ABSTRACT

SPRANGER, L. L. A comparison of the physiological responses to exercise on five different upper and lower body ergometers. MS in Adult Fitness/Cardiac Rehabilitation, December 1998, 27pp. (J. Porcari).

A wide variety of indoor exercise machines are available for improving aerobic fitness and altering body composition. The purpose of this investigation was to compare VO_2, HR, RER, RPE, Kcals, and O_2 pulse to exercise at a self-selected submaximal intensity on an air walker (ST), an elliptical exerciser (ELLP), a cross-country skiing simulator (XC), a nonmotorized treadmill (WALK), and an Airdyne bicycle (AD). Ten female college-aged volunteers exercised for 30 minutes at a self-selected pace on each modality on separate days, in random order.

	ST	ELLP	XC	WALK	AD
VO_2	31.4	34.6	29.2[a]	32.7	30.5[a]
Kcals/min	9.9	10.9	9.2[a]	9.9	9.6[a]
HR	170	172	162[a]	166	167
RER	0.97	0.99	0.97	0.96	0.98
RPE	13.0	12.6	12.2	11.6[a]	12.5
O_2 Pulse	11.7[a,b]	12.8	11.4[a,b]	12.5	11.5[a,b]

a = significantly different than ELLP, b = significantly different than WALK

In general, responses to WALK and ELLP were greater than ST, XC, and AD, respectively. When comparing WALK to ELLP, O_2 Pulse values were similar, but since WALK values were achieved at a lower RPE (11.6 vs. 12.6) exercising on the WALK may be the most beneficial exercise mode for maximizing energy expenditure while exercising at self-selected, moderate intensities.

A COMPARISON OF THE PHYSIOLOGICAL RESPONSES TO EXERCISE ON FIVE DIFFERENT UPPER AND LOWER BODY 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

LANCE L. SPRANGER

DECEMBER 1998

COLLEGE OF HEALTH, PHYSICAL EDUCATION, AND RECREATION

UNIVERSITY OF WISCONSIN – LA CROSSE

THESIS FINAL ORAL DEFENSE FORM

Candidate: Lance L. Spranger

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.

[signature] 7/27/98
Thesis Committee Chairperson Signature Date

[signature] 7/27/98
Thesis Committee Member Signature Date

[signature] 7/27/98
Thesis Committee Member Signature Date

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

[signature] 10-8-98
Associate Dean, College of Health, Physical Education, and Recreation Date

[signature] 10-8-98
Dean of Graduate Studies Date

ACKNOWLEDGEMENTS

I would like to thank my thesis chairperson, Dr. Porcari, for all of your intelligence, guidance, and humor. I greatly appreciate all that you have done for me. A special thanks also goes to my committee members, Dr. Freeman and Dr. Keaton, for their support during this study.

To all my friends that I have been fortunate enough to meet over the last year, thanks for your help with this study and thanks for a very memorable year.

I would also like to acknowledge my mother and father. Without your care, support, and love I would have never been able to reach this academic achievement.

Last, but not least, I would like to thank Kimberly. Your never-ending love and understanding made this year very rewarding. I look forward to spending many more rewarding years with you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

APPENDIX PAGE

INTRODUCTION

The benefits of regular exercise have been well documented. They include improvement in cardiorespiratory function, reduction in coronary artery disease risk factors, decreased mortality and morbidity, decreased anxiety and depression, and enhanced feelings of well-being (1,2). According to the guidelines published by the American College of Sports Medicine (1), many different exercise modes can produce the aforementioned benefits. However, modes may differ in their energy expenditure requirements during exercise (7,12,13). Although differences may be subtle, when accumulated over several months and years of exercise training, the physiological effect could be significant. Many people have turned to home exercise equipment to provide the modalities for their regular exercise.

Every year millions of people purchase home exercise equipment. The search for the perfect exercise machine never seems to cease. Consumers are constantly bombarded with advertisements making claims that certain pieces of exercise equipment will help them shed unwanted pounds, burn more fat, increase energy, trim and tone the hips, thighs, arms and buttocks, and strengthen their heart and lungs. The recent trend of companies producing home exercise equipment is to manufacture modalities that provide a total body workout by incorporating upper body as well as lower body movements. The reason for this is that research has found that lower body only modalities, such as walking, may not provide sufficient intensity to elicit cardiovascular benefits in fitter individuals (10); and that walking fast enough to elicit cardiovascular benefits increases the risk of injury (4). Thus, by combining upper and lower body movements, it may be possible to elicit a greater training response with less risk of injury.

Determining which mode elicits the greatest cardiovascular effect could prove to be very beneficial to the fitness industry and the public. Kravitz et al. (7) recently compared the energy expenditure at self-selected intensities on four different modes of exercise. The modes consisted of submaximal treadmill running (TR), simulated cross-country skiing (XC), cycle ergometry (CE), and aerobic riding (AR). Total energy expenditure was significantly higher for TR than all other modes. In a similar study, Zeni et al. (13) also compared the energy expenditure while subjects exercised on 6 different indoor exercise machines at RPE (rating of perceived exertion) levels of 11, 13, and 15. The modalities included XC, CE, and TR, along with an Airdyne (AD), a rowing ergometer (RE), and a stair stepper (SS). The TR induced significantly higher energy expenditure rates than all of the other modalities, and the XC, RE, and SS induced higher rates of energy expenditure than the AD and CE. In both studies TR was found to provide the greatest physiological effect. However, the risk of injury associated with a high impact activity such as TR must also be weighed when selecting exercise modalities, especially for the novice exerciser or an obese individual. A mode that combines low-impact activity and enhanced physiological changes would be most beneficial to the public.

The combined upper and lower body ergometers have steadily gained popularity since their recent introduction into the home exercise equipment market. However, their training effects have not been fully investigated. Furthermore, few comparative studies solely analyzing modalities that include both upper and lower body components have been performed. The purpose of this study was to compare the physiological responses to 30 minutes of exercise, at a self-selected submaximal intensity, on five modalities, which each have an upper and lower body component. This study may provide further insight as to which exercise modality would be potentially most effective in altering cardiovascular endurance and body composition.

METHODS

Subject Selection

The subject population included 10 female volunteers between the ages of 20 and 26 years. All subjects were apparently healthy, with no known cardiovascular or metabolic disease. Apparently healthy was indicated by not answering 'yes' to any of the Personal Activity Readiness Questionnaire (PAR-Q) questions (see Appendix A). Each subject signed an informed consent form (see Appendix B) prior to participation in the study. All procedures of the study were reviewed by the Institutional Review Board at the University of Wisconsin-La Crosse (UW-L) and were determined to place the subjects at minimal risk. No compensation was given to the subjects for participation in the study.

Modalities Tested

The five exercise modalities tested included a SkyTrek air walker (ST), (Fitness Quest, Canton, Ohio); a NordicTrack Ellipse E7 (ELLP), (NordicTrack, Chaska, MN); a NordicTrack Pro cross-country skiing machine (XC), (NordicTrack, Chaska, MN); a NordicTrack Walkfit 5000 treadmill (WALK), (NordicTrack, Chaska, MN); and a Schwinn Airdyne (AD), (Schwinn Cycling and Fitness, Boulder, CO).

Data Collection and Procedures

Testing Schedule. All testing and data collection were performed at the UW-L Human Performance Laboratory. After signing the informed consent document, the subjects then completed a minimum of three practice sessions on each modality. Subjects were randomly assigned the order of testing for each modality.

Practice Sessions. Subjects unfamiliar with the modalities completed a minimum of three, 10 minute practice sessions on each modality. The practice session consisted of starting and stopping on the machine, setting the exercise intensity levels, and engaging in the exercise activity.

Testing Sessions. Prior to each test, the subject's height and weight were measured and entered into the Quinton QMC (Quinton Instrument Company, Seattle, WA). The QMC, an automated metabolic cart, was used to assess the subjects' expired air for the determination of VO_2, caloric expenditure, and respiratory exchange ratio (RER). The QMC was calibrated prior to each test using known gas concentrations and a 3.0 L syringe. Heart rates (HR) were determined using a Polar Vantage HR monitor (Polar CIC, Port Washington, NY) and ratings of perceived exertion (RPE) were determined using the Borg 15 point scale (3).

For each exercise test, subjects were given a 5 minute, self-paced warm-up. The subjects then exercised for 30 minutes at a self-selected pace or one they normally would choose while performing a steady state exercise bout. Subjects were able to adjust the workload of the modality throughout the session. Every 15 seconds the QMC collected VO_2 (ml/kg/min), Kcal/min, and RER. HR was recorded every minute and RPE was assessed every 5 minutes. Oxygen pulse values were calculated from the VO_2 and HR data. Following each test, a 5-minute cool-down was performed.

Statistical Analysis

Standard descriptive statistics were used to characterize the subject population. VO_2, HR, RER, RPE, Kcals, and O_2 pulse were averaged for each 30-minute period and compared between modalities using a one-way analysis of variance with repeated measures (REANOVA). If a significant F ratio was found between modalities, a Tukey's post-hoc test was performed to isolate pairwise differences. The alpha level was set at $p < .05$ to achieve statistical significance.

RESULTS

The descriptive statistics of the subjects are displayed in Table 1. Subjects ranged in age from 20 – 26 years of age and were all recreational exercisers.

Table 1. Descriptive characteristics of the subjects.

Variable	Age (yr) $x \pm SD$ (range)	Height (cm) $x \pm SD$ (range)	Weight (kg) $x \pm SD$ (range)
Females (10)	21.9 ± 1.7 (20 – 26)	167.4 ± 2.6 (157.5 – 180.3)	63.5 ± 16.0 (52.2 – 75.8)

A comparison of the physiological responses between modalities is presented in Table 2. It was found that VO_2 and caloric expenditure (Kcal) were significantly

($p < .05$) higher on the ELLP than XC and AD. HR was significantly ($p < .05$) lower on XC than ELLP and RPE on the WALK was significantly ($p < .05$) lower than ELLP. There were no significant differences ($p > .05$) in O_2 pulse values between ELLP and WALK, however both were significantly greater ($p < .05$) than ST, XC, and AD. No other significant differences ($p > .05$) were found between the modalities.

Table 2. A comparison of the physiological responses to exercising on the five upper and lower body ergometers.

	ST x ± SD	ELLP x ± SD	XC x ± SD	WALK x ± SD	AD x ± SD
VO_2	31.4 ± 4.0	34.6 ± 5.0	29.2 ± 3.6[b]	32.7 ± 5.2	30.5 ± 2.4[b]
Kcals/min	9.9 ± 0.95	10.9 ± 1.0	9.2 ± 1.3[b]	9.9 ± 1.1	9.6 ± 0.89[b]
HR	170 ± 12.2	172 ± 8.4	162 ± 14.0[b]	166 ± 12.3	167 ± 10.3
RER	0.97 ± 0.04	0.99 ± 0.03	0.97 ± 0.03	0.96 ± 0.03	0.98 ± 0.04
RPE	13.0 ± 0.53	12.6 ± 0.97	12.2 ± 0.56	11.6 ± 0.77[b]	12.5 ± 0.72
O_2 Pulse	11.7 ± 2.7[b,d]	12.8 ± 2.2	11.4 ± 2.4[b,d]	12.5 ± 2.8	11.5 ± 2.5[b,d]

a = significantly different than ST
b = significantly different than ELLP
c = significantly different than XC
d = significantly different than WALK
e = significantly different than AD

DISCUSSION

The purpose of this study was to compare the physiological responses to exercise on five different upper and lower body ergometers. ELLP exercise produced the highest VO_2(ml/kg/min) and Kcals/min values, followed by WALK, ST, AD, and XC modes, respectively. However, only XC and AD were significantly lower than ELLP in regards to VO_2 and Kcals/min. XC exercise resulted in a significantly lower HR than ELLP. All other modes were similar in HR. RER values were similar for all modes. When comparing RPE, WALK was significantly lower than ELLP with all other modes being similar.

An important distinction between this study and previous studies, is the self-selected intensity characteristic of the exercise session. Other studies have established exercise to a given VO_2 (12), HR (11), or RPE (13). The intent of the study was to let the subjects self-select their own exercise intensity. It was felt that this would most clearly represent a "real world" situation. By using VO_2, HR, or RPE, the exercise session may be artificially controlled (7). Self-selected intensity is based on the subject's perception of discomfort, which is indirectly reflected by the RPE (7). For example, in this study the subjects volitionally exercised at a higher VO_2 during ELLP exercise than during XC, but had a similar RPE between the two. Analyzing this study's data reveals ELLP elicited the highest VO_2 values, followed by WALK, ST, AD, and XC, although only XC was significantly lower. ELLP exercise most resembles treadmill running/walking and if this is taken into account, several studies agree with the data. Kravitz et al. (7) revealed that treadmill exercise at a self-selected intensity expends more energy compared with simulated cross-country skiing, cycle ergometry, and aerobic riding exercise. Thomas et al. (11) also reported a higher submaximal VO_2 during jogging as compared with other modes of exercise. In comparing energy expenditure (Kcals/min), this study found that ELLP exercise produced the highest values followed by WALK, ST, AD, and XC. Both XC and AD were significantly lower than ELLP. In a multi-mode comparison study comparing energy expenditure during the last minute of 5-min trials at three RPE intensities (11 = fairly light, 13 = somewhat hard, and 15 = hard), Zeni et al. (13) found that treadmill exercise elicited the highest rate of energy expenditure followed by stair stepping, rowing, cross-country ski simulation, cycle ergometry with arm work, and cycle ergometry alone.

The data from this study revealed similar heart rates on all modalities except for XC, which was significantly lower than ELLP. Numerous researchers have compared submaximal HR responses to different exercise modalities, but the results are inconclusive. At a given submaximal VO_2, HR for stationary cycling was reported to be higher than treadmill jogging (5,6), similar to the treadmill exercise (8), or equal to rowing, skiing, and treadmill walking (11). In a multi-mode comparison study during prolonged submaximal steady-state exercise bouts, significantly higher HR's were observed while jogging compared with skiing, shuffle skiing, stepping, cycling, and rowing (12). Kravitz et al. (7) found higher HR's during treadmill running and simulated cross-country skiing compared with cycle ergometry and aerobic riding. Similarly, Zeni et al. (13) reported higher HR's for treadmill exercise and stair stepping compared with rowing, simulated cross-country skiing, and stationary cycling, with and without arm work.

The results of this study also revealed that there were no significant differences ($p > .05$) in O_2 pulse values between ELLP and WALK, however both were significantly greater ($p < .05$) than ST, XC, and AD. O_2 pulse values give an indirect estimate of stroke volume, as reflected by the amount of oxygen delivered per heart beat (8).

Based on the results of this study, the ELLP and WALK provided similar physiological responses, but since WALK values were achieved at a lower RPE, exercising on the WALK may be the most beneficial exercise mode for maximizing energy expenditure while exercising at self-selected, moderate intensities.

REFERENCES

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

2. Blair, S. N. C. H. McCloy Research Lecture: Physical activity, physical fitness, and health. *Res. Q. Exerc. Sport* 64:365-376, 1993.

3. Borg, G. A. V. Psychological basis of perceived exertion. *Med. Sci. Sports Exerc.* 14:377-381, 1982.

4. Carroll, J. F., M. L. Pollock, J. E. Graves, S. H. Leggett, D. L. Spitler, and D. T. Lowenthal. Incidence of injury during moderate and high intensity walking training in the elderly. *J. Gerontology* 47:M61-66. 1992.

5. Faulkner, J. A., D. E. Roberts, R. L. Elk, and J. Conway. Cardiovascular responses to submaximum and maximum effort cycling and running. *J. Appl. Physiol.* 30:457-461, 1971.

6. Hermansen, L., B. Ekblom, and B. Saltin. Cardiac output during submaximal and maximal treadmill and bicycle exercise. *J. Appl. Physiol.* 29:82-86, 1970.

7. Kravitz, L., R. A. Robergs, V. H. Heyward, D. R. Wagner, and K. Powers. Exercise mode and gender comparisons of energy expenditure at self-selected intensities. *Med. Sci. Sports Exerc.* 29:1028-1035, 1997.

8. McArdle, W. D., F. I. Katch, and V. L. Katch. *Essentials of Exercise Physiology*, ed. 4. Philadelphia, PA: Lea & Febiger, 1994.

9. Pannier, J.L., J. Vruens, and D. Van Cauter. Cardiorespiratory response to treadmill and bicycle exercise to runners. *Eur. J. Appl. Physiol.* 48:243-251, 1980.

10. Porcari, J. P., C. B. Ebbeling, A. Ward, P. S. Freedson, and J. M. Rippe. Walking for exercise testing and training. *Sports Med.* 8:189-200, 1989.

11. Thomas, T. R., C. W. Felock, and J. Araujo. Metabolic responses associated with four modes of prolonged exercise. *J. Sports Med. Phy. Fit.* 29:77-82, 1989.

12. Thomas, T. R., G. Ziogas, T. Smith, Q. Zhang, and B. R. Londeree. Physiological and perceived exertion responses to six modes of submaximal exercise. *Res. Q. Exerc. Sport.* 66:239-245, 1995.

13. Zeni, A. I., M. D. Hoffman, and P. S. Clifford. Energy expenditure with indoor exercise machines. *J. A. M. A.* 275:1424:1427, 1996.

APPENDIX A

PERSONAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

Name: ________________ DOB: ______________

Date: ______________

A Comparison of The Physiological Responses To Exercise On Five Different Upper and Lower Body Ergometers.

Personal Activity Readiness Questionnaire (PAR-Q)*

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.

Par – Q

____ 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 of <u>any other reason</u> why you should not do physical activity?

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

APPENDIX B

INFORMED CONSENT

Informed Consent to Participate in a Research Study

Title:

A comparison of the physiological responses to exercise on five different upper and lower body ergometers.

Principal Investigators:

Lance L. Spranger – Graduate Student, UW – La Crosse
John Porcari, Ph.D. – Committee Chairperson

Explanation of the Exercise Tests:

I, ____________________, voluntarily agree to be a subject in a research study to compare the energy cost achieved during exercise among five upper and lower body modalities. I understand that five separate exercise sessions on five different days will be required. After instruction on the proper usage of each modality and a brief practice session, I realize that I will exercise for 30 minutes at a self-selected pace on each modality. The modalities will include a SkyTrek air glider, a Schwinn Airdyne, a NordicTrack Ellipse, a NordicTrack Cross-Country Ski Simulator, and a NordicTrack Walkfit treadmill. During all tests my heart rate will be monitored continuously with a heart rate monitor strapped to my chest. I will also breathe room air through a mouthpiece so that my expired air can be collected and analyzed.

Risks and Discomforts:

I realize that I can stop the testing anytime I wish. As with any exercise there exists the possibility of adverse changes occurring during the test. They could include abnormalities of blood pressure or heart rate and, in rare instances, stroke, heart attack, or even death. If any abnormal observations are noted at any time, the test will be immediately terminated. In addition, I will probably feel tired at the end of the test and may experience some muscle soreness.

Testing Scheduling:

All testing sessions will be scheduled at my convenience and will be conducted by Lance Spranger under the supervision of John P. Porcari, Ph.D. If any questions arise concerning the testing, Dr. Porcari can be contacted at 785-8684.

Confidentiality:

I consent to the publication of the results of this study so long as the information is anonymous and disguised so that no identification of individual subjects can be made.

I further understand that although a record will be kept of my participation in the experiment, all experimental data collected from my participation will be identified by number only.

Freedom of Consent:

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 related to my heart, that would preclude my participation in the tests described above. I have read the foregoing and I understand what is expected of me. Any questions that I may have had have been answered to my complete satisfaction. I, therefore, voluntarily consent to be a subject in this study. Furthermore, I know that I may withdraw at any time without any type of penalty.

Signed: ____________________ Date: _______________

Witness: ____________________ Date: _______________

APPENDIX C

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A wide variety of indoor exercise machines are available for improving aerobic fitness and altering body composition. Exercise machines also vary in the amount of muscle mass they utilize. Some models have only a leg component, some only an arm component, and some combine both arm and leg action in one machine. Because working muscle demands oxygen to metabolize energy, more working muscle mass should result in a higher demand for oxygen and thus a higher energy expenditure (2,4,10,17). This would give the combined arm/leg machines an advantage over leg only or arm only modes. Research, however, has not found this to be totally valid. When comparing combined arm and leg exercise to leg bicycling, some investigators have found a 5-10% higher VO_2max during combined arm and leg exercise (4,14). Other studies, however, have reported VO_2max values to be the same (1,13). Also, several studies (5,15,18) have found that different modes of exercise may elicit significant differences in energy expenditure.

The Contribution of Muscle Mass in Determining VO_2max

Investigators have found that VO_2max in combined arm/leg cycling may be dependent on the proportion of arm and leg contributions to the total work output (2,7). Other studies have also found that the level of arm training of subjects may influence arm/leg proportions contributing to VO_2max (11,12).

Bergh, Kanstrup, and Ekblom (2) conducted a study to determine if VO_2 during maximal combined arm and leg exercise was influenced by the ratio of arm work to total work output. The results were then compared to values obtained from maximal uphill running and cycling values. Each of the ten subjects were required to perform a submaximal and a maximal test on the following exercise modes: 1) uphill running on a treadmill, 2) arm cranking, 3) cycling in a sitting position, and 4) combined arm cranking and leg cycle work. The combined arm and leg work was performed in four different ratios, with the arm work being 10, 20, 30, and 40% of the total work, respectively. The VO_2max values for arm cranking, leg cycling, combined work of 10%, and combined work of 40% were significantly lower than uphill treadmill running. The VO_2max for combined work of 20% and combined work of 30% were lower, but not significantly different than uphill treadmill running. The results of this study suggest that the ratio of arm work to total work may be a significant factor influencing VO_2, and that the leg workload in combined exercise should be intense enough to elicit aerobic power values close to maximum.

Nagle et al. (7) also found that the relative contribution of the arms and legs in performing maximal exercise affects VO_2max values. The study consisted of nonarm trained males performing maximal arm work, leg work, and combined arm/leg work on an air-braked ergometer. The combined arm/leg tests consisted of three different trials with the arms contributing 10, 20, and 30% of the total combined workload, respectively. No significant differences in VO_2max were found for the 10% combined and 20% combined workloads, but the values for the 10% combined workload were significantly higher than the values for the arm work alone, leg work alone, and the 30% combined workload. This agrees with the finding of Bergh et al. (2) that the 20% combination workload was not significantly different from leg work alone, however, there is a disagreement on the 10% combined and 30% combined values.

One of the factors that may affect the extent to which combined arm/leg proportions contribute to VO_2max is the level of arm training of subjects. Seals and Mullin (11) maximally compared the responses of well-trained upper body athletes and untrained individuals during four different types of exercise: 1) arm cranking, 2) leg only cycling, 3) graded treadmill running, and 4) combined arm cranking and leg cycling. The untrained subjects attained their highest VO_2max on the treadmill, whereas the well-trained upper body athletes attained equivalent values under the treadmill and combined arm/leg conditions. It appears from the results of this study that treadmill running may be the most appropriate mode of exercise for eliciting VO_2max values in individuals not trained for upper body activities.

Mostardi et al. (6) conducted a 6-week training study to determine whether improvements in conditioning associated with conventional leg work are comparable to those associated with both arm and leg work. The researchers trained six healthy males using both arms and legs while a similar group of five males trained using legs only. The subjects trained 3 times per week and covered an average distance of 3 miles per session. Both groups showed an increase of 12% in VO_2max after training. While there were no significant differences in the improvement of VO_2max between the two groups, the combined arm/leg subjects were able to do more work at a lower heart rate during the training program. The investigators concluded that combined arm/leg work places less physical stress on the heart and skeletal muscle than does leg work alone. They indicated that the feeling of stress might be related to metabolic rate per square area of working muscle rather than to total metabolism.

Stenberg et al. (13) have also demonstrated that exercise using combined arm and leg work was better tolerated and accepted by subjects because the overall stress and subjective physical effort was less. These studies suggest that an exercise that has both an arm and leg component may be beneficial and more tolerable to individuals. This type of exercise may be especially useful to the aging and cardiac populations.

Physiological Responses to Submaximal Exercise

Many different exercise modes can produce cardiovascular benefits. Several studies have attempted to determine which mode may be the most beneficial.

Kravitz et al. (5) compared the submaximal responses to exercising on four different exercise modalities at self-selected intensities.

Eighteen subjects (9 male, 9 female) first completed a test of VO_2max during treadmill running. On separate days, subjects randomly completed 20 minutes of submaximal treadmill running (TR), simulated cross-country skiing (XC), cycle ergometry (CE), and aerobic riding (AR) exercise. Total VO_2 and energy expenditure were significantly higher for TR than all other modes for both females and males, respectively. For males and females, heart rate was similar during TR and XC and lower during CE and AR. Compared with females, males had significantly greater VO_2 and energy expenditure, while females had higher heart rates. Ratings of perceived exertion (RPE) were not different between TR, XC, and CE, but were significantly lower during AR. TR elicited the greatest VO_2 and energy expenditure during self-selected exercise despite RPE values being similar to XC and CE. They concluded that treadmill exercise may be the modality of choice for individuals seeking to improve cardiorespiratory endurance and improving body composition.

Thomas et al. (16) also compared the physiological and perceived exertion responses to six modes of submaximal exercise. Ten male recreational exercisers were habituated to treadmill running (TR), stationary skiing (STSK), shuffle skiing (SHSK), stepping (SS), cycling (CE), and rowing (RE). After following a specific dietary plan, each participant performed a 20-minute exercise bout at a constant RPE rating of 14, followed by a second exercise bout at 60% of mode-specific peak oxygen consumption (VO_2peak). On the RPE - 14 trial, oxygen consumption (VO_2) and oxygen pulse were significantly higher during TR than during the other exercise modes, and oxygen pulse was higher during STSK than during SHSK. On the 60% VO_2peak bout, oxygen pulse was significantly higher during TR than SHSK, CE, and RE. But RPE's were significantly higher during CE than during TR. These results indicated that a variety of exercise modes can be used to develop fitness, but TR may induce a slightly more favorable VO_2-to-RPE relationship.

Zeni et al. conducted a similar study using set RPE values as the exercise intensity (18). The subjects were healthy young, adult volunteers, including 8 men and 5 women. The subjects underwent a 4-week habituation period to become familiar with the RPE scale and exercising on each of the modalities. The modalities included an Airdyne (AD), a cross-country skiing simulator (XC), a cycle ergometer (CE), a rowing ergometer (RE), a stair stepper (SS), and a treadmill (TR). Following habituation, each subject completed 3 stages of 5 minutes at self-selected work rates corresponding to RPE values of 11 (fairly light), 13 (somewhat hard), and 15 (hard). Oxygen consumption, from which the rate of energy expenditure was calculated, was measured during the last minute of each 5-minute exercise stage. Heart rate was measured during the last minute of each stage of the exercise test, and blood lactate levels were obtained immediately after each exercise stage. Treadmill exercise induced the highest rates of energy expenditure at all levels of RPE when compared to all of the other exercise machines. The XC, RE, and SS induced higher rates of energy expenditure than the AD and CE. Heart rate varied significantly among exercise machines, with the highest values associated with the TR and SS, respectively. Lactate concentrations varied significantly with highest values associated with use of the SS and RE. Under the conditions of this particular study, the treadmill was found to be the optimal indoor exercise machine for increasing energy expenditure when perceived exertion is used to establish exercise intensity.

Boge, Porcari, and Perry (3) performed a study comparing the physiological responses when exercising on four common exercise modalities at a self-selected intensity. The modalities included stepping (ST), stationary cycling (BK), treadmill walking (TM), and simulated cross-country skiing (XC). Eight men and 8 women between the ages of 30 and 62 years served as subjects. After given ample practice time (at least 5 practice sessions per machine), subjects performed 20 minutes of steady-state exercise on each modality, in random order, at an intensity of their own choosing. It was found that subjects exercised at a higher HR and VO_2 and burned more calories on XC compared to the other exercise modalities. Theoretically, if individuals were to train under these conditions, XC would result in the greatest changes in aerobic capacity and body composition.

Training Responses to Exercise on Different Modalities

Pollock, Dimmick, Miller, Kendrick, and Linnerud (8) looked at the effects of mode of training on cardiovascular function and body composition of adult men. Twenty-six sedentary men volunteered for the study and were assigned randomly to one of the following training groups: running, walking, bicycling. All groups trained for 30 minutes, 3 times/week for 20 weeks at 85 to 90% of maximal heart rate. A control group of 7 men of similar qualifications also were evaluated. All experimental groups improved significantly in cardiovascular and body composition measures. The former was shown by significant increases in VO_2max, V_Emax, and O_2 pulse and a significant decrease in resting heart rate. Body composition results showed that all of the training groups had a significant reduction in body weight, skinfold fat, and abdominal girth measurements. The control group showed no significant changes for any of the variables. The researchers concluded that the improvement in the experimental groups was independent of mode of training.

In a similar study, Porcari et al. researched the effects of 12 weeks of stationary cycling (BK), treadmill walking (TM), stepping (S), or simulated cross-county skiing (XC) on aerobic capacity and body composition (9). Forty-eight men and 54 women were randomized equally to either a control group or one of the four aforementioned modalities. Subjects in the exercise groups trained 3 times/week for 12 weeks. Subjects were tested before and after the study for body composition (hydrostatic weighing and anthropometrics) and aerobic capacity (VO_2max). The VO_2max tests for each group were conducted on the specific training modality used during the study. No significant differences were found in responses between any of the training groups, and changes were generally significantly different than the control group. Results of this study found that when subjects trained at the same exercise intensity, changes in aerobic capacity and body composition were similar regardless of the exercise modality.

Summary

A wide variety of indoor exercise machines may improve aerobic capacity and alter body composition. When searching for the optimal ratio of arm to leg work to elicit the highest VO_2max, the arm workload in combined exercise was found to be the most beneficial at 20-30% of the total work and that the leg workload in combined exercise should be intense enough to elicit aerobic power values close to maximum. Comparing physiological responses to submaximal work reveals that treadmill exercise may be superior to other modalities, although cross-country skiing was also found to be beneficial in altering aerobic capacity and body composition. Training studies comparing physiological responses to exercise on different modalities have shown that changes in aerobic capacity and body composition were similar regardless of the exercise modality and were independent of the mode of training.

REFERENCES

1. Astrand, P. O. and B. Saltin. Maximal oxygen uptake and heart rate in various types of muscular activity. *J. Appl. Physiol.* 16:977-981, 1961.

2. Bergh, U., I. L. Kanstrup, and B. Ekblom. Maximal oxygen uptake during exercise with various combinations of arm and leg work. *J. Appl. Physiol.* 41:191-196, 1976.

3. Boge, J., J. P. Porcari, and S. Perry. 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: S80, 1996.

4. Gleser, M. A., D. H. Horstman, and R. P. Mello. The effect of VO_2 max of adding arm work to maximal leg work. *Med. Sci. Sports Exerc.* 6:104-107, 1974.

5. Kravitz, L., R. A. Robergs, V. H. Heyward, D. R. Wagner, and K. Powers. Exercise mode and gender comparisons of energy expenditure at self-selected intensities. *Med. Sci. Sports Exerc.* 29:1028-1035, 1997.

6. Mostardi, R. A., R. N. Gandee, and W. A. Norris. Exercise training using arms and legs versus legs alone. *Arch. Phys. Med. Rehabil.* 62:332-335, 1981.

7. Nagle, F. L., J. P. Richie, and M. D. Giese. VO_2max responses in separate and combined arm and leg air-braked ergometer exercise. *Med. Sci. Sports Exerc.* 16:563-566, 1941.

8. Pollock, M. L., J. Dimmick, H. S. Miller, Jr., Z. Kendrick, and A. C. Linnerud. Effects of mode of training on cardiovascular function and body composition of adult men. *Med. Sci. Sports Exerc.* 7:139-145, 1975.

9. Porcari, J. P., J. Steffen, D. Fater, T. Eber, B. Zeimer, M. Angelini, and K. Holloway. Effects of 12 weeks of stationary cycling, treadmill walking, stepping, or simulated cross-country skiing on aerobic capacity and body composition. *Med. Sci. Sports Exerc.* 28: S77, 1996.

10. Reybrouke, T., G. F. Heigenhauser, and J. A. Faulkner. Limitations to maximum oxygen uptake in arm, leg, and combined arm-leg ergometry. *J. Appl. Physiol.* 38:774-779, 1975.

11. Seals, D. R. and J. P. Mullin. VO_2max in variable type exercise among well-trained upper body athletes. *Res. Q. Exerc. Sport.* 53:58-63, 1982.

12. Secher, N. H., N. Ruberg-Larsen, R. A. Binkhorst, and F. Bonde-Petersen. Maximal oxygen uptake during arm cranking and combined arm plus leg exercise. *J. Appl. Physiol.* 36:515-518, 1974.

13. Stenberg, J., P. O. Astrand, B. Ekblom, J. Royce, and B. Saltin. Hemodynamic response to work with different muscle groups, sitting, and supine. *J. Appl. Physiol.* 22:61-70, 1967.

14. Taylor, H. L., E. Huskirk, and A. Henschel. Maximal oxygen intake as an objective measure of cardio-respiratory performance. *J. Appl. Physiol.* 8:73-80, 1955.

15. Thomas , T. R., C. W. Feiock, and J. Araujo. Metabolic responses associated with four modes of prolonged exercise. *J. Sports Med. Phy. Fit.* 29:77-82, 1989.

16. Thomas, T. R., G. Ziogas, T. Smith, Q. Zhang, and B. R. Londeree. Physiological and perceived exertion responses to six modes of submaximal exercise. *Res. Q. Exerc. Sport.* 66:239-245, 1995.

17. Toner, M., E. L. Glickman, and W. D. Mcardle. Cardiovascular adjustments to exercise distributed between the upper and lower body. *Med. Sci. Sports Exerc.* 20:773-778, 1990.

18. Zeni, A. I., M. D. Hoffman, and P. S. Clifford. Energy expenditure with indoor exercise machines. *J. A. M. A.* 275:1424-1427, 1996.