

## ABSTRACT

ALLABACK, N. J. A comparison of physiologic responses when exercising on five exercise modalities at a self-selected exercise intensity. MS in Adult Fitness/Cardiac Rehabilitation, December 1998, 39pp. (A. Freeman)

This study evaluated the physiologic responses ( $\text{VO}_2$ , Kcal, HR, RPE,  $\text{O}_2$  Pulse, and RER) to five exercise modalities (Schwinn Airdyne, NordicTrack cross-country skier, Ellipse, Walkfit, and Skytrek) at a self-selected pace. Ten male subjects (age = 21-27 yrs) volunteered in the study. Each subject completed 30 minutes of exercise at a self-selected pace on each apparatus. During all exercise sessions HR and RPE were recorded and expired air was analyzed using an automated open-circuit gas system each minute. Oxygen consumption ( $\text{VO}_2$ ) and caloric expenditure ( $\text{Kcal} \cdot \text{min}^{-1}$ ) were significantly higher ( $p < .05$ ) on the Walkfit when compared to the Airdyne, NordicTrack, and SkyTrek. The Ellipse was also significantly higher ( $p < .05$ ) than the NordicTrack and SkyTrek. Heart rates were significantly higher ( $p < .05$ ) on the Ellipse when compared to the NordicTrack and SkyTrek. Ratings of perceived exertion were significantly higher ( $p < .05$ ) on the Airdyne, Walkfit, NordicTrack, and Ellipse when compared with the SkyTrek. The Walkfit was significantly higher ( $p < .05$ ) than the Airdyne and NordicTrack when comparing  $\text{O}_2$  pulse values. There were no significant differences ( $p > .05$ ) in RER between the five different exercise modalities. This study, therefore, indicated that the Walkfit and the Ellipse provide the most effective cardiovascular workout when compared to the Airdyne, SkyTrek, and NordicTrack in young healthy males between the ages of 21 to 27 years.

**A COMPARISON OF PHYSIOLOGIC RESPONSES WHEN  
EXERCISING ON FIVE EXERCISE MODALITIES AT A  
SELF-SELECTED EXERCISE INTENSITY**

**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 1998**

COLLEGE OF HEALTH, PHYSICAL EDUCATION, AND RECREATION

UNIVERSITY OF WISCONSIN-LA CROSSE

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Master of Science in Adult Fitness/Cardiac Rehabilitation

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## ACKNOWLEDGMENTS

I would like to thank Dr. Alan Freeman, Dr. John Porcari, and Dr. Paul Keaton for their patience and guidance throughout my research and thesis preparation. I would also like to thank all of my classmates for their friendship. This has been one of the most valuable experiences of my entire life. I have never met such wonderful people, and I am truly blessed to have met them all.

Most importantly, I would like to thank my family. I am the luckiest person on earth to have such a beautiful family. They have been there for me whenever I needed them, and I know they will continue to be there for me. I would not have accomplished all that I have if it wasn't for their love. I love you Mom and Dad!

I would finally like to dedicated this research to my grandmother who passed away from breast cancer before she was able to see me finish graduate school. She touched my life with so much love. I miss her dearly.



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## INTRODUCTION

The progressive attempts to link increased physical activity with positive health benefits have intensified the need for the public to purchase home exercise equipment. The excessive advertisement for home exercise equipment is on the rise, and there is a wide variety of exercise machines designed to improve cardiovascular fitness and body composition. According to the American College of Sports Medicine (1), regular exercise protects against the development and progression of many chronic diseases and is an important component of a healthy lifestyle. A problem that may arise for the general public is how to know which piece of exercise equipment is effective in eliciting cardiovascular improvement. There are a vast amount of fitness machines available to the public, and it may be difficult to find the appropriate machine to meet their individual needs.

Several studies have been completed to demonstrate the effectiveness of different exercise modalities. Treadmills, NordicTrack cross-country ski simulators, stairsteppers, and elliptical trainers can be purchased in fitness equipment stores for home use. Walking is probably the most easily accessible mode of physical activity. Almost everyone can walk, and it is a normal everyday function. The results of a study performed by Spelman et al. (9) indicated that the self-selected exercise intensity of most healthy, habitual walkers between the ages of 20 and 60 is adequate for the



maintenance and improvement of cardiovascular fitness. The results from the study demonstrated the effectiveness of walking on treadmills for enhancement of cardiovascular fitness.

NordicTrack has developed a cross-country ski machine for indoor exercise. The NordicTrack cross-country ski machine has been a very popular modality that is currently advertised throughout the media. According to Goss et al. (5), using the NordicTrack cross-country skiing machine resulted in energy expenditures of 6 to 12 Mets. The NordicTrack skier presents an appropriate cardiovascular stimulus for a wide range of functional exercise capacities (5). The caloric cost of simulated cross-country skiing, ranging from 223 to 622 kcal·min<sup>-1</sup>·kg<sup>-1</sup>, would establish this exercise modality as a useful component of weight management programs (5).

Stepper machines have been on the market for quite some time and are now a very popular exercise machine in both homes and exercise facilities. A study by Swan et al. (10) compared the cardiovascular effects of running, walking, and stepping. It was found that running elicited the highest oxygen consumption (VO<sub>2</sub>) caloric expenditures (Kcal·min<sup>-1</sup>) of the three modes (10). The study completed by Swan and colleagues would support the purchase of home use treadmills for increasing exercise capacity (10). Concerning the energy cost of stair climbing, a study was done at the University of Tennessee-Knoxville on college age females. This study compared the caloric expenditure of climbing stairs versus stair descending. It was found that climbing, or going up stairs, elicited a higher caloric expenditure versus going down stairs, .15 kcal per step versus .05 kcal per step respectively (2). The study done by Basset et al. (2)

would encourage purchasing a stairmaster simulating an upward motion rather than the commonly seen steppers that only incorporate the downward motion.

One of the newest exercise machines on the market is the elliptical trainer. The elliptical trainer provides a low impact workout utilizing a combination of the treadmill and the stepper. Porcari et al. (7) performed a study comparing the physiological effects between the elliptical exerciser, the treadmill (walking and running), the stationary cycle and the stepper machine. Sixteen healthy volunteers between the ages of 27 and 54 years served as subjects. Each subject was required to complete 20 minutes of aerobic exercise at a self-selected pace on each apparatus.  $\text{VO}_2$  ( $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ), caloric expenditure, and heart rate (HR) were recorded every minute. The results concluded  $\text{VO}_2$ , HR, and Kcals were not significantly different between the elliptical machine and the treadmill run (7). However, the elliptical machine and the treadmill run were in fact significantly higher than the treadmill walk, stationary cycle, and stepper (7). These findings would demonstrate that the elliptical trainer and the treadmill run elicit a greater physiological workload at a self-selected pace when compared to the treadmill walk, bike, and stepper. The study completed by Porcari et al. (7) would support the use of the elliptical exercise machines for cardiovascular enhancement.

The purpose of this investigation was to compare the physiological responses of oxygen consumption ( $\text{VO}_2$ ), respiratory exchange ratio (RER), rate of perceived exertion (RPE), caloric expenditure (Kcal),  $\text{O}_2$  pulse, and heart rate (HR), to 30 minutes of exercise at a self-selected submaximal pace, on a variety of exercise modalities utilizing both an upper and lower body component. The five exercise machines tested included



the Schwinn Airdyne (Schwinn Cycling and Fitness, Boulder, CO.), Walkfit 5000 (NordicTrack Inc., Chaska, MN.), NordicTrack Pro (NordicTrack Inc., Chaska, MN.), NordicTrack Ellipse E7 (NordicTrack Inc., Chaska, MN.), and the SkyTrek Air Walker (Fitness Quest, Canton, OH.). Utilizing these data, it can be determined which modality would be potentially the most effective in improving cardiovascular endurance.

## METHODS

### Subjects

This study involved 10 apparently healthy males between the ages of 21 and 27 years. Each subject volunteered their time in the study and was required to complete an informed consent form approved by the University of Wisconsin-La Crosse Institutional Review Board before performing any testing procedures (see Appendix A). All subjects were also required to complete a PAR-Q form prior to any testing procedures to screen participants for any health related concerns (see Appendix B). The mean weight, age, and height of the subjects was 85.62 kg, 23.6 yrs, and 177 cm.

### Testing Methodology

Each participant was required to perform a minimum of three practice sessions on each exercise modality. These practice sessions were required to be completed in three, one hour sessions where the subject practiced for 10 minutes on each exercise modality (see Appendix C). When the researcher felt the subject was comfortable on each piece of equipment, the subject performed a 30 minute exercise session on each modality in random order. Each test was completed on a separate day.

Prior to each testing procedure, a 5 minute warm-up was to be completed by each subject. The subject was then asked to perform a 30 minute exercise session at a pace that simulates a self-selected submaximal pace. If the subject chose to, the exercise intensity was allowed to be adjusted throughout the exercise session. Each exercise session was also followed by a 5 minute cool-down. The warm-up and cool-down components were required to ensure the safety and health of the subject participating in the study.

### Measurements

Expired gases were collected during each test using a Quinton QMC metabolic system (Quinton Instrument Company, Seattle, WA). The expired gas analysis was used to calculate the relative oxygen consumption, caloric expenditures, and respiratory exchange ratios for each minute of exercise testing. The QMC was calibrated prior to every testing session using calibration gases determined by the micro-Scholander technique (8). The flow meter volume was calibrated using a 3.00 L syringe pump at various flow rates. The HRs of each subject were collected using the Polar Vantage HR monitor (Polar CIC, Port Washington, NY), every minute of exercise. Every five minutes during the testing procedure, the RPE was assessed using the Borg 6-20 scale (4). The mean average values of the entire 30 minute testing session were utilized in all statistical analyses (see Appendix D).

### Statistical Analyses

The data collected ( $\text{VO}_2$ , HR, RER, RPE,  $\text{O}_2$  Pulse, and Kcal expenditure) for each 30 minute testing session was averaged and compared between each modality. A



one-way analysis of variance with repeated measures was used to compare differences in responses among the five pieces of exercise equipment. The significance level 0.05 was used. A Tukey's post hoc test was utilized to isolate the differences.

## RESULTS

Table 1 presents the subject's descriptive statistics. Subjects ranged in age from 21 – 27 years and were all habitual exercisers.

Table 1. Descriptive characteristics of subjects

Variable	Age (yr) X $\pm$ SD (range)	Weight (kg) X $\pm$ SD (range)	Height (cm) X $\pm$ SD (range)
Males (N=10)	23.6 $\pm$ 1.9 (21 – 27)	85.6 $\pm$ 15.1 (77.2 – 95.4)	177 $\pm$ 3.1 (168.3 – 184.1)

The physiological responses to the five exercise modalities are presented in Table 2. There were significant differences between the five exercise machines in heart rate, O<sub>2</sub> pulse, oxygen consumption (ml·kg<sup>-1</sup>·min<sup>-1</sup>), ratings of perceived exertion, and caloric expenditure (Kcal·min<sup>-1</sup>). Oxygen consumption (VO<sub>2</sub>), and caloric expenditure were significantly higher (p < 0.05) on the Walkfit when compared to the Airdyne, NordicTrack, and SkyTrek. The Ellipse was also significantly higher (p < 0.05) than the NordicTrack and SkyTrek. Heart rates were significantly higher (p < 0.05) on the Ellipse when compared to the NordicTrack and SkyTrek. Ratings of perceived exertion were significantly higher (p < 0.05) on the Airdyne, Walkfit, NordicTrack, and Ellipse when

Table 2. A comparison of the physiological responses to 30 minutes of exercise at a self-selected pace on five different exercise modalities.

	WALK X $\pm$ SD	ELLP X $\pm$ SD	ST X $\pm$ SD	AD X $\pm$ SD	XC X $\pm$ SD
VO <sub>2</sub>	33.2 $\pm$ 4.2	31.7 $\pm$ 5.0	27.0 <sup>ab</sup> $\pm$ 4.1	28.7 <sup>a</sup> $\pm$ 2.2	27.2 <sup>ab</sup> $\pm$ 3.8
HR	145 $\pm$ 14.1	152 $\pm$ 13.2	136 <sup>b</sup> $\pm$ 14.6	141 $\pm$ 12.8	137 <sup>b</sup> $\pm$ 11.2
O <sub>2</sub> pulse	16.0 $\pm$ 2.5	14.7 <sup>a</sup> $\pm$ 2.0	13.8 <sup>ab</sup> $\pm$ 1.6	14.2 <sup>a</sup> $\pm$ 2.0	13.8 <sup>ab</sup> $\pm$ 2.3
RER	.98 $\pm$ .03	.98 $\pm$ .04	.98 $\pm$ .05	.97 $\pm$ .03	.95 $\pm$ .04
Kcal·min <sup>-1</sup>	13.8 $\pm$ 1.8	13.4 $\pm$ .97	11.2 <sup>ab</sup> $\pm$ 1.6	11.9 <sup>a</sup> $\pm$ 1.5	11.5 <sup>no</sup> $\pm$ 1.0
RPE	12.3 <sup>c</sup> $\pm$ .83	12.4 <sup>c</sup> $\pm$ .94	10.9 $\pm$ .70	12.2 <sup>c</sup> $\pm$ .81	12.0 <sup>c</sup> $\pm$ .83

<sup>a</sup> significantly different than WF (p < 0.05)

<sup>b</sup> significantly different than ELLP (p < 0.05)

<sup>c</sup> significantly different than ST (p < 0.05)

<sup>d</sup> significantly different than AD (p < 0.05)

<sup>e</sup> significantly different than XC (p < 0.05)

WALK = Walkfit

ELLP = Ellipse

ST = SkyTrek

AD = Airdyne

XC = NordicTrack cross-country skier



compared with the SkyTrek.  $O_2$  pulse values were significantly higher ( $p < 0.05$ ) on the Walkfit when compared to all four other modalities tested. The Ellipse produced significantly higher ( $p < 0.05$ )  $O_2$  pulse values than the SkyTrek and the NordicTrack. There were no significant differences ( $p > 0.05$ ) in respiratory exchange ratios (RER) between the five different exercise modalities.

## DISCUSSION

This study compared the physiologic responses to 30 minutes of exercise at a self-selected pace between five various pieces of exercise equipment. During 30 minutes of exercise at a self-selected submaximal pace, significant differences were found between HR,  $VO_2$ , Kcal,  $O_2$  pulse, and RPE.

Heart rate increases in a linear fashion as a result of increases in oxygen uptake and utilization with increasing intensity during exercise (1). Heart rate increased as expected with all pieces of exercise equipment. There was, however, a significant difference between the Ellipse, NordicTrack, and the SkyTrek. The Ellipse elicited significantly higher heart rates than the NordicTrack and SkyTrek. These current findings are consistent with a study done by Porcari et al. (7), which compared an elliptical trainer, a treadmill, a stationary cycle, and a stepper machine, and found the Ellipse to provide the most effective workout.

As mentioned earlier, oxygen consumption also increases with an increase in activity level (1). This improvement is measured by assessing  $VO_2$ . Measurement of  $VO_2$  involves analysis of expired air collected while a subject performs exercise (1). The greatest improvement in  $VO_2$  occurs when exercise involves the use of large muscle

groups over prolonged periods and is rhythmic and aerobic in nature (1). To support this, the current study found a significant difference in the amount of oxygen used between the various exercise equipment. It was found that the Walkfit resulted in a greater increase in oxygen consumption than the Airdyne, NordicTrack, and SkyTrek. The Ellipse also resulted in a higher increase in oxygen consumption than the NordicTrack and SkyTrek. These current findings conflict with a study done by Boge et al. (3), which compared HR, RPE, and  $\text{VO}_2$  responses to 20 minutes of exercise on the NordicTrack cross-country ski simulator, stairstepper, stationary cycle, and treadmill (walking). They found that the NordicTrack cross-country skier elicited a higher energy expenditure, and therefore, a higher oxygen consumption than the other various pieces of exercise equipment compared in the study. A potential cause of this difference may be the familiarity with the equipment as well as coordination and skill level of the subjects used. The subjects in the current study may not have obtained as high a coordination and skill level as the subjects used in the study conducted by Boge et al. (3).

Ratings of perceived exertion (RPE) were another variable compared in this current investigation. RPE is a commonly used scale to evaluate an individual's exercise tolerance (1,4). At most times it is used in conjunction with monitoring HR. In this study, it was found that the SkyTrek elicited lower RPE values than the Airdyne, Walkfit, NordicTrack, and Ellipse. Unfortunately, there are no studies available comparing other exercise modalities to the SkyTrek exercise machine. The current study would suggest the SkyTrek provides a low to moderate intensity and an easily tolerable workout.



The combination of intensity, duration, and frequency of exercise determines caloric expenditure (1). Since reduction of body weight is a frequently desired outcome of exercise programs, considerable research has been done to determine the appropriate volume of activity necessary to reduce adiposity (1). The American College of Sports Medicine recommends a minimal threshold of 300 kcals per exercise session completed 3 days per week (1). The differences between exercise equipment could influence caloric expenditure, thus increasing the effectiveness of an exercise session. A significant difference was found in the current study when assessing the caloric expenditure between the five pieces of exercise equipment. The Walkfit utilized more calories than the Airdyne, NordicTrack, and SkyTrek. The Ellipse also utilized more calories than the NordicTrack and SkyTrek. These data would suggest that the Walkfit and the Ellipse provide a more effective workout.

The results of this current study also found that there was a significant difference in  $O_2$  pulse values between modes. The Walkfit was significantly higher than all four other modalities when comparing  $O_2$  pulse values. The Ellipse produced significantly higher  $O_2$  pulse values than the SkyTrek and the NordicTrack.  $O_2$  pulse values give an indirect estimate of stroke volume, as reflected by the amount of oxygen delivered per heart beat (6).

### SUMMARY

The current study assessed five machines, some of which were relatively new on the market. Few studies have been completed comparing these five pieces of exercise equipment and would suggest the need for more research in this related area.

from the current data that the Walkfit and the Ellipse provide the most effective means of achieving cardiovascular fitness in young males between the ages of 21 to 27 years.

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**APPENDIX A**  
**INFORMED CONSENT FORM**



**INFORMED CONSENT FOR A COMPARISON OF THE PHYSIOLOGIC  
RESPONSES WHEN EXERCISING ON FIVE EXERCISE  
MODALITIES AT A SELF-SELECTED EXERCISE INTENSITY**

I, \_\_\_\_\_, give my informed consent to participate in this study comparing the physiological responses (submaximal oxygen utilization, O<sub>2</sub> pulse, respiratory exchange ratio, rate of perceived exertion, kcal expenditure, and heart rate) to 30 minutes of exercise, at a self-selected submaximal pace, on five different modalities (NordicTrack, Airdyne, SkyTrek, Walkfit, and Ellipse) utilizing both an upper and a lower body component. I consent to the presentation and publication or other dissemination of the study results understanding that the information is anonymous and disguised so no identification can be made. I further understand that all experimental data collected will be identified by number only.

I have been informed and fully understand I will have to exercise on five different pieces of equipment, for 30 minutes on each piece of equipment, at a self-selected pace. I will also be given a practice session on each piece of exercise equipment to insure proper use and form. I understand I will have to wear a heart rate monitor and also wear a headgear system with a mouth piece enabling the use of a metabolic gas analyzer. These procedures during the exercise session may cause some discomfort.

I understand that there are risks associated with exercise. Abnormal blood pressure, fainting, disorders of heart beat - too rapid, irregular, or ineffective, and in rare instances, death are some health risks that could occur with exercise. Fatigue, muscle soreness, and heavy breathing may occur during the testing sessions but are normal to exercise. I understand that I will be supervised by an ACLS (Advanced Cardiac Life Support) certified researcher.

I, being mindful of my own health and physical condition, have read this form and I understand the test procedures that I will perform. I voluntarily consent to participate in this study.

Signed \_\_\_\_\_ Date \_\_\_\_\_

Researcher \_\_\_\_\_ Date \_\_\_\_\_

Witness \_\_\_\_\_ Date \_\_\_\_\_

1

I understand I can withdraw from this study at anytime, without penalty.

Questions or concerns on any aspect of this study may be referred to the researcher, (Niki Allaback, 784-6942), and the thesis advisor, (Dr. Alan Freeman, 785-6532).

## **APPENDIX B**

### **PERSONAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)**



Name: \_\_\_\_\_

DOB: \_\_\_\_\_

Date: \_\_\_\_\_

**A Comparison of the Physiologic Responses When Exercising on Five Exercise Modalities at a Self-Selected Exercise Intensity.**

**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 for any other reason 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 C**  
**PRACTICE/TESTING INSTRUCTIONS**

## PRACTICE/TESTING INSTRUCTIONS

As a subject in this study, you will be completing a minimum of three practice sessions and five testing sessions. Each practice session will be at least 20 minutes in duration on each exercise apparatus. After the practice sessions have been completed, you will be completing five testing sessions. Each test will be completed on a separate day, and each testing session will be 30 minutes in duration on each different exercise apparatus.

The location of all practice and testing sessions will be:  
UW-L Human Performance Laboratory  
225 Mitchell Hall  
(2nd floor on southeast side of the building)

Prior to the practice and testing sessions, please adhere to the following instructions:

1. Please refrain from consuming alcohol or caffeinated beverages, using tobacco, or eating food for at least 3 hours before a practice or a testing session.
2. Please wear comfortable exercise clothes and proper athletic shoes for exercising.
3. Please report at your scheduled appointment time well rested, and having not performed heavy exercise for 24 hours prior to the practice or testing sessions.

### YOUR SCHEDULED PRACTICE SESSIONS:

1. \_\_\_\_\_

2. \_\_\_\_\_

3. \_\_\_\_\_



**APPENDIX D**  
**TESTING SESSION DATA SHEET**

## TESTING SESSION DATA SHEET

NAME \_\_\_\_\_

DATE \_\_\_\_\_

DOB \_\_\_\_\_ AGE \_\_\_\_\_ SEX \_\_\_\_\_ HEIGHT \_\_\_\_\_

WEIGHT \_\_\_\_\_ TEMP. \_\_\_\_\_ BAROMETRIC PRESS. \_\_\_\_\_

REL. HUM. \_\_\_\_\_ TESTING SESSION NO. \_\_\_\_\_

EXERCISE EQUIPMENT \_\_\_\_\_

### MEAN VALUES;

RPE \_\_\_\_\_

HR \_\_\_\_\_

VO<sub>2</sub> \_\_\_\_\_

RER \_\_\_\_\_

KCAL \_\_\_\_\_

**APPENDIX E**  
**REVIEW OF LITERATURE**



## REVIEW OF LITERATURE

### Introduction

The attempts to link increased physical wellness with positive health benefits has improved the awareness of exercise and therefore the need for home exercise equipment within the general public. There are several types of exercise equipment including treadmills, stairsteppers, bikes, and even the latest in exercise machine development, elliptical trainers. Various studies have been completed to justify which piece of equipment elicits the most effective cardiovascular adaptations. Studies have also been completed that look at the comparison of machines utilizing both upper and lower extremities versus lower extremity use only. The following is a review of literature focusing on different types of exercise equipment and their effectiveness, as well as a comparison of upper and lower extremity use.

### Effectiveness of Upper and Lower Extremity Use

Many studies have been completed that look at the effectiveness of exercise equipment that utilize lower extremities only. The question is, is a piece of exercise equipment more effective if it utilizes both upper and lower extremities such as in this study.

A study completed by Butts et al. (8) compared arm and leg use on the Stairmaster 4000PT versus legs alone. This study used an adaptable upper arm attachment on the Stairmaster to utilize upper extremities. It was found that there was a significant

difference between using arms and no arms with several workloads (8). The arm use resulted in an increased  $\text{VO}_2$ , MET level, HR, and RPE when compared to not using the upper extremities. However, there was inconsistent results with several of the workloads resulting in no increase with the use of arms when exercising on the Stairmaster. Possible factors contributing to this discrepancy are subjects utilizing the upper body attachment as support for their weight and lack of experience using the upper arm attachment by subjects.

Another study used a motorized treadmill with built in levers for arm exercise (the CrossWalk) and reported significant increases in energy cost when arm levers were utilized when compared to normal walking without arms (7). The subjects were required to hold and pull the arm levers in opposition to their feet, similar to cross-country skiing. An average increase in energy expenditure of 55% was reported when the arms were used walking at speeds of 2-, 3-, and 4-miles per hour compared to no arms used (7). This suggested the added arm movement is enough to significantly increase energy expenditure and is therefore more effective.

Porcari et al. (18) and Hendrickson et al. (10) performed a study utilizing rubber tipped ski poles (Power Poles) incorporated with walking. The subject simulated the arm motions of cross-country skiing while walking utilizing a larger muscle mass. It was found that the use of Power Poles significantly increased  $\text{VO}_2$ , HR, and kcal/min by approximately 20% when compared to normal walking without poles (18). This study concluded the use of Power Poles can increase the intensity of walking, therefore providing additional training benefits.



To support the use of additional upper body extremity use, another study performed by Porcari et al. (17) looked at the effects of exercising on the WalkFit. The WalkFit is a nonmotorized treadmill with additional arm poles. This study compared exercising on the WalkFit using the arm poles to walking on a treadmill without exercising the arms. The use of the arms resulted in an increase of 51% in energy expenditure and an increase in heart rate by 28 bpm when compared to walking on the treadmill without using arms (17). These results support the use of additional upper extremity use and demonstrate the effectiveness of the WalkFit treadmill.

A recent study by Alvarez et al. (2) looked at the physiological differences between lower body and combined upper and lower body rowing. Fifteen females were utilized as subjects for the study. Each subject was required to complete four, 5 minute randomized exercise trials on the rower. Oxygen consumption, heart rate, respiratory exchange ratio, expiratory volume, and rate of perceived exertion were collected during each trial. The results of the study concluded that the upper and lower body combination increased the metabolic response when compared to the lower body only rowing trials (2).

A similar study to Alvarez's was completed by Mayo and colleagues (14). Mayo looked at the metabolic response of lower versus upper and lower body rowing within males (14). Fifteen apparently healthy males performed four randomized rowing trials with different conditions. Oxygen consumption, ventilation, respiratory exchange ratio, and heart rate were monitored throughout each trial. Mayo concluded that with the increased muscle mass of the combined lower and upper body rowing, greater



physiological responses resulted, and therefore the combined rowing of both the upper and lower extremities would result in a more effective training stimulus (14).

The above literature supported the use of both the upper and lower extremities when exercising when compared to using the lower extremities only. Using the combination of both the upper and lower extremities utilizes an increase in muscle mass and therefore, increases one's metabolic expenditure effectively burning more calories.

#### Research Involving Related Exercise Modes

The NordicTrack was developed to simulate cross-country skiing due to the positive cardiovascular benefits from the sport. The NordicTrack cross-country simulator has been on the market since 1976 (16), however, there has been few extensive studies completed using this piece of exercise equipment. The reasoning for this may be due to the fact that the NordicTrack has arm and leg resistance settings that are unable to be calibrated, making it difficult to compare work rates with other exercise machines. Regardless of the NordicTrack and its difficulty being calibrated, there are studies available.

A study completed by Goss et al. (9) used five healthy male subjects who completed four exercise sessions on the NordicTrack. Each subject performed three randomly assigned trials within each session. The movement frequencies and the arm and leg resistances were adjusted in each 6 minute trial. It was found that there was a significant increase in oxygen consumption as movement frequency increased regardless the arm and leg resistance (9).

A training study performed by Porcari et al. (19) utilized 102 apparently healthy subjects who were randomized into one of five groups each using a different apparatus. The five different groups included the stepper, treadmill, cross-country skiing machine, a stationary cycle, and a control group. Each subject trained three times per week for 12 weeks. Porcari and colleagues concluded that if the subject trained at the same exercise intensity and monitored their caloric intake, changes in aerobic capacity were similar regardless of the exercise mode (19). This demonstrated that the NordicTrack is just as effective as the treadmill or stepper in achieving cardiovascular benefits.

Butts et al. (6) performed a study measuring the energy cost of the NordicTrack, motorized treadmill, and nonmotorized treadmill. A total of 24 males completed three, 5 minute exercise sessions at 2.0, 2.5, and 3.0 mph with a 9.6% grade on each of the exercise modes. The results showed that the cross-country skier simulator and the nonmotorized treadmill would elicit a higher  $VO_2$  and HR than a motorized treadmill (6). Butts concluded that exercising on a cross-country ski simulator and or a nonmotorized treadmill would provide similar exercise intensities to those of running on a motorized treadmill (6).

A study by Hulme (11) looked at cardiorespiratory and perceived exertion responses to submaximal and maximal exercise on a NordicTrack and Schwinn Airdyne. Twenty healthy males volunteered to perform maximal and submaximal exercise sessions on each apparatus. Variables measured were rate of perceived exertion, heart rate, oxygen consumption, pulmonary ventilation, respiratory exchange ratio, and kilocalories. It was found that the NordicTrack elicited a greater HR and  $VO_2$  than the Airdyne when



RPE was the same, and the Airdyne elicited a greater  $\text{VO}_2$  and caloric expenditure than the NordicTrack when the HR was equivalent (11). These findings suggested the NordicTrack may be a preferable mode of exercise since it resulted in a higher HR and  $\text{VO}_2$  with a lower perceived exertion.

Zeni and colleagues performed a study comparing 6 commonly used indoor exercise machines to determine which would elicit the highest rate of energy expenditure at specified levels of perceived exertion (23). The exercise machines utilized were the Airdyne, NordicTrack, a cycle ergometer, a rowing ergometer, a stairstepper, and a treadmill for walking and running. This study utilized RPE for intensity levels. Thirty healthy subjects had to perform work rates of 11, 13, and 15. It was found that treadmill walking/running induced significantly higher rates of energy expenditure compared with other exercise machines tested at RPE levels of 13 and 15 (23). The simulated cross-country skier, rower, and stairstepper induced significantly higher rates of energy expenditure compared with the Airdyne at RPE levels of 11 and 13 and compared with the cycle ergometer at all 3 RPE levels examined (23). In this study the treadmill elicited the highest rates of perceived energy expenditure than the other machines (23). An interesting concept demonstrated during the study is how exercise intensity is established by RPE and how the metabolic demand varies considerably among exercise machines. For example, the study completed by Zeni et al. (23) demonstrated the average individual exercising on the treadmill at an RPE of 13 would expend approximately 700 kcal/hr. The same individual would expend less than 500 kcal/hr at the same RPE when using



cycle ergometer. This demonstrated that the energy expenditure would be more than 40% greater for treadmill work than cycle ergometer exercise (23).

Several of the above studies incorporated many different modes of exercise equipment. Probably one of the newest developed pieces of exercise equipment now on the market is the elliptical trainer. The elliptical exercise machine is a unique combination of a treadmill and a stairstepper. Elliptical machines are low-impact and offer a total body workout. A study by Kravitz and colleagues (12) involved the elliptical trainer. This study focused on the physiological comparisons between the forward and backward motion of the machine. Twenty healthy volunteers served as subjects and were required to complete 5 minute trials for each condition. Heart rate and  $\text{VO}_2$  were continuously monitored with open circuit spirometry. The results reflected that resistance and speed elicit the greatest physiological response with the backward motion rather than the forward motion (12). This demonstrated that elliptical training provides a sufficient means to develop and maintain the cardiovascular system.

#### Research Incorporating a Self-Selected Pace

A study similar to this current study used a comparison of four different exercise modes utilizing a self-selected intensity. Boge et al. (4) compared a stairstepper, a stationary cycle, a cross-country skier simulator, and a treadmill (walking) for the differences in physiologic responses to a self-selected exercise session on each machine. Sixteen apparently healthy volunteers performed 20 minutes of exercise on each piece of equipment. HR,  $\text{VO}_2$ , and RPE were recorded every 2 minutes. It was found that

subjects exercised at a higher HR and  $\text{VO}_2$ , and burned more calories on the cross-country ski simulator compared to the other exercise modalities (4).

A second study incorporating a self-selected pace utilized the new elliptical machine discussed earlier. Porcari and colleagues performed a study comparing the physiological effects between the elliptical exerciser, the treadmill (walking and running), the stationary cycle, and the stepper machine (20). Sixteen apparently healthy volunteers between ages of 27 and 54 years served as subjects. Each subject was required to perform 20 minutes of exercise on each piece of equipment at a self-selected pace. Each test was completed on a separate day and in random order.  $\text{VO}_2$ , caloric expenditure, and HR were recorded every minute. RPE was recorded every 5 minutes. The results concluded that  $\text{VO}_2$ , HR, and Kcals were not significantly different between the elliptical machine and the treadmill run (20). However, they were significantly higher than the bike, stepper, and the treadmill walk (20). The RPE values were similar between all modes of exercise (20). This would demonstrate that the elliptical exerciser and the treadmill run elicit a greater physiologic load at a self-selected pace than compared to the treadmill walk, and stepper. In other words, they provided a better exercise workout than the other machines.

Another study looking at the effects of a self-selected exercise pace included a comparison between a rowbike, a treadmill, and a bicycle (15). The rowbike is a combination of a rower and a recumbent bicycle. Fifteen volunteers between the ages of 24 and 56 years were required to perform 20 minutes of a self-selected pace on each exercise apparatus. The Aerosport KB1-C portable metabolic analyzer was used to



measure  $\text{VO}_2$ . Heart rates were assessed using a Polar HR monitor. The results concluded that the rowbike required higher  $\text{VO}_2$  and caloric expenditures than a treadmill jog (15). The heart rates, on the other hand, were higher for the treadmill jog than the rowbike. The  $\text{VO}_2$ , kcal expenditure, and HR values were lower for the bike when compared with the rowbike and treadmill jog. The RPE values were similar for all of the exercises modalities. This conveys that the rowbike can offer a workout comparable to a treadmill jog and more intense than a regular bike.

#### Research Evaluating the Validity of Borg (RPE) Scale

Research is still being done to evaluate the validity of the RPE scale. The Borg RPE scale is a commonly used measuring device to evaluate exercise intensity. This scale is well accepted in medical and fitness facilities throughout the nation. The Borg scale consists of numbers ranging from 6 to 20 printed with descriptive phrases appearing next to the odd numbers (1). Heart rate closely corresponds to 10 times the RPE value.

A study conducted by Wright et al. (22) evaluated the reliability and validity of the Borg RPE scale during walking. Forty subjects between the ages of 30 and 69 years were required to perform three walking trials. An estimation trial was first done where the subjects walked for 5 minutes with varying intensities, low (93.8 meters per minute) and high (107.2 meters per minute). Subjects were required to give an RPE at the last minute of exercise. The next two production trials were then done. During the two production trials the subjects walked on the treadmill at intensities that matched the RPEs recorded in the estimation trial. The first production trial was done 15 minutes after the estimation trial and the second production trial was completed 2-7 days after the estimation trial.



Heart rate, oxygen consumption, and treadmill speed were recorded with each trial. There were no significant differences in the first production trial concluding that RPE was effective in short term situations (22). There was a significant difference between production 1 trial and production 2 trial (22). However, these differences were very small. Wright and colleagues concluded that RPE can be used to indicate exercise intensity at both walking speeds among females between the ages of 30 to 69 years (22).

A second study evaluating the validity and reliability of the Borg RPE scale was completed at Northeastern University. Thiel tested faculty and staff members at Northeastern University who volunteered to participate in the study (21). Each subject was required to complete a 45 minute aerobic exercise class. All subjects were instructed to rate and record local and central perceptions and a carotid pulse. EKG telemetry was randomly used on two subjects. The results of this study found no significant differences between the central and local perceived exertion ratings and palpated heart rates (21). The local and central perceived exertion ratings seem to be similar during the aerobic class, therefore, indicating that the local cues and the central cues of subjects were perceived to be of the same intensity demonstrating the validity of the Borg RPE scale (21).

### The Accuracy and Reliability of Heart Rate Monitors

Heart rate monitors are commonly used by exercisers to assist in exercise prescription. They are a popular means of monitoring one's exercise workload and observation of the cardiac beats per minute. Several studies have been completed to evaluate the effectiveness of different heart rate monitors.

A study by Macfarlane et al. (13) tested several heart rate monitors to determine the most effective monitors. The following monitors were tested: Sport tester PE300 (Medical Equipment Distributors, Auckland), Exersentry 3A (Respironics, Hong Kong), PU-801 "Pulse Monitor" and PU-701 (Akarana Accessories, Auckland), Monark Trim Guide 2000 and Boso Card-II (Watson Victor, Dunedin), Biosig "Instapulse" (Salmond Smith Biolab, Dunedin). The Sport Tester and PU-801 used an adjustable chest strap containing two electrodes with a transmitter that transmitted the signal to a wrist watch (13). The Exersentry and Monark Chest used a combined chest shoulder strap containing three electrodes that were connected by a wire to a processor unit (13). The Instapulse used a cylindrical tube designed so that the action of grasping it between the hands made contact with three surface mounted electrode rings (13). The Monark Ear, Boso and PU-701 Ear all used a photoelectric emitter-detector that was clipped to the ear lobe. The PU-701 Finger used a photoelectric device that covered the distal segment of the finger (13). All the monitors contained a digital display. The heart rate monitors were tested using EKG simulators. Frequencies of 50, 75, 100, 150, 200, and 240 min<sup>-1</sup> were tested. Subjects were required to exercise with the heart rate monitors during submaximal exercise on a treadmill and cycle. Macfarlane et al. (13) concluded those monitors which detected the heart rate with electrodes on the anterior chest wall outperformed the monitors which detected heart rate from pulsatile blood flow in either the ear lobe or finger. These findings suggest that heart rate monitors similar to the Sport Tester and Exersentry would provide high accuracy and low variability needed for exercise testing and safe exercise prescription (13).



Another study investigating the reliability of heart rate monitors was done by Burke and Whelan (5). Four different heart rate monitors were tested labeled A, B, C, and D. Monitor A consisted of two electrodes which picked up the cardiac electrical impulse. Monitor A contained a wrist watch making contact with the wrist and a metal sensing pad on the front of the watch where the tip of a finger was to be placed (5). The detected signal was then displayed on a liquid crystal display. Monitors B, C, and D operated by a different means utilizing infra-red phototransducers to detect blood volume pulse in the subject's finger (5). The signals on monitors B, C, and D also amplify the heart rate signal onto a liquid crystal display. The heart rates of four young healthy males were studied. Electronic equipment was used to test the effectiveness of the heart rate monitors. Testing was done on a weightlifting bench and walking and running on a treadmill. The testing completed on the bench rarely exhibited errors exceeding 2-3 beats per minute over a 30-230 bpm range (5). However, when tested on the treadmill, both walking and running, errors were recorded to range greater than 20 bpm (5). In some cases, over 50% of the readings had errors exceeding 50 bpm (5). These findings contraindicate the use of heart rate monitors for reliable data. This would disagree with the study by Macfarlane et al. (13). Perhaps the small sample size or ineffective testing measurements occurred in Burke and Whalen's study resulting in this discrepancy.

A study by Bar-Or et al. (3) utilized the same Polar Vantage XL heart rate monitor as used in this current study. Bar-Or looked at the validity of the heart rate monitor on preschoolers (3). Heart rates were taken on 27, 3 to 5 year old girls and boys and compared to simultaneous EKG monitoring. It was found that the EKG monitor and



heart rate monitor were nearly identical on the preschoolers during rest (3). During submaximal cycling exercise the heart rates were nonsignificantly underestimated during steady-state activity and nonsignificantly overestimated during recovery when compared to the EKG monitoring (3). The study by Bar-Or et al. (3) concludes the Polar Vantage XL heart rate monitor to be highly valid when utilized by preschoolers (3).

### SUMMARY

The review of related literature addresses the different exercise apparatuses on the market today and how effective they are for cardiovascular adaptation. Research indicates that exercise including a combination of both the upper and lower extremities involves a larger muscle mass and therefore is a more effective use of energy expenditure than the use of lower extremities only. The development of such a vast amount of indoor exercise modes has allowed much improvement in selection for the individual exerciser. Most of the above exercise equipment provides excellent means of obtaining cardiovascular benefits and a healthier lifestyle.

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