ABSTRACT

ECKSTROM, N. E. A comparison of submaximal exercise responses to upright and semi-recumbent cycle ergometers with habituation. MS in Adult Fitness/Cardiac Rehabilitation, December 2000, 33pp. (R. Mikat)

To clarify the influence of body position with cycle ergometery this study compared the responses to 20-minutes of submaximal exercise on the upright (UP) and semi-recumbent (SR) cycle at self-selected intensities. Twenty-two subjects (14 M, 8 F), 20-27 years old, volunteered for the study. Subjects spent 4 weeks habituating to each cycle prior to testing. All subjects performed randomized UP and SR cycle ergometer testing a minimum of 24 hours apart. The physiological responses (VO_2, HR, Kcal/min, SBP, DBP, and RPE) were averaged for each exercise session. Comparisons of submaximal values were analyzed using a 2 x 6 MANOVA with repeated measures and alpha was set at .05. Overall, it was found that there were no statistically significant differences ($p >$ .05) between the UP and SR cycles with males or females. However, when gender was ignored and data were combined, there were significantly higher VO_2 and HR responses on the UP versus the SR cycle. Also, no significant differences were found in Kcal/min, SBP, DBP, and RPE. Subjects worked at significantly higher ($p < .05$) workloads on the SR cycle than on the UP cycle (SR = 152; UP = 135). Therefore, it appears that when subjects exercise at self-selected intensities, the UP provides a higher cardiovascular workout. Since these findings were similar to previous research, it was concluded that habituation had little or no affect on physiological response differences between UP and SR cycle ergometery.

A COMPARISON OF SUBMAXIMAL EXERCISE RESPONSES TO UPRIGHT AND SEMI-RECUMBENT CYCLE ERGOMETERS WITH HABITUATION

A MANUSCRIPT STYLE THESIS PRESENTED

TO

THE GRADUATE FACULTY

UNIVERSITY OF WISCONSIN-LA CROSSE

IN PARTIAL FULLFILLMENT

OF THE REQUIREMENTS FOR THE

MASTER OF SCIENCE DEGREE

BY

NORA A. ECKSTROM

DECEMBER 2000

COLLEGE OF HEALTH, PHYSICAL EDUCATION, AND RECREATION

UNIVERSITY OF WISCONSIN-LA CROSSE

THESIS FINAL ORAL DEFENSE FORM

Candidate: Nora A. Eckstrom

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 — Date: 5-9-00

Thesis Committee Member Signature — Date: 5-9-00

Thesis Committee Member Signature — Date: 5-9-00

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

Associate Dean, College of Health Physical Education and Recreation — Date: 6/28/00

Director of University Graduate Studies — Date: 6/28/00

ACKNOWLEDGEMENTS

I would like to express my thanks to Dr. Richard Mikat for his time and commitment he gave me as my thesis chairperson. Thesis completion would not have been possible without his guidance. I would also like to extend my gratitude to Dr. John Porcari and Dr. David Reineke who served on my thesis committee. I would not have made it through this process without my dedicated committee members.

Also, I would like to thank my wonderful thesis partner, Charlotte Goebel. Her humor along with her dedication, helped me get through this process. She was a delight to work with.

I would also like to express my appreciation to my family. They have always supported my choices and without their unconditional love and support, I would never be where I am today. They are the people who made this all possible.

Finally, I would like to express my gratitude and thanks to my boyfriend, Brandon. He has been there and supported me through the most stressful and toughest times this past year. With his love and support, I was able to complete my masters degree.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

APPENDIX | PAGE

INTRODUCTION

Previous studies have extensively documented the cardiovascular responses to acute exercise in various adult populations using different modes of exercise. While the treadmill is the most widely used exercise modality, practical considerations sometimes favor the use of cycle ergometers. There are several types of cycle ergometers. Traditional upright ergometers (UP) are the most widely used, however, the semi-recumbent (SR) cycle ergometer is gaining popularity and has proven to be effective. A SR cycle places the subject in a seated position with an angled backrest. On a SR cycle, subjects peddle with their legs extended forward while sitting in a chair. There is a wide spread belief that exercising on a SR cycle is easier and more accommodating, especially with individuals who may have difficulty with their range of motion.

Several comparisons of cardiovascular responses during UP and SR exercise have been reported. Generally, it has been noted that submaximal heart rate (HR) responses in the SR position tend to be lower at the same workload when compared to the UP position. Currie et al. (1) suggested that the potentially increased venous return associated with the SR position could produce significantly lower HR responses when compared to the UP.

To further clarify the influence of body position on exercise responses, Bonzheim et al. (2) studied the effects of UP and SR cycle ergometery in 14 men with coronary artery disease. At 100 watts, the relative oxygen uptake (VO_2) was 15% greater in the UP position. The reduced VO_2 seen in the SR position during submaximal work was potentially caused by the fact that the weight of the legs did not have to be raised against gravity, and therefore the external work may have been reduced (3). Similarly, along with a reduction in external work, Smith et al. (4) suggested that subjects have a higher muscular efficiency with more reclined positions, thus creating a lower VO_2 response at a given workload on the SR cycle. Therefore, it appears that the SR tends to have lower HR and VO_2 responses when compared to the UP cycle ergometer.

Blood pressure (BP) has been shown to respond differently based on cycle position. According to Quinn et al. (3), BP was similar for both positions. However, Bonzheim et al. (2) found a higher systolic blood pressure (SBP) in the UP position, and Proctor et al. (5) observed a higher SBP on the SR cycle.

While several studies have compared physiological responses between UP and SR cycles using set workloads, few have examined these responses during exercise at a self-selected intensity. One study by Swensen (6) examined the differences between UP and SR cycles while exercising at self-selected intensities. However, Swensen (6) did not include a period of habituation. Therefore, the purpose of this study was to determine the physiological differences of submaximal exercise responses to the Stairmaster UP cycle and the Stairmaster SR cycle ergometers during self-selected intensities. Because habituation may significantly affect exercise responses to activity, all subjects underwent 4 weeks of training on both cycle ergometers prior to testing.

METHODS

Subject Selection

Subjects in this study included 14 male and 8 female volunteers between the ages of 20-27 who were moderately active. Moderately active was defined as individuals who participate in some type of physical activity three to five times a week for 30-60 minutes per session. Prior to participation, subjects were required to read and complete an informed consent form, which was approved by the University of Wisconsin-La Crosse (UW-L) Institutional Review Board (see Appendix A). Participants were selected from students at UW-L. All subjects were apparently healthy with no cardiovascular limitations to exercise as stated by the Physical Activity Readiness Questionnaire (PAR-Q) (7) (see Appendix B). American College of Sports Medicine (ACSM) (7) defines apparently healthy as individuals who are asymptomatic and have no more than one coronary risk factor.

Practice Sessions

Subjects were required to begin 4 weeks of habituation after an initial orientation meeting. During the 4 weeks of habituation, subjects practiced 8 times on each cycle ergometer. Four sessions were conducted at the Human Performance Laboratory (HPL) at UW-L on the same machines, which were used for testing. The other practice sessions were completed on campus at the Mitchell Hall strength center using UP and SR cycles. Exercise sessions lasted 30 minutes and were conducted at a self-selected intensity. During practice sessions, subjects self-recorded their HR and rating of perceived exertion (RPE) using the 6-20 Borg scale (8) (see Appendix C). In addition, each subject underwent at least one practice session while wearing the equipment that was used for metabolic and HR measurements during testing.

Testing Methodology

All testing took place at the HPL at UW-L. Prior to testing, subject's age, height, and body mass were recorded. Testing included 20-minute submaximal exercise bouts on both the UP and SR ergometers. The order in which subjects took these tests was randomly assigned. Tests were administered with a minimum of 24 hours of rest, and were performed at the same time of the day. Physiological exercise responses (VO_2, caloric expenditure (Kcal/min), HR, SBP, DBP, and RPE) were measured throughout the entire test. While testing, subjects exercised at a self-selected intensity and were allowed to change the intensity at any time. Subjects were asked to work similar to their normal aerobic workouts.

Expired air was collected and analyzed with a Quinton (Q-Plex 1, Quinton Instrument Company, Seattle, WA) metabolic cart. The Quinton metabolic cart (QMC) was calibrated prior to the testing of each subject. The QMC was used to measure relative VO_2 (ml/kg/min) and Kcal each minute of the tests. Heart rate was recorded each minute with the Polar Vantage Heart Rate Monitor (Polar-CIC Inc., Port Washington, NY). The monitor components included a heart rate watch and a radio-telemetry transmitter unit, which was held to the body with a chest strap. Blood pressure was taken every 5 minutes using a calibrated mercury sphygmomanometer. Finally, RPE was measured every 5 minutes using the 6-20 Borg scale (8) (see Appendix C).

Statistical Analysis

Standard descriptive statistics were used to describe the physical characteristics of the subjects and their mean responses of VO_2, Kcal, HR, SBP, DBP, and RPE for both the

UP and SR cycle ergometers. Submaximal values were analyzed using a 2 x 6 multivariate analysis of variance (MANOVA) with repeated measures and a Greenhouse-Geisser adjustment. Alpha was set at .05.

RESULTS

The present study compared the physiological responses during submaximal exercise on the UP and SR cycle ergometers. Their physical characteristics are presented in Table 1.

Table 1

Descriptive Physical Characteristics of the Subjects

Variable	Males (n = 14) X ± SD	Females (n = 8) X ± SD
Age (yr)	22.9 ± 2.11	22.0 ± 2.33
Height (cm)	182.7 ± 7.86	167.9 ± 6.98
Mass (kg)	87.9 ± 21.14	62.0 ± 10.40

Values are presented as mean ± standard deviation

All subjects completed 20 minutes of submaximal exercise at self-selected intensities for both the UP and SR cycles. Comparisons of physiological responses between UP and SR cycles are presented in Tables 2-4.

Table 2

Average Submaximal Responses of Males on the UP and SR Cycles (n = 14)

Variable	UP X ± SD	SR X ± SD	Difference
VO_2 (ml/kg/min)	28.0± 6.20	26.8 ± 6.20	1.3
Kcal/min	12.1 ± 1.91	11.8 ± 1.7	0.3
HR (bpm)	151.8 ± 11.46	141.4 ± 16.58	10.4
SBP (mmHg)	167.7 ± 18.85	163.0 ± 11.63	4.7
DBP (mmHg)	57.6 ± 15.55	51.3 ± 11.15	6.3
RPE	13.4 ± 1.29	13.6 ± 0.97	0.2

Table 3

Average Submaximal Responses of Females on the UP and SR Cycles (n = 8)

Variable	UP X ± SD	SR X ± SD	Difference
VO_2 (ml/kg/min)	30.4 ± 5.37	27.8 ± 4.15	2.6
Kcal/min	9.8 ± 2.51	8.8 ± 2.10	1.0
HR (bpm)	170.0 ± 6.21	158.1 ± 8.11	11.9
SBP (mmHg)	152.5 ± 19.74	140.8± 11.91	11.8
DBP (mmHg)	57.0 ± 13.38	52.5 ± 7.05	4.5
RPE	14.5 ± 1.00	13.8 ± 0.97	0.8

Table 4

Average Submaximal Responses on the UP and SR Cycles (N = 22)

Variable	UP X ± SD	SR X ± SD	Difference
VO_2 (ml/kg/min)	28.9 ± 6.16	27.1 ± 5.70	1.8*
Kcal/min	11.3 ± 2.49	10.7 ± 2.45	0.5
HR (bpm)	158.4 ± 13.51	147.45 ± 16.61	11.0*
SBP (mmHg)	162.2 ± 21.01	154.9 ± 16.26	7.3
DBP (mmHg)	57.4 ± 15.15	51.7 ± 10.11	5.6
RPE	13.8 ± 1.33	13.7 ± 0.99	0.1

* Significantly different ($p < .05$)

There were no significant differences ($p > .05$) in any of the variables between UP and SR cycles in either males or females. The responses of individual variables are presented in Figure 1. Furthermore, there were no significant interaction effects ($p > .05$) found between gender, therefore males and females responded similar to both cycle ergometers. Since this study showed no significant differences between UP and SR cycles with males or females, the data were combined to better illustrate the differences in cycle positions.

When data were combined significant differences were found between UP and SR cycles. Overall, it was found that VO_2 and HR were significantly greater ($p < .05$) on the UP when compared to the SR cycle. No significant differences ($p > .05$) were found in

Kcal/min, SBP, DBP, and RPE. The responses of physiological variables are presented in Figures 2 through 7. Also, it was found that the values for work levels (power output) on the SR cycle were significantly greater ($p < .05$) than the UP cycle. The average mean work level on the SR was 152 watts versus 135 watts on the UP cycle.

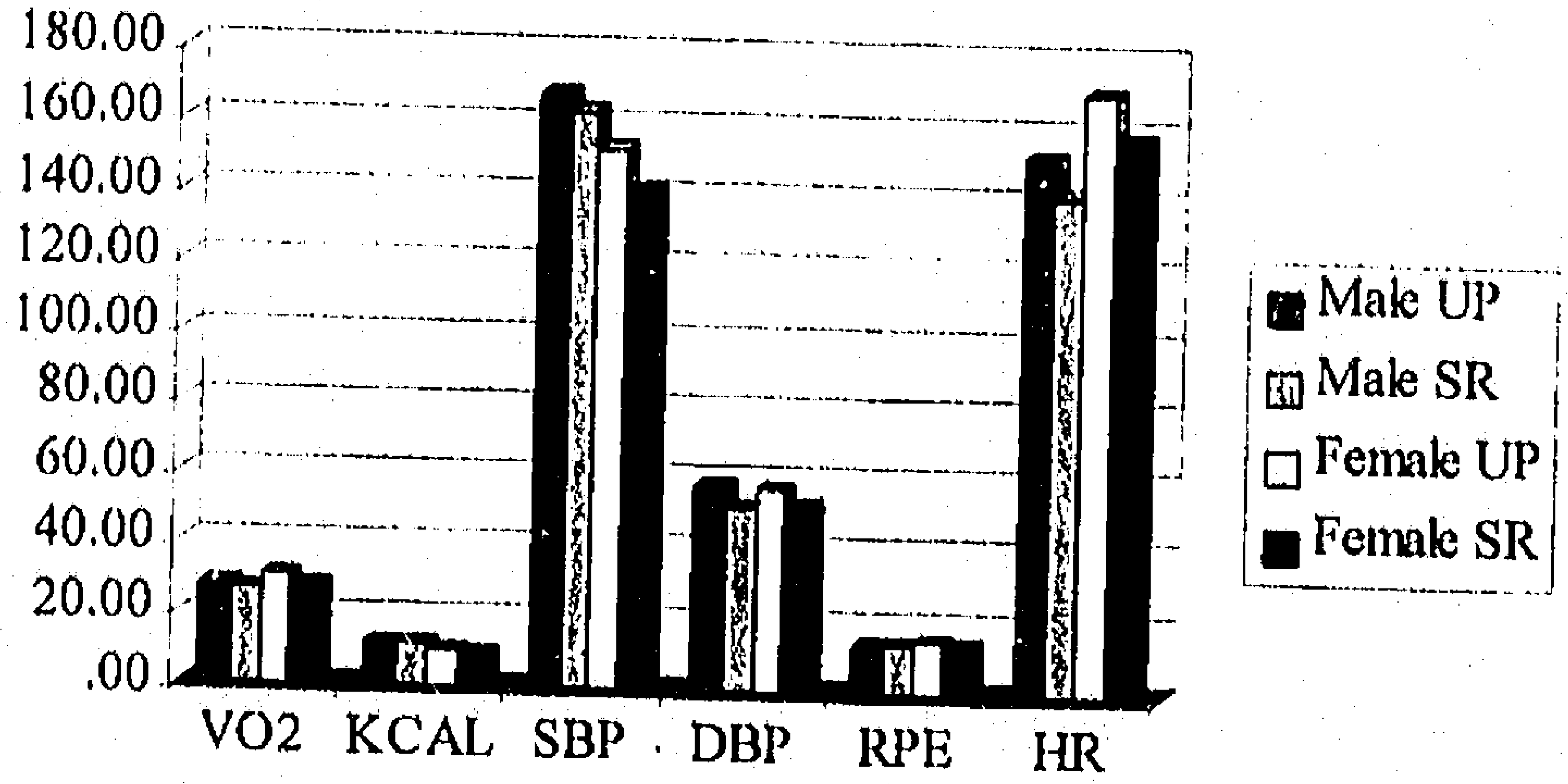

Figure 1. Comparison of submaximal responses for males and females on the UP and SR cycles. No statistically significant differences were found.

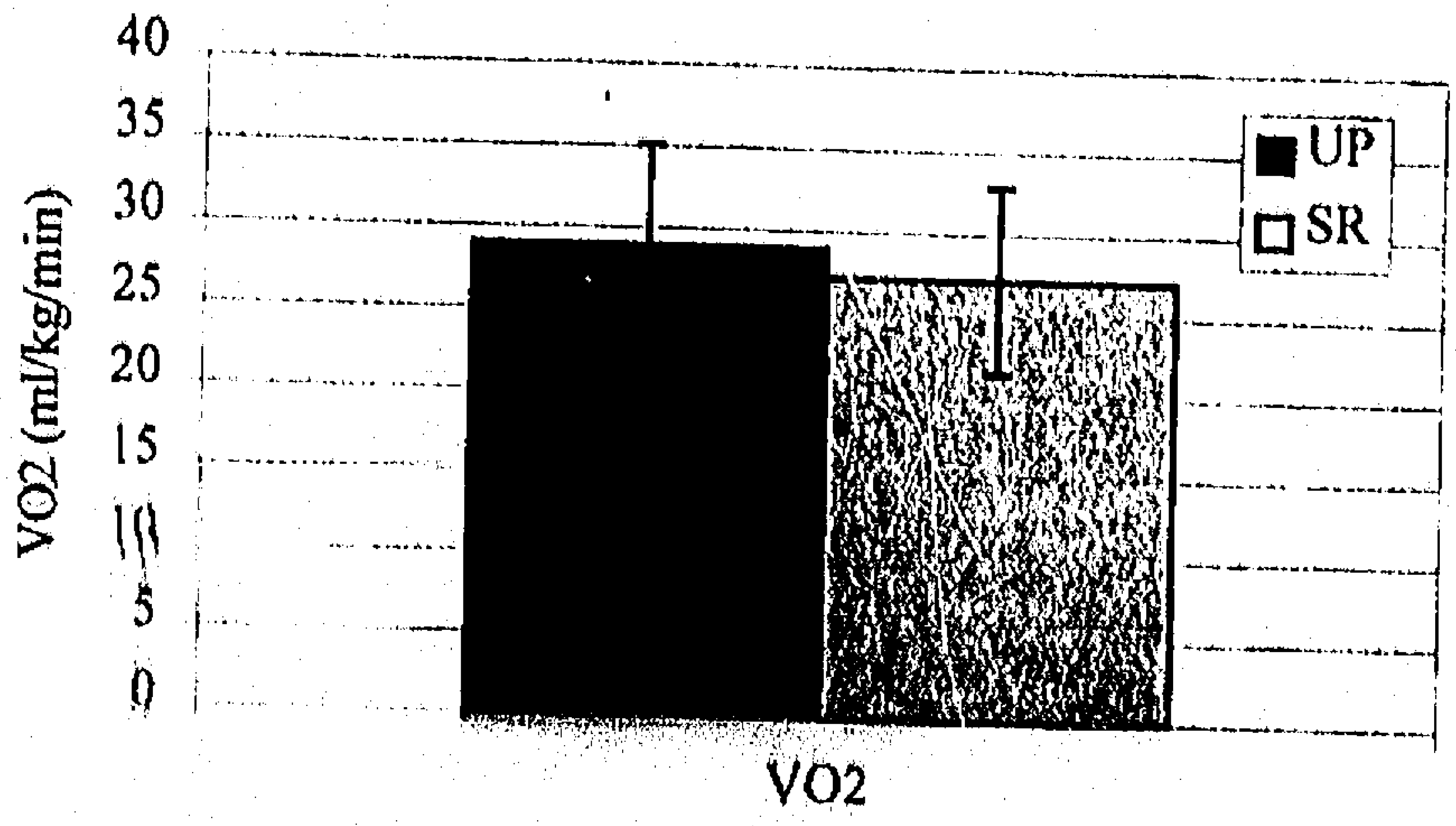

Figure 2. Comparison of VO_2 on UP and SR cycles. Bars represent standard deviation. ($N = 22$).

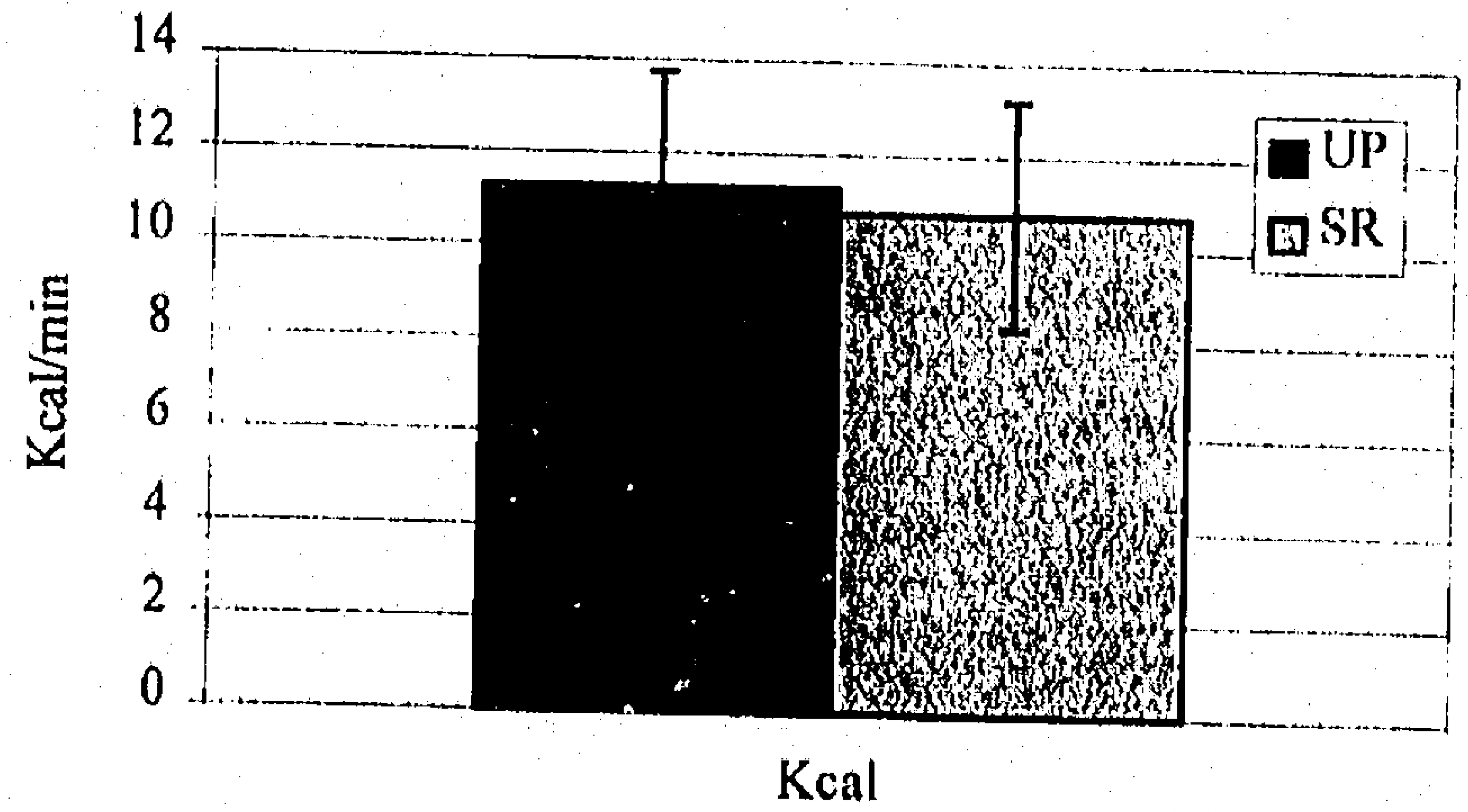

Figure 3. Comparison of Kcal/min on UP and SR cycles. Bars represent standard deviation. (N = 22).

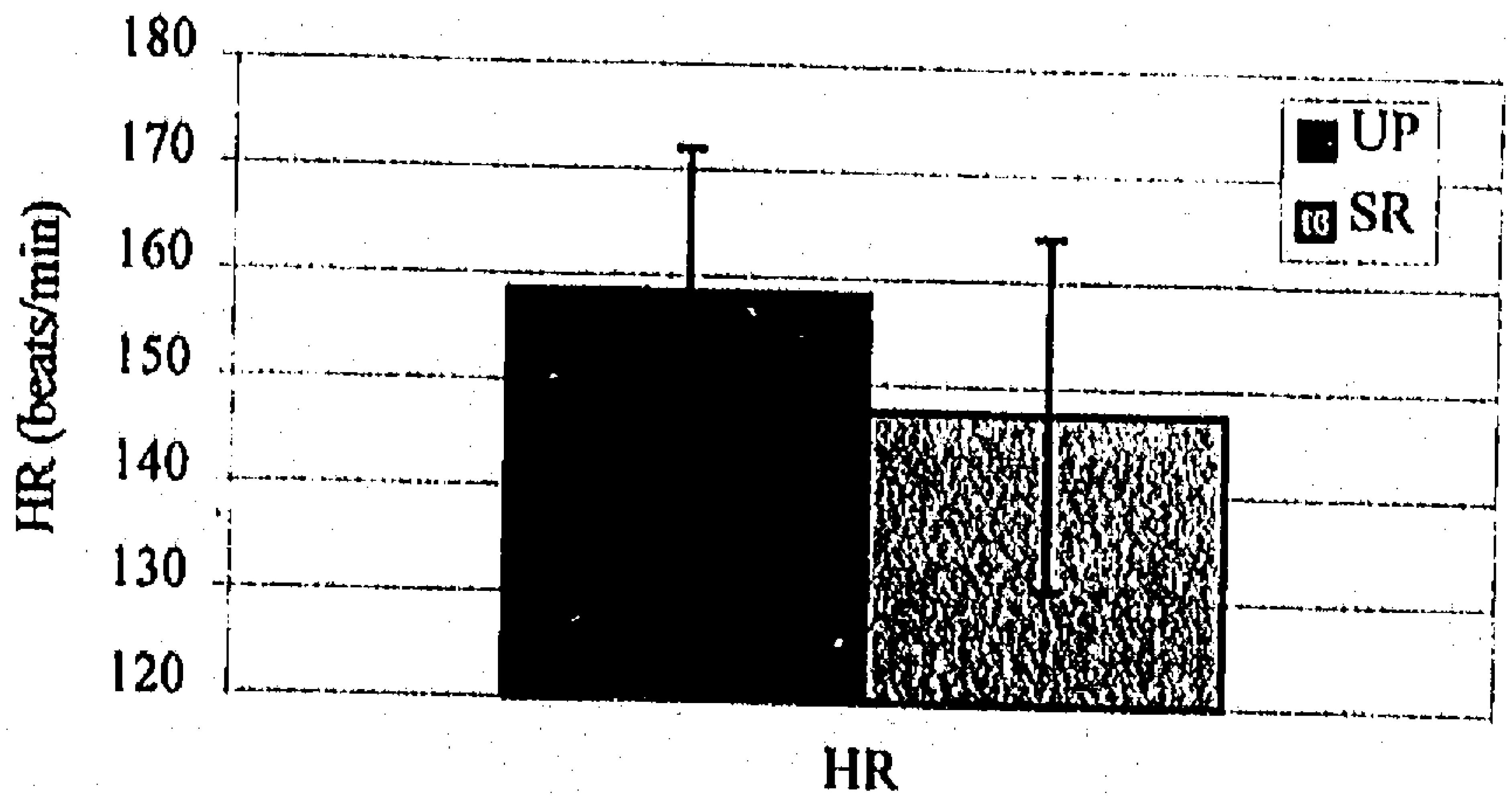

Figure 4. Comparison of HR on UP and SR cycles. Bars represent standard deviation. (N = 22).

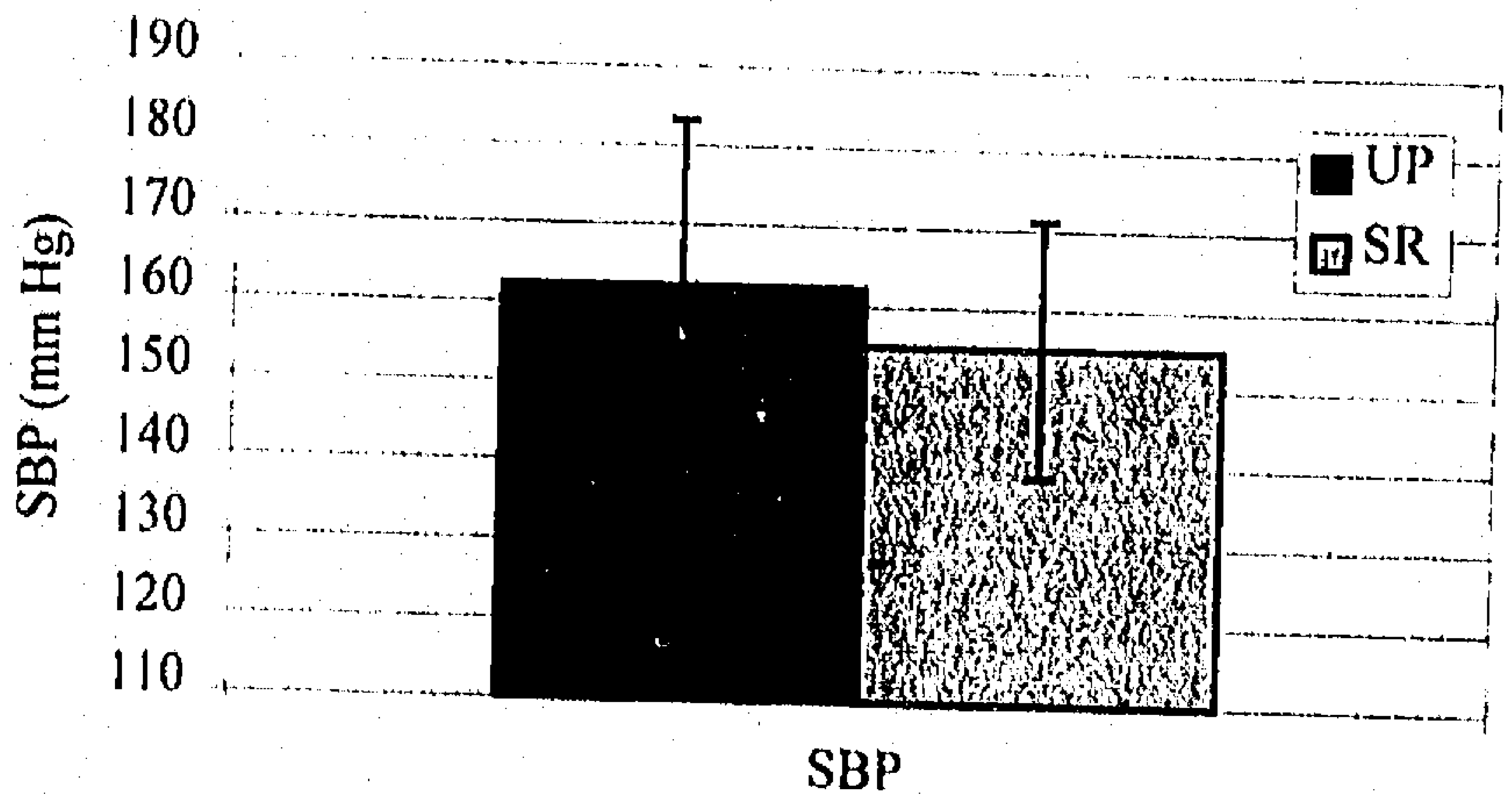

Figure 5. Comparison of SBP on UP and SR cycles. Bars represent standard deviation. (N = 22).

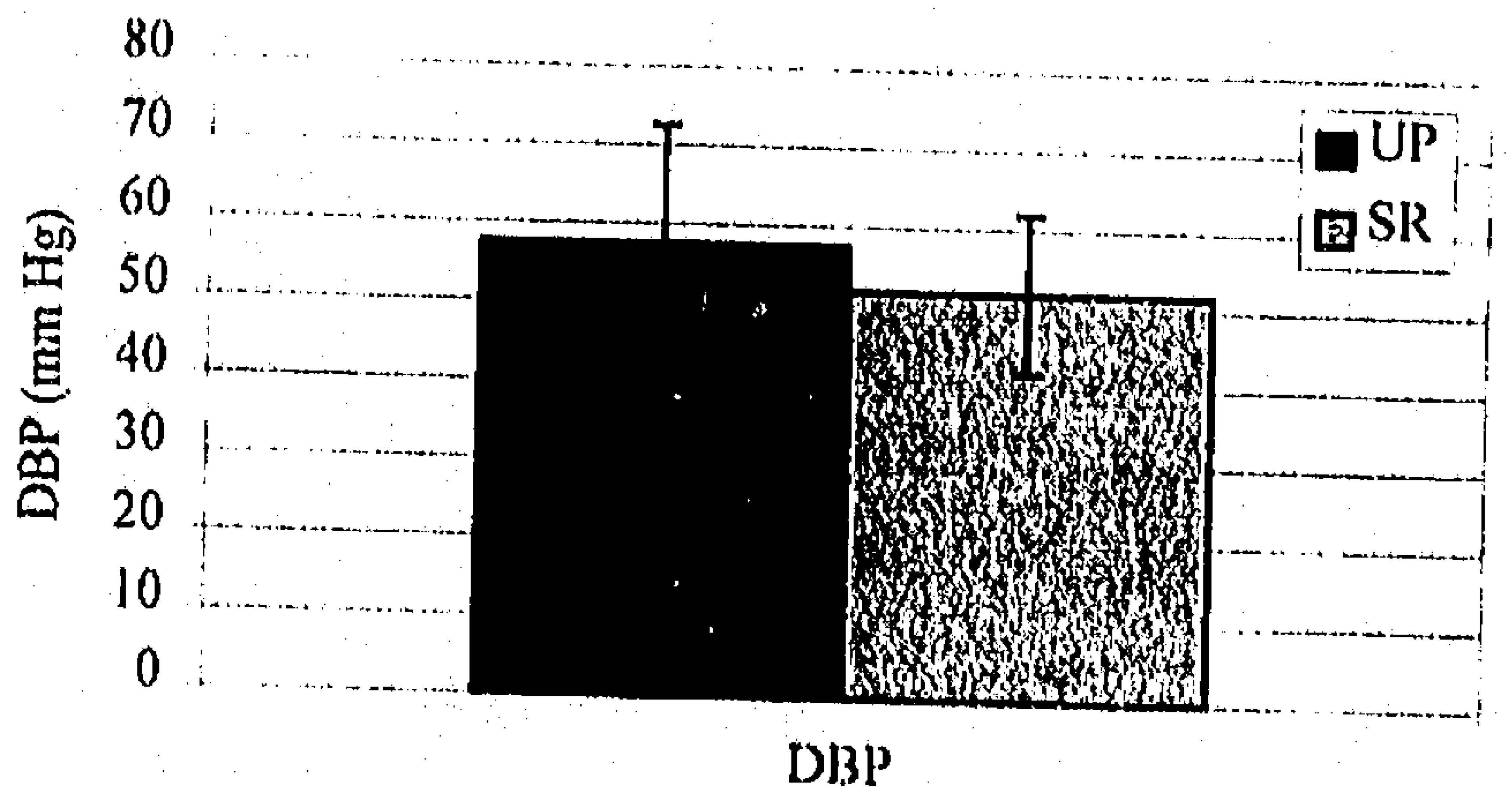

Figure 6. Comparison of DBP on UP and SR cycles. Bars represent standard deviation. (N = 22).

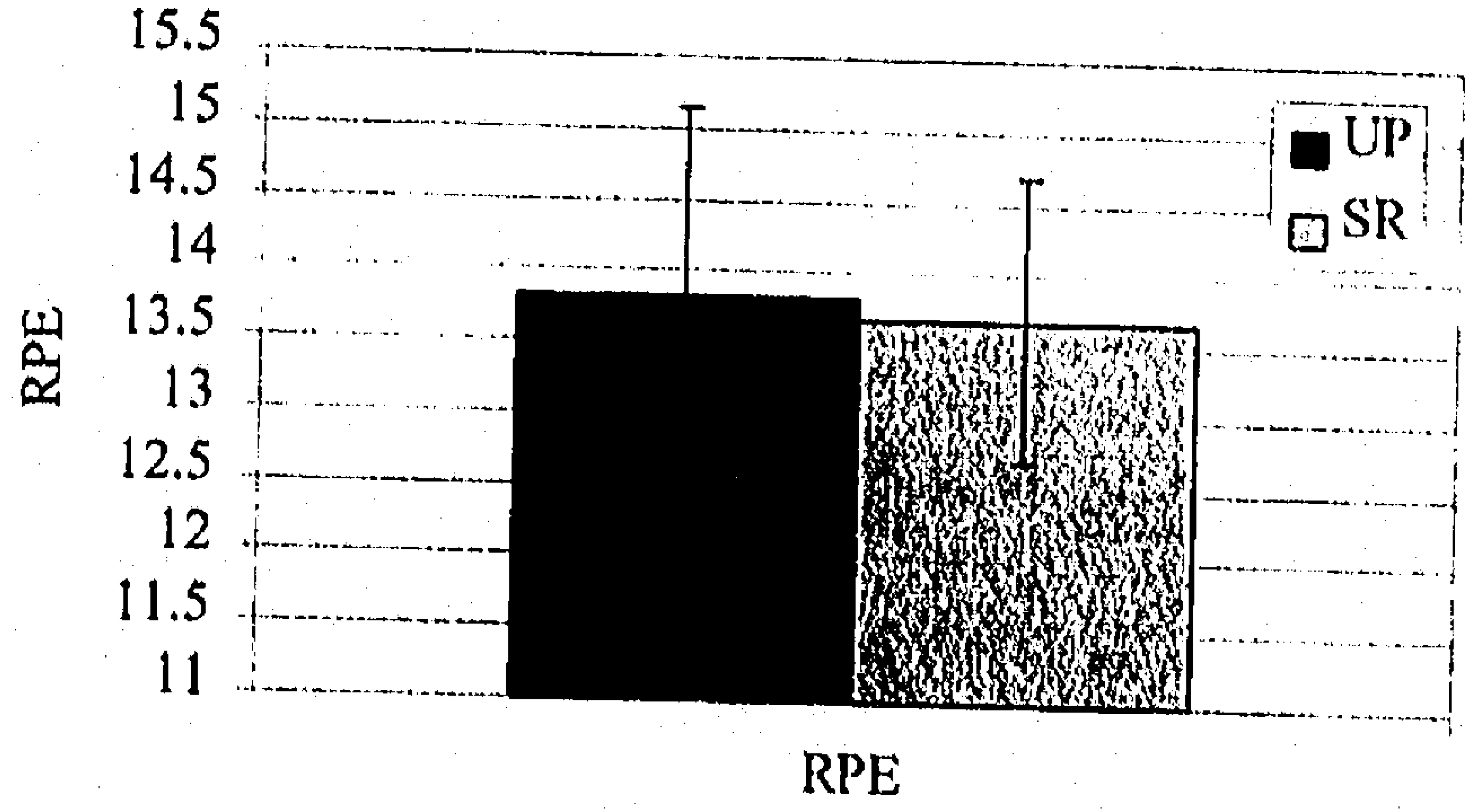

Figure 7. Comparison of RPE on UP and SR cycles. Bars represent standard deviation. (N = 22).

DISCUSSION

This study evaluated the physiological responses to self-selected, submaximal exercise on the UP and SR cycle ergometers with controlled habituation. It was found that during submaximal, self-selected exercise the UP cycle elicits significantly higher values for relative VO_2 and HR. There were no significant differences in Kcal/min, SBP, DBP and RPE between UP and SR cycles. Furthermore, no significant differences were found between both modalities within male or female samples.

In the current study, relative VO_2 was significantly higher on the UP than on the SR cycle. This is consistent with the findings of Bonzheim et al. (2), Walsh-Riddle and Blumenthal (9), Swensen (6), and Smith et al. (4). They theorized that the lower relative VO_2 on the SR might be due to an increase in muscular efficiency in a more reclined position. Since the backrest on the SR cycle provides a stable back support to push against, it allows the legs to push more efficiently. This increase in muscular efficiency would result in a lower VO_2. Only one other study has examined the submaximal responses of cycle ergometry with self-selected intensities. Similarly, Swensen (6) found relative VO_2 to be greater on the UP than on the SR cycle using self-selected intensities.

According to Bonzheim et al. (2), Currie et al. (1), Swensen (6), Walsh-Riddle and Blumenthal (9) and Wescott (10), the UP position led to higher HR measurements than the SR position. It is suggested that there is an increase in venous return associated with SR or supine positions, which can produce a significantly lower HR response when compared to the UP cycle (1). The elevated leg position during SR or supine cycling may facilitate blood returning to the heart more quickly, therefore increasing stroke volume and decreasing HR. Another factor may be due to the reduced external work, since the weight of legs does not have to be raised against gravity in the SR position (1). The impact of increased venous return, along with increased muscle efficiency and reduced external work may all contribute to the lower physiological responses on the SR cycle.

Similar to the above mentioned investigations, the present study concluded there were significantly higher HR responses on the UP than the SR cycle. This is in disagreement with Smith et al. (4), who reported that HR is not affected by seat back angle with cycle ergometry. In addition, they concluded that the selection of a more reclined position for cycling could improve muscular efficiency without affecting HR response (4).

In this study, it was found that there were no significant differences in SBP and DBP between the UP and SR cycles. This is in agreement with Quinn et al. (3) and Walsh-Riddle and Blumenthal (9). In contrast, Bonzheim et al. (2) and Swensen (6) found SBP to be higher on the UP than the SR position. On the other hand, Currie et al. (1) found that both SBP and DBP were significantly higher in SR for a given workload. They suggested this response might be due to the effects of handgripping, which they found occurred more often on the SR cycle (1). Differences in blood pressure between studies may be caused by a variety of error sources. These may include the angle of the arm during blood pressure measurements, body position between cycles, or one cycle may be louder than the other making it difficult to get accurate, reliable measurements.

The current findings for RPE were not significantly different when comparing both the UP and SR cycles. The subjects perceived the exercise intensity between both modalities to be similar despite the elevated oxygen consumption and HR response on the UP cycle. These data agree with the findings from Smith et al. (4), who found that RPE was not affected by differences in seat angle. Conversely, our data disagrees with the findings of Bonzheim et al. (2). They concluded that at 100 watts, patients perceived SR cycling to be significantly easier than UP exercise. These observations may be due to the lower cardiovascular needs of SR cycling such as a lower submaximal VO_2 and HR with absolute workloads and self-selected intensities. In the current study, it appears that when subjects are allowed to choose their own intensity for a workout, they perceive their workouts to be similar with both cycles. This agrees with Swensen (6), who also examined self-selected intensities. Our study suggests that since subjects were habituated, they were able to get familiar with both cycles and became more comfortable with their workout intensity, resulting in similar RPE responses for both cycle ergometers. Despite the similar RPE values, it was found that subjects worked at significantly higher workloads on the SR compared to the UP cycle.

From this investigation, we can conclude that the UP provides significantly greater VO_2 and HR responses than the SR cycle when exercising at self-selected intensities. Swensen (6) also examined UP and SR differences using self-selected intensities. Both studies found that the UP produced higher physiological differences than the SR cycle. The primary difference between this former study and the present investigation is that subjects in the present study were given a period of habituation prior to testing. Since both studies resulted in similar findings, it is reasonable to assume that habituation does not appear to provide any significance to the physiological responses of cycle ergometry when applying self-selected intensities.

In establishing an exercise prescription for individuals interested in using cycle ergometery, it is important to consider an appropriate workload for both modalities, which best represents the desired intensity of the workout. When developing an exercise prescription, the appropriate absolute workload for UP exercise would need to be increased for SR exercise. Bonzheim et al. (2) found that more than half of the subjects preferred the SR to the UP ergometer (2). In addition, these researchers state that one advantage of a SR cycle ergometer appears to be its utility in patients with limited cardiorespiratory capacity (2).

In conclusion, this study found that the UP cycle ergometer provides higher VO_2 and HR responses than the SR cycle from habituated subjects during submaximal exercise with self-selected intensities. Since higher workloads and lower VO_2 and HR responses were achieved on the SR cycle, it would appear that the SR cycle may not give as good of a workout as the UP cycle when subjects self-select their intensity. The current investigation concluded that the differences in cycle ergometers were attributed to the cycle types and the findings were not credited to the controlled period of habituation.

It is important to note that these findings should not be generalized to all populations. This study examined healthy subjects between the ages 20-27. Other populations, including unfit subjects, cardiac patients, post-surgery patients, obese subjects or subjects in other age ranges may respond differently. It is therefore recommended that future research be done to evaluate these populations under the conditions of the present study.

REFERENCES

1. Currie PJ, Kelly MJ, Pitt A (1983). Comparison of supine and erect bicycle exercise electrocardiography in coronary heart disease: accentuation of exercise-induced ischemic ST depression by supine posture. *Amer. J. of Cardio.* 52:1167-1173.

2. Bonzheim SC, Franklin BA, Dewitt C, et al. (1992). Physiologic responses to recumbent versus upright cycle ergometry, and implications for exercise prescription in patients with coronary artery disease. *Amer. J. of Cardio.* 69:40-44.

3. Quinn TJ, Smith SW, Vroman NB, Kertzer R, Olney WB (1995). Physiologic responses of cardiac patients to supine, recumbent, and upright cycle ergometry. *Arch. Physic. Med. Rehab.* 76:257-261.

4. Smith JC, Hill DW, Zolfoghary MC, Davis GM (1990). Effect of seat back angle on responses to cycle ergometry. *Med. Sci. Sports Exerc.* 22:S12.

5. Proctor D, Sinning W, Quinn T, Roemmich J, Ehrlich V, Goodpaster B (1990). Submaximal responses to upright, recumbent, and supine bicycle ergometer exercise. *Med. Sci. Sports Exerc.* 22:S12.

6. Swensen CT (1999). Physiological responses between a Stairmaster upright and a Stairmaster semi-recumbent cycle at submaximal self-selected pace. Unpublished master's thesis, University of Wisconsin-La Crosse, La Crosse.

7. American College of Sports Medicine (1995). *Guidelines for Exercise Testing and Prescription* (5th ed.). Baltimore, MD: Williams & Wilkins.

8. Borg GAV (1982). Psychological basis of perceived exertion. *Med. Sci. Sports Exerc.* 14:377-381.

9. Walsh-Riddle M, Blumenthal J (1989). Cardiovascular responses during upright and semi-recumbent cycle ergometry testing. *Med. Sci. Sports Exerc.* 21:581-585.

10. Westcott WL (1991). Recumbent cycling keeps exertion levels high but cardiac effort low. *Perspective* 2:34-35.

APPENDIX A

INFORMED CONSENT FORM

INFORMED CONSENT FOR THE COMPARISON OF SUBMAXIMAL EXERCISE RESPONSES TO UPRIGHT AND SEMI-RECUMBENT CYCLE ERGOMETERS WITH HABITUATION

I, ______________________________ agree to volunteer to participate as a subject in this study, which compares the submaximal exercise responses to upright versus semi-recumbent cycle ergometers with practice training while exercising at a self-selected intensity. Training requires that I practice exercising 10 times on each cycle prior to the testing sessions. Practice sessions will last 30 minutes each session for 10 sessions on each type of cycle ergometer. Six of the 20 practice sessions must take place in the Human Performance Research Laboratory at the University of Wisconsin-La Crosse.

A total of two exercise tests will be performed and data collection will also last 30 minutes. Participation requires me to have my oxygen consumption, caloric expenditure, heart rate, rate of perceived exertion, and blood pressure measured throughout each test. Repeated tests will take place within a 24 to 48 hour period. During each test, I have been informed I will be wearing a mouthpiece, headgear and nose clip along with a heart rate monitor. Wearing these pieces of equipment may cause slight discomfort.

Furthermore, I have been informed there are certain risks associated with exercise. The possibility of changes in blood pressure, heart rate, difficulty breathing, along with muscle soreness, nausea, dizziness may exist. In some rare instances, death may occur. All precautions will be taken to avoid any foreseeable problems. If any complications do occur, the test will be terminated.

To the best of my knowledge I do not have any existing medical complications that may prohibit me from participating in this study. I also was informed that my participation is voluntary and I have the right to refuse or discontinue my participation at any given time throughout the study without penalty.

I also consent to the publication or dissemination of the results and I have been informed that all of my personal information will remain confidential. If I have any questions or concerns, either prior to testing or during testing, I can call Nora Eckstrom at 782-4206, Charolette Goebel at 796-9340, or Dr. Richard Mikat, research advisor, at 785-8182.

I have been informed of my responsibility in this study and I have had all my questions answered to the best of my satisfaction, I voluntarily consent to be a subject in this study. Please contact Dr. Garth Tymeson, Chair of UWL Institutional Review Board, if you have any questions about the protection of human subjects, at (608) 785-8155.

Participant ______________________________ Date ____________________

Researcher ______________________________ Date ____________________

APPENDIX B

PERSONAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

Personal Activity Readiness Questionnaire (PAR-Q)

A Comparison of Submaximal Exercise Responses to Upright and Semi-recumbent Cycle Ergometers with Habituation

Name ______________________________ Date____________________

Date of Birth_________________________

The PAR-Q is a standard form designed to determine your initial health and activity level. The test identifies those individuals who may be at risk if they engage in this study. Answer the following questions to the best of your ability. Check "yes" or "no" to answer the questions as they pertain to you.

_____ yes _______ 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?

_____ yes _______ no 2. Do you feel pain in your chest when you do physical activity?

_____ yes _______ no 3. In the past month, have you had chest pain when you were not doing physical activity?

_____ yes _______ no 4. Do you lose your balance because of dizziness or do you ever lose consciousness?

_____ yes _______ no 5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

_____ yes _______ no 6. Is your doctor currently prescribing drugs)for example, water pills) for your blood pressure or heart condition?

_____ yes _______ no 7. Do you know for any other reason why you should not do physical activity?

APPENDIX C

RATINGS OF PERCEIVED EXERTION (RPE)

Fifteen-Point Borg Perceived Exertion Scale *

Ratings of Perceived Exertion	Level of Exertion
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	

* Borg, G. A. Psychological bases of perceived exertion. *Med. Sci. Sports.* 14:377-381, 1983.

APPENDIX D

REVIEW OF RELATED LITERATURE

REVIEW OF RELATED LITERATURE

Introduction

There are multitudes of indoor exercise equipment which promote aerobic fitness and the control of body weight. According to the guidelines published by the American College of Sports Medicine, many different exercise modes can produce beneficial cardiovascular effects (1). However, it is possible that some modes may elicit significant differences in cardiovascular responses and thus may favor a particular piece of equipment for certain individuals. For example, results from a previous study reported that when participants exercised at a self-selected pace over the course of an exercise program, jogging would utilize considerably more calories each year than would walking (2). This energy expenditure difference could significantly impact weight loss.

Cycle ergometers have become more widely used among exercise participants. There are several different types of cycle ergometers. There are the upright (UP), semi-recumbent (SR) and supine (SUP) cycles. The UP cycle resembles a traditional bicycle, whereas a SR cycle has individuals pedal in a seated position with an angled backrest. The SR cycle can be described as cycling with legs extended forward at a horizontal level while sitting in a chair. There is a wide spread belief that exercising on a SR cycle is easier and more accommodating, especially with individuals who may have difficulty with their range of motion. With the SUP cycle, the subject pedals while lying flat on the seat. In an attempt to explain the benefits of each cycle ergometer, the following sections discuss previous research regarding cycle ergometery.

Benefits of Semi-Recumbent Cycle Ergometry

There are many benefits of semi-recumbent cycle ergometry. Since the SR cycle is a seated position with a backrest, it helps support the upper body. There are certain situations, which favor SR cycling over traditional UP cycling. This is especially true for older populations. The bike seat is lower to the ground, which allows easier access on and off the cycle. This is advantageous for both older and younger populations who have a lower level of fitness. Also, individuals with a lower level of fitness may find the SR cycle beneficial since it elicits a lower energy cost at the lowest workloads as compared to the UP cycle. Furthermore, it has been suggested that increased venous return associated with the SR and SUP body positions can produce significantly lower HR responses when compared to the UP position (3, 4). The horizontal leg position used with SR cycling may increase venous return, which may produce lower submaximal heart rates. Thereby, some individuals, such as the elderly, may benefit from exercising on the SR cycle since this position may produce lower submaximal exercise heart rates. The seated backrest on the SR cycle offers a more comfortable position than standard cycles. Thus, individuals who may experience low back or orthopedic problems may find the SR cycle most suitable for their benefit.

Submaximal Responses of Cycle Ergometery

Bonzheim et al. (5) evaluated the cardiorespiratory and perpetual responses of 14 patients with coronary artery disease (CAD) to UP and SR cycle ergometry. At 100 watts, they found that VO_2, HR, SBP, DBP, and RPE were all significantly greater on the UP than the SR position. They also noted that relative VO_2 and HR were 15 and 10%

lower in the SR than in the UP position. In addition, they hypothesized that submaximal SR ergometry may be attributed to reduced external work because the legs did not have to be raised against gravity as in the UP position. A second factor may be the result of an increase in muscular efficiency (5). These factors may contribute to the reduced physiological responses on the SR cycle.

Walsh-Riddle and Blumenthal (6) also compared the physiological responses on the UP versus the SR cycle. They examined 20 unmedicated mild hypertensive subjects. The cardiovascular variables were measured at rest, at relative workloads, and at peak exercise. They found lower HR, VO_2, and RPE on the SR cycle at rest and at 75% and 90% of VO_{2peak}. These results are similar to those found by Bonzheim et al. (5).

Currie at al. (3) investigated the SUP and UP comparisons in 43 patients with CAD. Submaximal exercise was completed with a workload of 100 to 300 kpm/min (17 to 50 watts) on both cycles. They found HR responses to be significantly lower in the SUP both at rest and during exercise. However, SBP and DBP were higher in the SUP position when compared with the UP at absolute workloads. Currie et al. (3) suggested that there is an increase in venous return during supine exercise with the legs above atrial level. An increase in venous return would thus increase myocardial oxygen requirements and would eventually lead to a higher SBP response and a lower HR in the SR position (3).

Furthermore, Smith et al. (7) studied the effect of seat back angle on responses to cycle ergometry in 30 healthy subjects. Subjects performed steady-state exercise at 100 watts using different seat back angles from 90° (UP) to 150° (SR). They found VO_2 to be significantly lower in the most reclined position and there were no differences found in HR and RPE compared to all angles of seat back. The findings that HR is not different between angles disagree with Bonzheim et al. (5) and Walsh-Riddle (6), who found HR to be higher on the UP than the SR cycle. Smith et al. (7) concluded that the selection of a more reclined position for cycling could result in improved muscular efficiency without affecting traditional indicators of effort such as RPE and HR (7).

Wescott (8) studied 7 healthy subjects to compare RPE, HR, SBP, and DBP responses during identical submaximal workloads on the UP and SR cycles. This investigation was unique in that the researcher included an 8-week training and equipment familiarization period. It was found that HR and SBP responses were significantly lower on the SR cycle than the UP. Westcott stated the elevated leg position during SR cycling attributes to an increase in venous return, which causes a reduction in cardiac effort (8). No differences were found in DBP, and RPE was only significantly higher on the UP at 15 minutes of cycling compared to SR. It was concluded that because there was an increase in cardiac effort on the UP cycle, it resulted in a greater perception of difficulty (8). Although HR was lower during SR cycling, the work levels were much higher (8). Westcott (8) advises to introduce unfit individuals to SR cycling prior to UP cycling because there is less likelihood of exceeding desirable HR and blood pressure limits.

Furthermore, only two studies have been done comparing the responses with all three ergometers, UP, SR, and SUP. Quinn et al. (4) examined submaximal responses with 9 cardiac patients. At 300kg/min (50 watts), Quinn et al. (4) found significantly lower HR and VO_2 responses in the SUP compared to either the UP and SR cycles. They found no significant differences in RPE, SBP, and DBP between all three cycles at the same intensity. Similar to most studies, they concluded that the lowered HR response in SUP ergometry was mediated by an augmented venous return in the SUP position (4). However, the reduced VO_2 seen in the SUP position was most likely caused by the reduction in external work (4). Also, the muscular efficiency may be optimized in the SUP position compared with either the UP or SR (4).

Proctor et al. (9) studied the submaximal responses to UP, SR, and SUP ergometry in 9 healthy subjects. They found that SUP exercise also resulted in a significantly lower HR and VO_2 than either the UP or SR. Conversely to the findings from Quinn et al (4), who also compared all three cycles, Proctor et al. (9) noted that SBP was significantly elevated in the SR position during submaximal work compared to either the SUP or UP positions. One possible explanation for the increased SBP values may have been related to isometric handgripping for body stabilization (9). This would cause an elevated blood pressure response.

The previous studies all used submaximal absolute workloads, where the workload was controlled by the investigators. Most investigators have equated exercise to a given VO_2, HR, or RPE (10). Only one previous study has been done using self-selected intensities with cycle ergometery rather than controlled workloads. Swensen (11) compared the differences between the UP and SR cycles in 24 healthy subjects who worked at their own intensity. Working at a self-selected pace will more accurately reflect what the subjects would do in normal aerobic workout (11). According to Boge et al. (12), the self-selected pace represents a more real world situation, which may enhance exercise adherence, since people are exercising at a level that is more comfortable for them. The objective of the study by Swensen (11) was not to control the subjects, but to produce results from a natural, self-selected intensity. He found VO_2, Kcal, HR, and SBP were significantly higher on the UP when compared to the SR. There were no differences between DBP and RPE. However, Swensen (11) observed that subjects worked at significantly higher workloads on the SR compared to the UP. Even with self-selected intensities, Swensen (11) found similar differences between UP and SR positions, as did other investigators.

Maximal Responses of Cycle Ergometry

At maximal exercise, Bonzheim et al. (5) found no significant differences in all variables (VO_{2max}, HR, SBP, DBP, and RPE) when comparing the UP and SR cycle ergometers. Although responses to maximal exercise were not significantly different, the SR position yielded a longer exercise time and a higher power output (5). Bonzheim et al. (5) concluded that the SR cycle allows patients to achieve the same maximal HR and energy expenditure as the UP position, but over a wider power output range. Therefore, the SR cycle is applicable to subjects with higher functional capacities as well (5).

Walsh-Riddle and Blumenthal (6) studied both the UP and SR cycles with hypertensive subjects. They found significantly higher peak HR and VO_2 responses on the UP cycle when compared to SR cycling. It was suggested that these findings are associated with greater overall body and muscle involvement and less localized muscular fatigue in the UP position, which may explain why subjects were able to attain higher peak HR and VO_2 responses (6). According to Hermansen and Saltin (13), greater peak VO_2 is associated with activities that involve larger muscle mass. This may explain why subjects on the UP cycle were able to achieve higher VO_2 peaks. The SR position tends to rely heavily on the hamstrings and quadriceps, limiting torso and upper body involvement (6). Localized muscular fatigue of the quadriceps may also limit exercise capacity on the SR cycle (6). Walsh-Riddle and Blumenthal (6) concluded that these findings make it preferable to evaluate maximal exercise performance in the UP position. This data are in contrast with those found by Bonzheim et al. (5).

At maximal exercise, Currie et al. (3) found HR to be significantly higher in the UP than the SUP position. However, the SUP cycle elicited significantly higher SBP and DBP responses than the UP cycle (3). They also found that maximal workload was higher and exercise time was longer on the UP compared to the SUP (3).

Kramer et al. (14) also studied the maximal physiological differences between SUP and UP exercise. They found that the UP cycle elicited significantly higher HR and VO_2 responses during maximal exercise (14). These findings agree with Currie et al. (3).

Finally, Quinn et al. (4) was the only study that examined maximal responses to SUP, SR, and UP cycle ergometers. The investigators found no differences in maximal VO_2, HR, SBP, DBP, and RPE (4). This agrees with the findings of Bonzheim et al. (5). In addition, Quinn et al. (4) found regressions of HR and VO_2 showed similar slopes and intercepts for SUP, SR, and UP cycles. They suggested that because the regressions were found similar among all three positions, a given HR during SUP ergometry results in a given SUP oxygen uptake that is comparable with either SR or UP (4). This is important for clinical testing, since many clinical tests are performed in the SUP or SR position (4). When prescribing exercise, the peak data from tests performed in the SUP or SR positions will allow for the prescription of UP exercise (4).

Summary

Through an extensive examination of research studies comparing the different modes of cycle ergometers, it has become clear that SR or SUP cycling keeps the exertion levels high, but the cardiac effort is low, thus the results of lower HR, VO_2, and BP. It has been reported that the SR or SUP cycles are more practical for unfit individuals, cardiac patients, post surgery patients, obese individuals as well as seniors (8). In addition, it can be concluded that SR cycles are recognized as much more comfortable and the most preferred when comparing the UP cycle. Proctor et al. (9) found similar findings when ratings of comfort were examined; the UP cycle was the least favorite among subjects.

There is limited research comparing the physiological responses of UP to SR cycles using self-selected intensities. The data available provide conflicting findings regarding the submaximal and maximal cardiovascular responses to exercise on cycle ergometers. These conflicting findings make exercise prescription difficult. There is a need to investigate the physiological responses to self-selected cycle ergomerty exercise, which includes habituation, in order to investigate the contrasting data.

REFERENCES

1. American College of Sports Medicine (1995). *Guidelines for Exercise Testing and Prescription* (5th ed). Baltimore, MD: Williams and Wilkins.

2. Howley ET, Glover ME (1974). The caloric costs of running and walking one mile for men and women. *Med. Sci. Sports Exerc.* 6:235-237.

3. Currie PJ, Kelly MJ, Pitt A (1983). Comparison of supine and erect bicycle exercise electrocardiography in coronary heart disease: accentuation of exercise-induced ischemic ST depression by supine posture. *Amer. J. of Cardio.* 52:1167-1173.

4. Quinn TJ, Smith SW, Vroman NB, Kertzer R, Olney WB (1995). Physiologic responses of cardiac patients to supine, recumbent, and upright cycle ergometry. *Arch. Physic. Med. Rehab.* 76:257-261.

5. Bonzheim SC, Franklin BA, Dewitt C, et al. (1992). Physiologic responses to recumbent versus upright cycle ergometry, and implications for exercise prescription in patients with coronary artery disease. *Amer. J. of Cardio.* 69:40-44.

6. Walsh-Riddle M, Blumenthal J (1989). Cardiovascular responses during upright and semi-recumbent cycle ergometry testing. *Med. Sci. Sports Exerc.* 21:581-585.

7. Smith JC, Hill DW, Zolfoghary MC, Davis GM (1990). Effect of seat back angle on responses to cycle ergometry. *Med. Sci. Sports Exerc.* 22:S12.

8. Westcott WL (1991). Recumbent cycling keeps exertion levels high but cardiac effort low. *Perspective* 2:34-35.

9. Proctor D, Sinning W, Quinn T, Roemmich J, Ehrlich V, Goodpaster B (1990). Submaximal responses to upright, recumbent, and supine bicycle ergometer exercise. *Med. Sci. Sports Exerc.* 22:S12.

10. Kravitz L, Robergs RA, Heyward VH, Wagner DR, Powers K (1997). Exercise mode and gender comparisons of energy expenditure at self-selected intensities. *Med. Sci. Sports Exerc.* 29:1028-1035.

11. Swensen CT (1999). Physiological responses between a Stairmaster upright and a Stairmaster semi-recumbent cycle at submaximal self-selected pace. Unpublished master's thesis, University of Wisconsin-La Crosse, LaCrosse.

12. Boge J, Porcari JP, Perry S (1996). A comparison of the physiologic responses when exercising on four common exercise modalities at a self-selected or self-preferred exercise intensity. *Med. Sci. Sports Exerc.* 28:S14.

13. Hermansen L, Saltin B (1969). Oxygen uptake during maximal treadmill and bicycle exercise. *J. Appl. Physiol.* 26:31-37.

14. Kramer B, Massie B, Topic N (1982). Hemodynamic differences between supine and upright exercise in patients with congestive heart failure. *Circulation* 66:820-825.