsh-Riddle and Blumenthal (7) who found that subjects, 10 males and 10 females, achieved higher HR and VO_2 values during upright versus semi-recumbent cycling. However, previous studies reporting SBP and DBP agreed there were no differences between cycling modalities at maximal exertion.

From the information above, it is apparent that there is conflicting data regarding the physiological responses during upright (UP) versus semi-recumbent cycling. The conflicting data may have resulted from different sample sizes, different cycles, and/or different methodology. The specific purpose of this study was to determine if there were any differences in the submaximal and maximal responses to cycling exercise between the StairMaster UP and the StairMaster SR cycle. The study utilized identical protocols for each cycle, with each cycle differing only in position of the seat and legs.

METHODS

Subject selection. Fifteen female volunteers between the ages of 20-36 years participated in this study. The subjects were students enrolled at the University of Wisconsin-La Crosse or citizens living in the La Crosse area. All of these individuals were in the "apparently healthy" risk stratification category according to the standards of American College of Sports Medicine (ACSM) (1). Apparently healthy is defined as individuals who are asymptomatic with no more than one major coronary risk factor. Before beginning any testing, study approval for use of human subjects was obtained from the Institutional Review Board at the University of Wisconsin-La Crosse. The subjects were asked to read and sign an informed consent form (see Appendix A) and a Physical Activity Readiness Questionnaire (Par-Q) (see Appendix B) before beginning the study. Prior to testing, the subjects signed up for several sessions to practice on both cycles.

Practice sessions. Each subject was given 2-3 practice sessions. The number of practice sessions depended on the subject's familiarity with the two pieces of equipment. At this time the researcher gave instructions as to the proper technique of using the equipment safely, proper body positioning, and appropriate pedal speed. Also discussed were the use of the heart rate monitor, RPE scale, and the use of the headgear, mouthpiece, and nose clip used in the collection of expired gases. The subjects were then given a chance to practice on each modality. During the final practice session, the subjects wore the headgear and mouthpiece to become familiar with the equipment and to reduce anxiety. All subjects' questions and concerns were answered at this time.

The participants were also instructed to wear comfortable, loose-fitting clothing, to drink plenty of fluids over the 24-hour period before the test, and to avoid tobacco, alcohol, and caffeine for at least 3 hours prior to the test. Subjects were also asked to avoid strenuous physical activity on the day of the test (1). After instructions were given, the participants were encouraged to ask questions or express any concerns.

Maximal exercise test. Exercise testing was performed on the StairMaster UP and the StairMaster SR cycles. The tests were presented in random order and within 1 week of each other. All subjects pedaled at a rate of 60 revolutions per minute (rpm) for both cycles. A frequency of 60 rpm has been shown to elicit the highest VO_{2max} when compared with rates of 50, 70, and 80 rpm (4). With the aid of a metronome, pedaling was kept constant at 60 rpm. Tests were terminated once subjects reached volitional exhaustion or pedaling frequency dropped below 58 rpm for longer than 15 sec.

The subjects performed one incremental VO_{2max} test on each modality. Prior to each test, each subject was weighed without shoes to the nearest .1 kg and height was measured to the nearest 1 cm. The subjects began each test at level one and increased one level for each stage. Each stage continued for 2 minutes until volitional exhaustion.

During each exercise test, oxygen consumption, respiratory exchange ratio (RER), and caloric expenditure (Kcal) were recorded continuously. Each subject's heart rate was monitored throughout each test and was recorded during the last 30 seconds of each work stage. The subjects were asked their RPE using the 6-20 Borg Scale (3). Blood pressure was taken as subjects extended their left arm horizontally while continuing to cycle. It was measured at the end of each 2-minute stage and again at peak exercise.

Instrumentation. The UP and SR cycles used in this study were StairMaster (StairMaster, Kirkland, WA—Model #s 3300 CE and 3900 RC). The Q-Plex 1 Cardio-Pulmonary System (Quinton Instrument Company, Seattle, WA) was used to collect and analyze expired air. The Quinton metabolic cart (QMC) was calibrated prior to the testing of each subject. Compositions of the gases were determined by the micro-Scholander technique. The flow meter volume was calibrated using a 3.0 L syringe pump set at various flow rates. Blood pressure was measured using a calibrated mercury sphygmomanometer. The Vantage XL Heart Rate Monitor (Polar-CIC Inc., Port Washington, NY) was used to monitor heart rate. RPE was measured using the 6-20 Borg Scale (see Appendix C).

Statistical analysis. Data analysis was performed using the SPSS statistical software (Lawrence Erlbaum Associates, Publishers, Hillsdale, US), and Microsoft Excel 1997 statistical software. A two-way ANOVA with repeated measures (stage X modality) was used to compare the differences between modalities across the stages. Pairwise comparisons among submaximal stages were made with paired t-tests and the Bonferonni adjustment. Paired t-tests were used to compare maximal responses. Alpha was set at the .05 level of confidence.

RESULTS

This study was conducted to determine if there were differences between the submaximal and maximal responses to exercise on the StairMaster UP and the

StairMaster SR cycles. Fifteen female subjects ranging in age from 20 –36 years participated in the study. Their physical characteristics are presented in Table 1.

Table 1. Physical characteristics of subjects (N = 15).

Variable	Mean	SD	Range
Age (yr)	23.5	4.03	20 - 36
Height (cm)	165	6.08	155 - 178
Weight (kg)	62.2	10.19	49.0 - 79.4

All subjects completed at least four submaximal stages on each cycle ergometer. Data for VO_2, HR, Kcal, SBP, DBP, RER, and RPE are presented in Tables 2 – 8.

Oxygen consumption. Submaximal values for VO_2 are presented in Table 2. Overall values for UP were significantly ($p < .05$) greater than SR cycles. This was true for all stages except stage 1. There was also a significant interaction ($p < .05$). This indicates that the differences between UP and SR cycles got larger at each successive stage.

Heart rate. Values for submaximal heart rate are presented in Table 3. It was found that heart rate values were significantly ($p < .05$) higher during UP compared to SR cycling. This was true for all stages. There was also a significant interaction ($p < .05$) indicating that the differences between UP and SR cycles were not consistent across all stages, and generally increased as workload increased.

Table 2. Data for VO_2 during submaximal UP and SR cycling.

Stage	Upright Mean ± SD	Semi-recumbent Mean ± SD	Difference
1	15.9 ± 1.85	13.1 ± 3.12	2.8
2	20.3 ± 2.57	16.1 ± 2.27*	4.2
3	27.5 ± 3.33	21.6 ± 3.47*	5.9
4	34.2 ± 3.87	27.1 ± 4.52*	7.1

* Significantly different than upright cycle ($p < .05$)

Table 3. Data for HR during submaximal UP and SR cycling.

Stage	Upright Mean ± SD	Semi-recumbent Mean ± SD	Difference
1	123 ± 9.7	111 ± 7.4*	12
2	142 ± 6.0	120 ± 8.3*	22
3	163 ± 7.4	138 ± 9.3*	25
4	177 ± 8.9	157 ± 10.6*	20

* Significantly different then upright cycle ($p < .05$)

Calories. Values for submaximal Kcal are presented in Table 4. Overall values for UP were significantly ($p < .05$) greater then SR cycling. This was true for all stages. There was also a significant interaction ($p < .05$) indicating that the differences between UP and SR cycling got larger as the stages increased.

Table 4. Data for Kcal during submaximal UP and SR cycling.

Stage	Upright Mean ± SD	Semi-recumbent Mean ± SD	Difference
1	4.96 ± .504	4.11 ± .967*	.85
2	6.37 ± .481	5.03 ± .454*	1.34
3	8.79 ± .592	6.80 ± .367*	1.99
4	11.16 ± .724	8.70 ± .525*	2.46

* Significantly different than upright cycle ($p < .05$)

Systolic blood pressure. Values for submaximal SBP are presented in Table 5. Overall values for UP were significantly ($p < .05$) greater than SR cycling. This was true for all stages. There was no significant interaction ($p > .05$) indicating that the differences between UP and SR for each stage were fairly consistent and ranged from 10 – 14 mm Hg.

Diastolic blood pressure. Values for submaximal DBP are presented in Table 6. There were no significant ($p > .05$) differences between any of the stages or between cycles. There was also no significant ($p > .05$) interaction.

Table 5. Data for SBP during submaximal UP and SR cycling.

Stage	Upright Mean ± SD	Semi-recumbent Mean ± SD	Difference
1	122 ± 14.2	112 ± 9.8*	10
2	136 ± 13.7	126 ± 12.3*	10
3	154 ± 12.0	140 ± 15.8*	14
4	160 ± 11.7	149 ± 15.6*	11

* Significantly different than upright cycle ($p < .05$)

Table 6. Data for DBP during submaximal UP and SR cycling.

Stage	Upright Mean ± SD	Semi-recumbent Mean ± SD	Difference
1	72 ± 8.7	68 ± 7.0	4
2	76 ± 7.9	71 ± 7.5	5
3	76 ± 8.6	73 ± 7.1	3
4	78 ± 6.6	75 ± 7.6	3

Respiratory exchange ratio. Values for submaximal RER are presented in Table 7. Values for UP were significantly ($p < .05$) greater than SR cycling. This was true for stages 3 and 4. There was also a significant interaction ($p < .05$) indicating that the differences between UP and SR cycling increased with successive stages.

Table 7. Data for RER during submaximal UP and SR cycling.

Stage	Upright Mean ± SD	Semi-recumbent Mean ± SD	Difference
1	.92 ± .05	.91 ± .07	.01
2	.97 ± .05	.95 ± .05	.02
3	1.06 ± .05	1.02 ± .07*	.04
4	1.16 ± .07	1.10 ± .08*	.06

* Significantly different than upright cycle ($p < .05$)

Rating of perceived exertion. Values for submaximal RPE are presented in Table 8. Overall values for UP were significantly ($p < .05$) greater than SR cycling. This was true for stages 2 – 4. There was a tendency for the differences in RPE to increase across the stages, however this trend was not significant ($p > .05$).

Table 8. Data for RPE during submaximal UP and SR cycling.

Stage	Upright Mean ± SD	Semi-recumbent Mean ± SD	Difference
1	9.2 ± 1.52	8.5 ± 1.39	.7
2	11.4 ± 1.50	10.2 ± 1.63*	1.2
3	13.8 ± 1.17	12.4 ± 1.45*	1.4
4	16.7 ± 1.55	14.8 ± 1.09*	1.9

* Signficantly different than upright cycle ($p < .05$)

Maximal values between modalities were compared with paired t-tests. Values for VO_2, HR, Kcal, duration, and watts were significantly ($p < .05$) higher during UP compared to SR cycling. There were no significant ($p > .05$) differences found for SBP, DBP, RER, and RPE. Data for both maximal conditions are presented in Table 9.

Table 9. Data during maximal UP and SR cycling.

Variables	Upright Mean ± SD	Semi-recumbent Mean ± SD	Difference
VO_2 (ml/kg/min)	37.2 ± 4.91	34.8 ± 5.06*	2.4
HR (bpm)	184 ± 8.5	178 ± 8.6*	6.0
SBP (mm Hg)	170 ± 12.3	166 ± 12.3	4.0
DBP (mm Hg)	78 ± 6.5	77 ± 6.4	1.0
RPE	18.7 ± .59	18.9 ± 1.06	.2
RER	1.22 ± .08	1.20 ± .08	.02
Kcal/min	12.1 ± 1.44	11.2 ± 1.35*	.86
Watts	178.9 ± 15.00	213.4 ± 39.98*	34.50
Time (min)	9.5 ± 1.29	11.8 ± 2.18*	2.3

* Significantly different than upright cycle ($p < .05$)

DISCUSSION

This study compared the physiological responses of women exercising with the UP and SR stationary cycles. It was found that at all absolute workloads VO_2, HR, SBP, RPE, RER, and Kcal were higher during UP than during SR cycling. These findings agree with Bonzheim et al. (2) who found 14 individuals with coronary artery disease (CAD) to have higher VO_2 and HR values during UP versus SR cycling at a workload of 100 watts. These findings are also in agreement with studies conducted by Walsh-Riddle and Blumenthal (7) and Westcott (8). Although the latter two studies did not measure VO_2, it was found that HR was significantly higher during exercise in the UP compared to the SR position. The findings of the present study disagree with those of Quinn and associates (6) who found no difference between modalities for VO_2 and HR, and Proctor et al. (5) who did not measure submaximal VO_2, but measured HR and found no difference between the two modalities. In the present study, energy cost was also represented as Kcal/min, which is a linear function of VO_2. The data for Kcal/min mimicked those of VO_2.

Systolic blood pressure was also found to be significantly lower during SR compared to UP cycling. Other studies (6,7,8) have found similar results or no differences between modalities. Only Proctor et al. (5) found SBP to be higher during exercise in the SR than in the UP position. It was hypothesized that increased SBP was due to the isometric handgripping used for body stabilization.

The lower VO_2, HR, and SBP at the submaximal workloads during SR cycling may have occurred for several reasons. The lower heart rates may be due to the position of the legs. In SR cycling, the legs are parallel to the ground, thus facilitating venous return. A greater venous return would increase stroke volume and thus a given cardiac output could be achieved with a lower HR. During UP cycling the legs must be lifted against gravity while pedaling, whereas in the SR position they are just pushing horizontally against the pedals. This results in less external work and thus could have resulted in the lower VO_2 value observed during SR cycling. Also during SR cycling, the back is relatively flat against the cushioned seat, which provides a stable base to push against. This could result in a more efficient use of the leg musculature again minimizing VO_2.

When looking at RPE at the submaximal work levels, it was found to be significantly higher during exercise in the UP position. This is in agreement with only one previously conducted study (2) and is in disagreement with three other studies (6,7,8) that found no differences in RPE between modalities. It is difficult to explain the discrepancy between the present study and previous research, but the lower RPE is probably related to a more efficient muscle usage during SR cycling.

Diastolic blood pressure was the only variable in the present study that was not significantly different between the two cycle positions at submaximal workloads. This was in agreement with four previously conducted studies (2,6,7,8). Lack of change in DBP is normal during aerobic exercise.

At maximal exertion, VO_2, HR, and Kcal were found to be significantly higher during UP compared to SR cycling. This was in agreement with one study (7) and in contrast with two other studies (2,6) that found no differences in maximal VO_2 and HR between the two modalities. There were no significant differences found in maximal SBP, DBP, RPE, or RER between the two modalities. This was in agreement with three previous studies (2,6,7).

Hypothetically one would think during maximal exercise that VO_2 would be similar between the UP and SR positions, however in order to achieve a similar VO_2 during SR, the workload would be higher due to a more efficient pedaling motion. This, however, was not the case. The workload was significantly higher (213 vs 179 watts) and the duration was significantly longer (11.8 vs 9.5 min) in the SR position, but subjects still achieved lower VO_2 values in the SR position (see Appendix D).

Many of the subjects complained of localized muscular discomfort of the thigh muscle in the SR position when approaching near maximal exertion. The SR position also seems to rely more heavily on the hamstrings and quadriceps, thus limiting upper body movement. This was not as evident in the UP position as subjects were able to incorporate more overall muscle involvement including upper extremity muscles. Due to the localized fatigue with SR cycling subjects may not be able to achieve as high a cardiovascular response (VO_2 and HR) as with UP cycling. This explanation is in agreement with Walsh-Riddle and Blumenthal (7) who also found higher VO_2 values in the UP position.

In conclusion, it appears that at an absolute submaximal workload physiological responses are higher during UP compared to SR cycling. For maximal exercise, the UP cycle ergometer appears to permit subjects to attain higher maximal HR and achieve higher VO_{2max}.

These results suggest that when determining an exercise prescription, the cardiorespiratory responses will be lower on the SR cycle at any given workload compared to the UP cycle. Thus an individual must be prescribed a higher workload on the SR cycle to attain the same cardiovascular benefits as on the UP cycle.

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APPENDIX A

INFORMED CONSENT

INFORMED CONSENT
A COMPARISON OF THE SUBMAXIMAL AND MAXIMAL RESPONSES TO UPRIGHT VERSUS SEMI-RECUMBENT CYCLING IN FEMALES

I, ______________________________, volunteer to participate in a study to compare the submaximal and maximal responses to exercise between a StairMaster upright and a StairMaster semi-recumbent cycle. I understand that during each maximal test I will exercise until I feel I can no longer continue. The submaximal responses will be evaluated during each maximal test. Participation in this study requires me to have my oxygen consumption, caloric expenditure, heart rate, and blood pressure measured throughout each test. In order to test the above variables I am aware I will be wearing a mouthpiece, headgear and nose clip along with a heart rate monitor.

Prior to testing, I will be allowed two to three practice sessions on each modality to allow for familiarity. I will be completing two separate maximal tests, one on each cycle. The maximal tests will be completed during separate sessions lasting approximately 30 minutes each session. I am aware that the study includes cycling at incremental stages increasing the workload every two minutes until I can no longer continue.

I am aware that there may be certain risks involved while participating in this study. These risks may include abnormal heart rates and blood pressure readings and, in rare instances, death. I consider myself to be in good health and to my knowledge I have no known pre-existing cardiac problems, however, if at any time during the test I experience any lightheadedness or dizziness I will make the investigator aware immediately. Discomforts that may arise from testing may be sore legs and general fatigue.

From the results of this study, I will be able to see whether there is an advantage of one cycle ergometer over the other. From the standpoint of the general public, the perception is that the semi-recumbent cycle is "easier" and they do not get as good of a workout. The results will allow the general public and myself to see the relationship between the two modalities.

I agree to presentation and publication of the results of the study as long as the individual's identity is kept confidential. I understand although I will be kept on record as participating in this study, there will be no names listed in reports, abstracts, or journals.

I am encouraged to ask any questions that I may have whether it be prior to testing or during testing. If I have any questions or concerns, I can call Chuck Johnson at 779-4852, Marsha Pauly at 782-1978, or Dr. John Porcari, research advisor, at 785-8684.

After reading this consent form and having all my questions at this time answered to my satisfaction, I voluntarily consent to be a subject in this study. I am fully aware that participation is voluntary and that if I refuse to participate in this study or if I choose to withdraw from this study I may do so at any time with no penalty. Contact Garth Tymeson, Chair of UW-L Institutional Review Board, if there are any questions concerning the protection of human subjects (608) 785-8155.

Participant ______________________ Date ______________

Witness ______________________ Date ______________

APPENDIX B

HEALTH HISTORY QUESTIONNAIRE

Physical Activity Readiness Questionnaire

Name: ______________________ Date ________ 19 ____

Phone: Home: ________________

Work: ________________

YES NO 1. Has your doctor ever said you have heart trouble?

YES NO 2. Do you frequently have pains in your heart and chest?

YES NO 3. Do you often feel faint or have spells of severe dizziness?

YES NO 4. Has a doctor ever said your blood pressure was too high?

YES NO 5. Do you have a bone or joint problem such as arthritis that may be aggravated by exercise or even made worse with exercise?

YES NO 6. Do you know of any reason not mentioned above why you should not participate in maximal exercise testing?

The above questions have been answered truthfully and to the best of my knowledge. I am not withholding any information that would place me at an increased risk of injury by participating in maximal exercise testing.

Signature: __________________________ Date: ___________ 19 _____

Reference: PAR-Q Validation Report. British Columbia Dept. of Health, June 1975 (mod. Version-ACSM, 1995, p. 14)

APPENDIX C

RATING OF PERCEIVED EXERTION

Rating of Perceived Exertion

At various times throughout your cycle test I will hold up this scale and ask you to select the number that best represents how hard you feel the work is for you at this time. As you can see this scale ranges from a low of 6 to a high of 20. The higher the number the harder you feel the effort is for you. The highest number (20) should represent the maximum effort and fatigue level you have ever felt while cycling. There is no right or wrong answer. Just try to estimate your total feeling of exertion and effort as honestly and accurately as you possibly can. (Butts, N. K. Physiological profiles of high school female runners. *Research Quarterly for Exercise and Sport, 53(1)*: 9, 1982.)

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

[1]Borg, G. A. Perceived exertion: a note on "history" and methods. *Med. Sci. Sports Exerc.* 5:90-93, 1973.

APPENDIX D

CYCLE ERGOMETER PROTOCOL

StairMaster UP and SR Cycle Protocol

StairMaster UP and SR Cycle Protocol

Level	Time	Watts
1	0 – 2	50
3	2 – 4	84
5	4 – 6	118
7	6 – 8	152
9	8 – 10	180*
11	10 – 12	220**
13	12 – 14	254
15	14 – 16	288

* Average watts during UP cycling
** Average watts during SR cycling

APPENDIX E

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Introduction

There are several different types of cycle ergometers including upright, recumbent, semi-recumbent, and supine. The traditional upright cycle is the most widely used and has been involved in previous comparison studies between different cycle modalities. The recumbent cycle is another cycle that has been on the market for many years and the newest type of cycle to be introduced is the semi-recumbent cycle. Some studies that have compared the different modalities may interchange the terms recumbent and semi-recumbent. Even though our data collection did not involve supine cycling, the supine position was included in the discussion since this particular study addressed semi-recumbent cycling which falls between the upright and supine position.

In an attempt to explain the similarities and differences found in previous studies of cycle ergometer modalities, this section will review literature in several areas. The reviewed research is divided into submaximal effort, maximal effort, and physiological and perceptual responses of each cycle ergometer. The responses to cycling discussed in this section are heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), oxygen consumption (VO_2), HR/VO_2 slope, and rating of perceived exertion (RPE). The rationale for prescribing exercise guidelines using the upright and the semi-recumbent cycles in health club and clinical settings is also explained.

Potential Benefits of Semi-Recumbent Cycles

There are certain situations that favor using the recumbent cycle rather than the traditional upright cycle, especially for the older population. Since the bike seat is lower to the ground and resembles more of a supine position, it is easier to get into and rise from. Another advantage appears to be its use for participants, young and old, with a low level of fitness. The energy cost at the lowest workload for a recumbent cycle is lower than the energy cost for an upright cycle. Since recumbent cycles offer more comfort than standard cycles, healthy individuals who experience low back pain or orthopedic problems may also benefit. These are some of the factors that may influence the type of modality an individual chooses. In the following paragraphs the results and discussions from previous studies comparing various modalities are reviewed.

Submaximal Responses to Cycling in Different Postures

Heart rate was one variable used in almost every study comparing the physiological responses to exercise in recumbent, upright, and supine cycling. In a study conducted by Walsh-Riddle and Blumenthal (9), 20 mildly hypertensive individuals were tested at 50, 75, and 90% of VO_{2peak}. It was found that the participants had lower heart rates on the semi-recumbent cycle at rest and again at 75 and 90% of VO_{2peak}. The suggested reason for the lower HR was an increased venous return associated with the more supine body position on the semi-recumbent cycle. These findings were in agreement with studies conducted by Bonzheim et al. (1) and Westcott (10), but were in contrast to those of Quinn, Smith, Yroman, Kertzer, and Olney (6) and Proctor et al. (5).

Bonzheim et al. (1) conducted a study using 14 individuals with documented coronary artery disease. It was found that these individuals had higher HR and VO_2 values during upright cycling than during recumbent cycling when working at the same absolute workload of 100 watts.

Quinn and associates (6) performed a study using nine cardiac patients and compared the physiologic responses between the supine, recumbent, and upright cycle ergometers. They found HR to be 76 bpm lower in the supine position than in the recumbent or upright position, but found no difference between recumbent and upright cycling at a submaximal workload of 300 $kgm \cdot min^{-1}$. In agreement with these findings was a study conducted by Proctor et al. (5) who also reported no significant differences in the submaximal exercise responses during recumbent and upright cycling.

In a study conducted by Quinn and associates (6), supine VO_2 was significantly lower when compared with both the recumbent and upright positions during submaximal exercise. This is in agreement with Proctor et al. (5) but in contrast to a study conducted by Bonzheim et al (1). Bonzheim and associates (1) did not evaluate supine ergometry, however, they reported recumbent VO_2 to be significantly lower than upright ergometry. The reduced supine VO_2 during submaximal work most likely was caused by the fact that the weight of the legs did not have to be raised against gravity, therefore, the external work was reduced. Gravity would exert slightly more of an effect in the recumbent position and a much greater effect in the upright position. Also muscular efficiency may be better optimized in the supine position when compared to both the recumbent and upright positions because the lower back is stabilized and may provide a better base to push against (5).

Blood pressure is another variable commonly measured especially in studies that include cardiac patients or those participants with one or more coronary risk factors. The most recent study performed by Quinn et al. (6) found no significant differences in either SBP or DBP when nine patients with documented cardiac disease exercised at submaximal levels. A study conducted by Walsh-Riddle and Blumenthal (9) was also in agreement, however, the results of several other studies are in disagreement with the above findings (1,5,10).

Bonzheim et al. (1) reported significantly lower SBP and DBP during recumbent versus upright cycling at a submaximal workload of 100 watts. The subjects that participated in this study had documented coronary artery disease.

A training study conducted by Westcott (10) showed consistently higher SBP values on the upright cycle while exercising at 70 to 80% of maximum heart rate which indicates less cardiac effort while on the recumbent cycle. Diastolic blood pressure was similar during use of either modality.

Unlike Bonzheim et al. (1), Proctor and associates (5) showed a significantly higher SBP on the recumbent cycle when compared to the supine and upright cycles. A possible explanation for the increased SBP in their study may have been related to the isometric handgripping used for body stabilization. Isometric contractions tend to elevate blood pressure levels (8).

Rating of perceived exertion is the subjective means by which individuals rate how hard they feel they are working in relation to the present workload. There were mixed results in previous studies at submaximal exercise. A study conducted by Bonzheim and associates (1) found the submaximal workload of 100 watts was rated significantly easier during recumbent versus upright cycling. A study conducted by Walsh-Riddle and Blumenthal (9) found RPE to also be lower in the recumbent position when compared to the upright position at submaximal absolute workloads, but found no difference between the two modalities at submaximal relative workloads (75 and 90% of VO_{2peak}). According to Quinn and associates (6), there were no differences in perceptual response between users of the recumbent and upright cycle during submaximal exercise.

Maximal Responses to Upright versus Recumbent Cycling

A study conducted by Bonzheim et al. (1) examined the results of maximal exercise during upright cycling to see if they were similar to those found during recumbent cycling. They found that the HR and VO_2 responses of both cycles were not significantly different at maximal workloads. Also reported were findings that the recumbent position yielded longer exercise time and subjects achieved higher power output (177 vs 154 watts) than with the upright cycle. These findings were in agreement with a study conducted by Quinn et al. (6) which found no significant differences in HR and VO_2 at maximal levels of exertion.

In contrast to the findings above, Walsh-Riddle and Blumenthal (9) found that subjects achieved higher HR and VO_2 values during upright versus semi-recumbent cycling during maximal effort. The overall body/muscle involvement and less localized muscular fatigue in the upright position may explain why individuals were able to attain higher VO_2 levels. A higher VO_2 is associated with activities that involve use of large muscle mass (3). The semi-recumbent position seems to rely strongly on the hamstrings and quadriceps, limiting upper body movement. Fatigue of these muscles may limit exercise time, therefore, may result in a lower VO_2 at maximal effort.

Three previous studies (1,6,9) looked at SBP and DBP values at maximal exercise levels. All found that there were no differences between modalities at the maximal level.

Heart Rate/VO_2 Slope

Looking more closely at the relationship between HR and VO_2, also known as the HR/VO_2 slope, it has been agreed upon that there is a linear relationship. A study conducted by Quinn and associates (6) showed the regressions of VO_2 on HR to be nearly identical in supine, recumbent, and upright cycling. Studies conducted by Bonzheim and colleagues (1) are also in agreement. Since the %VO_{2max} and %HR were nearly identical in the two studies above, a given percentage of HR_{max} during recumbent cycling results in a given percentage of recumbent VO_{2max} comparable to that during upright cycling. It is important to note, even though the maximal physiological responses with use of the upright and recumbent cycles are similar, for any given power output, the cardiorespiratory responses with use of the recumbent cycle are lower. For example, the workloads during semi-recumbent cycling need to be higher to achieve the same HR and VO_2 as one would achieve during upright cycling.

Exercise Prescription for Using Recumbent and Upright Cycles

Maximal oxygen consumption is generally accepted as the best measure of the functional limit of the cardiovascular system and commonly interpreted as the index of cardiorespiratory fitness (7). Although it is common to use the treadmill to test an individual's fitness level, there are situations where cycle ergometers are more practical.

One area where recumbent cycles are becoming more popular is in cardiac rehabilitation exercise programs. Not only are hospital settings using these cycles for diagnostic testing but also health clubs are purchasing more semi-recumbent cycles. The majority of testing conducted in health club settings is used for administering exercise prescription. Benefits of using recumbent cycles for exercise were discussed earlier and certain conditions may predispose individuals, in both the healthy and sick populations, to use cycle ergometers rather than treadmills.

A question health/fitness professionals may be asking is whether exercise testing conducted in one position may be used to develop an activity prescription for subjects working in another position. Ideally exercise prescription for use of upright and recumbent cycles should be based on the results of the specific cycle ergometer test, but this is not always practical. In the clinical setting a treadmill graded exercise test is the most common kind of test for determining diagnosis of coronary artery disease (CAD). A major question is whether an exercise prescription developed from a treadmill is useful in determining exercise workloads on an upright or semi-recumbent cycle. A study conducted by McConnell, Swett, Jeresaty, Missri, and Al-Hani (4) found subject VO_{2peak} to be 10.2% lower during cycle ergometry than during treadmill exercise. This was attributed to the larger, more efficient muscle mass used during treadmill exercise and possibly less restriction of blood flow through the active muscle when compared to cycle ergometry.

The less restriction of blood flow and the larger muscle mass used during treadmill exercise have important implications when formulating an exercise prescription. The VO_{2peak} values obtained may be a result of the type of modality rather than the individual's actual maximum oxygen consumption. Walsh-Riddle and Blumenthal (9) conducted a study that found a lower VO_{2max} in subjects using the semi-recumbent cycle. Localized muscular fatigue of the quadriceps and hamstrings may have played a role in limiting exercise capacity on that modality. This could result in classifying individuals into a lower cardiorespiratory fitness level. According to McConnell and associates (4), the upper limit of exercise prescription is usually determined as 80% of VO_{2peak} or 85% of HR_{peak} obtained during treadmill testing. Prescribing exercise using the above HR criterion would allow individuals to exercise on the upright and semi-recumbent cycles at the appropriate intensity in terms of a VO_2 obtained on the treadmill.

Fitness/health practitioners should be cautious in prescribing the appropriate exercise intensity for the use of a recumbent cycle. A study completed by Quinn et al. (6) using 14 cardiac patients showed more ECG abnormalities in the recumbent position compared with the supine or upright positions. The abnormalities involved the degree of ST segment depression and dysrhythmias. Two men had 2-2.5 mm ST-depression while in the supine and recumbent positions, which was not observed in the upright position, even though identical workloads were obtained on all three modalities. According to a study done by Currie, Kelly, and Pitt (2), it was indicated that the supine position is a potentiator of myocardial ischemia due to an increased venous return. This information is not suggesting cardiac patients avoid recumbent cycling, it is just recommending exercise intensity of recumbent cycling be prescribed judiciously to patients who experience ischemia.

Summary

The newest cycle on the market is the semi-recumbent cycle. Studies conducted in the past compared the different cycling positions at both the submaximal and maximal levels. At the submaximal level one might think HR and VO_2 would be lower during recumbent than during upright cycling. Three studies have shown lower HR and VO_2 in the recumbent position than in the upright position and two studies found no differences between the two modalities. At maximal exertion two previous studies found little or no differences and one study found that HR and VO_2 were higher in the upright position. All investigators seemed to agree on maximal SBP and DBP readings and HR/VO_2 slope. The HR/VO_2 slope is helpful in explaining the workloads needed to achieve identical HR and oxygen consumption values during recumbent and upright cycling. Mixed results have been reported concerning the different cycling positions and further research is needed to clarify the issue.

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