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Physiologic Responses to Maximal Exercise on a Treadmill, Monarch Bicycle Ergometer and Schwinn Air-Dyne Ergometer

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PHYSIOLOGIC RESPONSES TO MAXIMAL EXERCISE ON A TREADMILL, MONARCH BICYCLE ERGOMETER AND SCHWINN AIR-DYNE ERGOMETER

by

Elaine Jason Naegele

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Physiologic Responses to Maximal Exercise on a Treadmill, Monarch Bicycle Ergometer and Schwinn Air-Dyne Ergometer

Elaine Jason Naegele, M.A.
Western Michigan University, 1985

This study was conducted to determine which of three exercise modes would elicit the highest values for maximal oxygen uptake and maximal heart rate. Maximal graded exercise tests were performed by 20 healthy adults, ten women and ten men. Five of the women and five of the men were trained and the remaining ten were untrained. Each subject used, in a random order: (a) a motorized treadmill, (b) a Monarch bicycle ergometer, and (c) a Schwinn Air-Dyne ergometer. For each test, subjects were encouraged to complete successively harder workload stages, until they reached volitional exhaustion or localized muscle fatigue.

The data indicated that maximal oxygen uptake values were significantly higher for men compared to women, as well as for trained subjects compared to untrained subjects. For maximal heart rate values, no significant difference was found between modes of exercise, gender or level of fitness.

It was concluded that any of the three exercise modes could be used to elicit similar maximal heart rate values. For maximal oxygen uptake, the treadmill was the mode that elicited the highest values at maximal exercise, compared to the Monarch bicycle ergometer and the Schwinn Air-Dyne ergometer.
ACKNOWLEDGEMENTS

I would like to express my gratitude for the maximal efforts of my subjects and assistants - they made the data collection the most exciting part of this study.

Special mention and thanks go to Jerry at Milwood Schwinn Bicycle Shop (Kalamazoo, Michigan) for the use of the Air-Dyne.

However, the long haul would have been more arduous without the support and love from my best friend. Thank you Dave.

Elaine Jason Naegele
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TABLE OF CONTENTS

ACKNOWLEDGEMENTS............................................................... ii
LIST OF TABLES........................................................................ v

CHAPTER

I. INTRODUCTION..................................................................1
  Statement of the Problem...................................................... 3
  Purpose of the Study............................................................. 3
  Need for the Study............................................................... 4
  Delimitations...................................................................... 4
  Assumptions....................................................................... 4
  Hypotheses......................................................................... 5
  Definition of Terms............................................................. 5

II. REVIEW OF LITERATURE..................................................8
  Treadmill........................................................................... 8
  Monarch Bicycle Ergometer............................................... 9
  Schwinn Air-Dyne Ergometer.............................................10
  Treadmill vs. Monarch.........................................................10
  Air-Dyne vs. Treadmill.......................................................15
  Maximal Oxygen Uptake and Maximal Heart Rate.................17
    Trained vs. Untrained Individuals......................................17
    Men vs. Women..................................................................19
  Testing Protocols...............................................................20
    Treadmill.......................................................................20
    Monarch Bicycle Ergometer.............................................22
    Schwinn Air-Dyne Ergometer...........................................23
LIST OF TABLES

1. Descriptive Analysis by Weight, Height and Age for Gender......26
2. Descriptive Analysis by Weight, Height and Age for Level of Fitness......................................................26
3. ANOVA Summary Table for Maximal Oxygen Uptake......................33
4. Descriptive Analysis by Level of Fitness, Gender and Mode of Exercise for Maximal Oxygen Uptake..................35
5. Multiple Range Comparisons of Maximal Oxygen Uptake for Modes of Exercise........................................36
6. ANOVA Summary Table for Maximal Heart Rate.........................38
7. Descriptive Analysis by Level of Fitness, Gender and Mode of Exercise for Maximal Heart Rate........................39
CHAPTER I

INTRODUCTION

Many different types of activities can provide an individual with enough stimulation to improve or maintain cardiovascular fitness. Walking, bicycling and running are among the most popular activities. Those who choose to participate in regular exercise must consider every aspect of an exercise program in order to attain maximum benefits. For this reason, the American College of Sports Medicine (ACSM) developed guidelines for exercise. The guidelines were based on existing evidence concerning exercise prescription for adults. They apply to the quantity and quality of exercise necessary to develop and maintain cardiovascular fitness.

ACSM members Pollock, Wilmore, and Fox (1978) provided five specific recommendations for exercise prescription. The components were: type, intensity, duration, frequency and progression of physical activity. The first component, type, includes any activity that: (a) is rhythmical and aerobic in nature, (b) uses large muscle groups, and (c) can be maintained continuously. Such activities include walking or hiking, running or jogging, swimming, skating, bicycling, rowing, cross-country skiing and rope skipping. Participation in a variety of activities is advised to add interest and enhance motivation. The second and third components, intensity and duration, can be discussed together, since one directly influences the other. Exercise duration should range from 15 to 60 minutes of continuous exercise. Exercise intensity should range from
60 to 90% of maximal heart rate or 50 to 80% of maximal oxygen uptake. Low-intensity, longer duration exercise sessions are recommended for beginners. As individuals progress, higher-intensity exercise is possible in a shorter session. The intensity component can be determined using information obtained during a maximal graded exercise test. During a test, heart rate response to workloads and oxygen consumption at those workloads can be measured. The exercise intensity is calculated as a per cent of maximal heart rate and maximal oxygen consumption values (Pollock et al. 1978). The fourth component, frequency, should be three to five days per week to produce some cardiovascular improvements and to allow for adaptation by the musculoskeletal system. Participants can later increase the frequency after several weeks or months of conditioning. The fifth component, progression of physical activity, involves modification of the type, intensity, duration and frequency to meet the needs of each individual. As cardiovascular improvements occur, a participant will have to increase the amount of work done in order to train in the appropriate intensity range. This may mean a change from walking to running, an increase in exercise duration, a change to another mode of exercise or an increase in the frequency of exercise sessions. Modifications should take place with individual preferences in mind.

Maximal oxygen uptake is considered to be the best physiological indicator of aerobic work capacity in women and men. This indicator can be measured while a subject performs exhaustive exercise, most commonly using a motorized treadmill or a bicycle ergometer.

Recently, a revolutionary bicycle ergometer, the Schwinn
Air-Dyne ergometer, was introduced in this country. Unlike traditional bicycle ergometers, the Air-Dyne ergometer allows for arm involvement in conjunction with work done by the legs (Hagan, Gettman, Upton, Duncan & Cummings, 1983). Thus, a greater amount of muscle mass is available to perform the desired workload. The Air-Dyne ergometer foot pedals and arm levers are connected to an air-resistant fly wheel. Arm work is performed as a push-pull movement and leg work is performed as pedal cranking.

Many investigators have entertained the possibility of using the Air-Dyne ergometer to measure aerobic work capacity. Since the workloads on an Air-Dyne ergometer can be adjusted by increasing or decreasing air-resistance, it is possible to follow a testing protocol similar to those that have been developed for traditional bicycle ergometers.

Statement of the Problem

The study compared maximal values for oxygen consumption and heart rate when subjects performed maximal graded exercise tests using three modes of exercise: (a) a motorized treadmill, (b) a Monarch bicycle ergometer, and (c) a Schwinn Air-Dyne ergometer.

Purpose of the Study

The purpose of the study was to determine which of three modes: (a) a motorized treadmill, (b) a Monarch bicycle ergometer, or (c) a Schwinn Air-Dyne ergometer, would produce the highest values for maximal oxygen uptake and maximal heart rate when subjects performed
maximal graded exercise tests on each mode of exercise.

Need for the Study

This study was conducted to determine whether the Schwinn Air-Dyne ergometer can be used as a reliable testing mode. Since the Air-Dyne ergometer is new, it was necessary to compare the results from maximal exercise testing using the Air-Dyne with results from the more familiar and widely accepted motorized treadmill and bicycle ergometer. The treadmill and bicycle ergometer have been used extensively in maximal exercise testing.

Delimitations

This study was delimitated to the following: (a) twenty subjects between the ages of 22 and 34 years; (b) three modes of exercise, a motorized treadmill, Monarch bicycle ergometer, and Schwinn Air-Dyne ergometer; (c) two variables, maximal oxygen uptake and maximal heart rate; and (d) protocols, the Bruce treadmill protocol (Bruce, 1974) and the Astrand protocol (Astrand and Rodale, 1977) for the Monarch bicycle ergometer and Schwinn Air-Dyne ergometer.

Assumptions

The study was conducted with the following assumptions:

1. Each subject was in the same state of health on each of the three testing days.

2. Each subject was injury-free at the time of each maximal graded exercise test.
3. Each subject continued each test until exhaustion.

4. Each subject had a positive attitude toward each of the three exercise modes.

5. Arms and legs were used by each subject throughout the performance on the Air-Dyne ergometer.

Hypotheses

This study was conducted to test the following hypotheses:

1. Maximal oxygen uptake values of subjects using the Air-Dyne ergometer were not significantly different from values obtained when subjects used the Monarch bicycle ergometer.

2. Maximal oxygen uptake values of subjects using the Air-Dyne ergometer were not significantly different from values obtained when subjects used a motorized treadmill.

3. Maximal heart rate values of subjects using the Air-Dyne ergometer were not significantly different from values obtained when subjects used the Monarch bicycle ergometer.

4. Maximal heart rate values of subjects using the Air-Dyne ergometer were not significantly different from values when subjects used a motorized treadmill.

Definition of Terms

The following terms and their definitions are important to the understanding of this study:

1. Maximal oxygen uptake. Maximal oxygen uptake is attained when, with further increments of exercise intensity, oxygen
consumption does not increase (American College of Sports Medicine, 1980). This is the most definitive criterion for the termination of a maximal graded exercise test, according to the Guidelines for Exercise Testing and Prescription (ACSM, 1980). The maximal value for oxygen consumption is the maximal level of exercise (work) achieved by the subject. Astrand and Rodale (1977) reported that maximal oxygen uptake provides a very good estimate of the potential of the cardiovascular system.

2. **Maximal work capacity.** Maximal work capacity is also referred to as the functional capacity and is the highest level of exercise achieved on a particular exercise mode (ACSM, 1980).

3. **Maximal graded exercise test.** A maximal graded exercise test is an assessment used to determine maximal oxygen uptake. Subjects are asked to perform increasing increments of work, thus increasing the exercise requirements to do that work. Subjects continue until volitional exhaustion occurs, workload cannot be maintained or increased, specific problems develop or localized muscle fatigue occurs.

4. **Cardiovascular fitness.** Cardiovascular fitness is the result of regular aerobic exercise. These results are dependent upon the type, intensity, duration, frequency and progression of exercise. Regular aerobic exercise can increase aerobic capacity (work capacity) and the function of the oxygen transport system. The effects of aerobic exercise are: (a) an increase in maximal oxygen uptake, (b) an increase in maximum cardiac output, (c) a decrease or
no change in maximum heart rate, (d) an increase in maximum stroke volume, (e) an increase or no change in maximum arterio-venous oxygen difference, (f) a decrease in submaximal heart rate at the same workloads, (g) a decrease in resting heart rate, and (h) a decrease or no change in resting blood pressure (Pollock et al. 1978).

5. **Maximal heart rate.** Maximal heart rate is the highest heart rate achieved by a subject during a maximal graded exercise test.

6. **Trained subject.** A trained individual exercises on a regular basis three or more times per week, for 30 minutes or more per exercise session. The exercise is aerobic, rhythmic and maintained continuously. The intensity of each exercise session is such that the heart rate is maintained between 60 and 90% of maximal heart rate or intensity is 50 to 80% of maximal oxygen uptake (Pollock et al. 1978).

7. **Untrained subject.** An untrained individual does not meet one or all of the requirements met by a trained individual. A subject classified as untrained may do some aerobic exercise, at a level lower than the criteria set forth for the trained subject classification, or exercise less than three times per week or exercise less than 30 minutes per session.
CHAPTER II

REVIEW OF LITERATURE

This chapter provides a brief overview of literature pertinent to this study. The three selected exercise modes are discussed individually to highlight the advantages and disadvantages of their use in a testing situation. Results of comparative studies between exercise modes (treadmill vs. Monarch and Air-Dyne vs. treadmill) follow. The results are presented with respect to maximal oxygen uptake and maximal heart rate differences between women and men and trained and untrained individuals. The chapter concludes with a look at testing protocols used for each exercise mode.

Treadmill

Walking and running on a treadmill are two examples of dynamic exercise, which Bruce (1974) defines as rhythmical contractions of flexor and extensor muscle groups. Arterial flow to working muscles and venous return to the heart are facilitated by the alternating contractions of the two types of muscle groups. Subjects do not take long to familiarize themselves with walking on a treadmill, since the motor pattern of walking is well established. The workload can be adjusted by increasing or decreasing the speed and/or grade. Hartley (1973) cautions that slippage of the belt must be controlled, as well as a subject's desire to hold on to the handrails in later stages of an exhaustive test. Both factors might cause a change in the actual amount of work done by a subject. The major disadvantages of a
treadmill are its cost and lack of mobility.

Monarch Bicycle Ergometer

Many maximal graded exercise tests have been conducted using the Monarch bicycle ergometer. Exercise intensity can be regulated by adjusting a friction belt that encircles the fly wheel. Workload is expressed in kilopond meters of work per minute (kpm/min). The graduation of workload increments is 150 kpm/min. The number "1" on the workload indicator represents 300 kpm/min, the number "2" represents 600 kpm/min, etc. Each whole number on the workload indicator is separated by a mark halfway between, so that it is very easy for an individual to increase or decrease the workload by 150 kpm/min. The ergometer seat can be adjusted up and down to correctly position it for efficient cycling. Too high or too low a seat can be uncomfortable. The advantages of this ergometer include its cost, portability and use as a non weight-bearing activity mode. Individuals who have orthopedic problems which make walking or running difficult can be tested using the Monarch bicycle ergometer. One disadvantage in using the Monarch bicycle ergometer in exercise testing is the difficulty of controlling the accuracy of the pedal rate at each workload. Another problem is the seat height adjustment (Hartley, 1973). A metronome must often be used to decrease the possibility of pedal rate variability. Most researchers have suggested 60 rpm is the ideal pedalling rate and have used this rate in their studies (Miyamura & Honda, 1972; McArdle, Katch, & Pecar, 1973; Hartley, 1973; Kitamura, Yamaji, & Shepard, 1982). Pollock,
Foster, Schmidt, Hellman, Linnerud, & Ward (1982) and Pannier, Vrijens, & Van Cauter (1980) suggested a rate between 60 and 70 rpm.

Schwinn Air-Dyne Ergometer

This relatively new ergometer allows for total body involvement as well as providing a cooling effect from the vaned wheel while it is in motion. In the manual, "Why a Fan?" (Excelsior Fitness Co., 1983) the details of the Air-Dyne operation have been explained. The numbers on the workload indicator represent increments of 300 kpm/min, just as are found on the Monarch bicycle ergometer. Increased workloads are achieved by raising the energy applied to the pedals and arm levers. The only factors which might influence the accuracy of the Air-Dyne are changes in air density and excessive mechanical friction, both of which are avoidable if proper care is taken. Testing times can be scheduled when barometric pressure readings are stable and the mechanical parts can be lubricated according to manufacturer directions. The problem of seat adjustment that was reported with respect to the Monarch bicycle ergometer would also apply to the Air-Dyne. The advantages of using the Air-Dyne for maximal exercise testing include its comparable price to other bicycle ergometers, relative portability, total body involvement and cooling air flow directed at the subject.

Treadmill vs. Monarch

Although Stewart and Ellestad (1980) found the treadmill to be the most widely used testing mode, the bicycle ergometer has often
been compared to the treadmill in hopes both modes would elicit similar results. Numerous investigators have reported that higher maximal oxygen uptake values were possible when a treadmill was used, compared to values obtained when subjects rode a bicycle ergometer. In 1980, Deutsch and Knowlton studied nine untrained men who exercised to exhaustion on a treadmill and a bicycle ergometer. Mean maximal oxygen uptake values were higher on the treadmill (p<.08). The investigators had expected this finding, based on research from similar studies. The mean maximal heart rate was significantly higher on the bicycle ergometer (p<.001).

Bruce (1974) cited the results of a study done by Shephard, Aleen, & Benade (1968) using male subjects aged 20 to 40. The results of maximal exercise showed a mean maximal oxygen uptake of 3.81 l/min on a treadmill test compared to a mean value of 3.56 l/min on a bicycle ergometer test. Mean maximal oxygen uptake values were 6.6% higher on the treadmill compared to the bicycle ergometer.

In addition, McArdle and Magel (1970) reported significantly lower maximal heart rate values (p<.01) for a bicycle ergometer test when compared to a treadmill test. The subjects were 23 male college students, three of whom were trained athletes. The remaining subjects were relatively untrained. Testing order was randomly assigned. An average reduction of 9.9% in maximal oxygen uptake values was noted on the bicycle ergometer, with differences ranging from .5 to 21% below treadmill values in 21 subjects and 2 and 10% higher in two subjects, respectively. The two subjects with higher values on the bicycle ergometer reported that they included bicycling in their...
outdoor recreation activities. The researchers suggested that the higher values on the bicycle ergometer could reflect specific muscular development, enabling the two subjects to have an advantage on this mode.

Later, McArdle et al. (1973) studied 12 untrained male college students and three male cross country collegians. Testing order was randomized to minimize any effect of an organized pattern. The mean maximal oxygen uptake value was significantly higher (p<.01) for the continuous treadmill test compared to the continuous bicycle ergometer test. No significant difference was found between maximal heart rates for the two tests. The investigators stated that subjects complained of intense local discomfort in the thigh muscles during the maximal bicycle ergometer test. Many subjects stated that this was a major factor in limiting their ability to do more work.

Miyamura, Kitamura, Yamada, & Matsui (1978) reported significantly lower maximal heart rates (p<.005) on the bicycle ergometer tests compared to treadmill tests. Nine untrained subjects and 11 trained subjects exercised to exhaustion on the two modes of exercise. It was suggested that the collegians experienced a decreased venous return while cycling, thus producing lower bicycle ergometer heart rate values. Deutsch and Knowlton (1980) also stated that this decreased venous return was due to high intramuscular pressure restricting the blood flow.

Other investigators have used the Monarch bicycle ergometer to assess maximal work capacity with satisfactory results. Taguchi, Raven, Drinkwater, Kaneko, & Matsui (1974) studied the physiological
responses to maximal exercise of subjects (45 men and 33 women) who performed maximal graded exercise tests on a Monarch bicycle ergometer and a motorized treadmill. Testing order was randomly assigned. For the men, Taguchi et al. (1974) found higher maximal oxygen uptake and maximal heart rate values on the treadmill test compared to the bicycle ergometer test (p<.01). The women had significantly higher (p<.01) maximal heart rate values on the treadmill compared to the bicycle ergometer but there was no significant difference between maximal oxygen uptake values for the two tests. The investigators could not explain the lack of significance in mean maximal oxygen uptake for the women based on body weight but suggested that: (a) less muscle tissue was available for each test for the women compared to the men, (b) the women did not attain true maximal values during the tests, or (c) there is an absolute work level which a subject must attain before differences would be apparent.

Harrison, Brown, & Cochrane (1980) reported that subjects complained of pain in the thigh muscles when performing a maximal test on a Monarch bicycle ergometer. Maximal oxygen uptake values averaged almost 20% less than values achieved on a maximal treadmill test (p<.001). It was concluded that a treadmill test would be more suitable than a bicycle ergometer test to measure maximal oxygen uptake, provided that maximal oxygen uptake could be determined with sufficient accuracy. Subjects in the study were volunteers (10 men) with above average physical fitness levels.

In a study which required subjects to perform maximal tests on a
motorized treadmill and a bicycle ergometer, Pannier et al. (1980) reported that subjects complained of quadriceps pain during the bicycle ergometer test. The subjects were long distance runners. It was suggested that work performances on the bicycle ergometer was limited by localized muscle fatigue before each subject's central circulation was fully utilized. The subjects had significantly higher maximal oxygen uptake values (p<.01) on the treadmill test compared to the bicycle ergometer test. Additionally, the maximal heart rate values were significantly higher (p<.02) on the treadmill test compared to the bicycle ergometer test. In the same study, Pannier et al. (1980) studied six students in physical education and three lab assistants as a control group and classified them as "reasonably well-trained". The order of testing was randomly assigned for both groups. The control subjects' performances on the treadmill and bicycle ergometer did not statistically differ with respect to maximal oxygen uptake, although it was 4.4% lower on the bicycle ergometer. No significant difference was found with respect to mean maximal heart rates. It was suggested that treadmill testing had no advantage over bicycle ergometer testing as a result of data collected on the control group. It was thought that the results of the distance runners were influenced by their training conditions. Subjects in a study by Hoyt, Bonbrisco, Brown, Roby, Yacavone, Harvard, Bowers, Mooney, & McWilliams (1973) thought that the Monarch bicycle ergometer fatigued their leg muscles before fully taxing their cardiorespiratory systems. When asked to rate the two exercise modes, the treadmill was their choice for testing. The eight
subjects in the study were healthy but rather sedentary male students. A statistical comparison of maximal oxygen uptake results was not included; however, Hoyt et al. (1973) reported that the values were similar. More precise data would have been beneficial in making a case for either of the two exercise modes.

Differences in maximal oxygen uptake and maximal heart rate values for the treadmill over the bicycle ergometer ranged from 9.9% (McArdle and Magel, 1970) to 10.2% to 11.2% (McArdle et al. 1973) to 12.8% (Pannier et al. 1980) to 20% (Harrison et al. 1980).

Air-Dyne vs. Treadmill

Fewer studies are available that compare the treadmill and Air-Dyne ergometer, since the Air-Dyne is a new exercise mode. Similar maximal values for heart rate and oxygen uptake (p<.05) were reported by Hagan et al. (1983) for tests using a treadmill and an Air-Dyne ergometer. The trained subjects included 15 men and 15 women who performed maximal graded exercise tests. The subjects also performed maximal tests on the Air-Dyne ergometer using the legs only, with significantly lower maximal heart rates (p<.05) than either the treadmill test or the Air-Dyne ergometer test using both arms and legs. No significant difference was found for maximal oxygen uptake values when all three tests were compared. However, maximal oxygen uptake values for the legs-only Air-Dyne test represented 95% of treadmill work for the men and 87% of treadmill work for the women. Maximal oxygen uptake values for the Air-Dyne test using both arms and legs represented 98% of treadmill work for
the men and 97% of treadmill work for the women.

Other investigators have used ergometers modified to include arm work, to compare work done by the legs alone with work done by both arms and legs. Studies by Bergh, Kanstrup, & Ekblom (1976) indicated 10 well-trained men attained comparable maximal oxygen uptake values for maximal treadmill work and arm and leg work combined. Bergh et al. (1976) used a bicycle ergometer constructed with two independent braking systems for combined arm and leg work. The subjects also performed a maximal test on a bicycle ergometer, with the average maximal oxygen uptake value equal to 93% of the average maximal value for the treadmill. Maximal heart rates were significantly higher (p<.01) on the treadmill compared to the combined arm and leg work test and also higher (p<.05) on the treadmill compared to the bicycle ergometer test.

Mostardi and Gandee (1981) chose 11 healthy but sedentary university faculty members to perform maximal tests on a Monarch bicycle ergometer and a Monarch bicycle ergometer with an adaptable Fleisch ergostat arm ergometer. He reported that his subjects commented on the ease of the ride when performing maximal arm and leg work, compared to the same workload using the legs alone. For two of the subjects, this was due to a lower maximal oxygen uptake, but the remaining subjects had nearly identical maximal oxygen uptake values. The maximal oxygen uptake values for the combined arm and leg work averaged 39.2 ml/kg/min and 41.3 ml/kg/min for the leg work.

Maximal bicycle ergometer tests and combined arm and leg work tests were performed by three healthy men in a study by Reybrouck,
Heigenhauser, & Falkner (1975). The subjects performed maximal exercise on a Monarch bicycle ergometer first, with maximal oxygen uptake results of 64, 44 and 39 ml/kg/min. For the combined arm and leg work test, maximal oxygen uptake values were the same, 17 and 21% higher (p<.05) respectively, compared to the bicycle ergometer tests. The two subjects had values which represented 82 and 84% of values obtained in the combined arm and leg work.

Maximal Oxygen Uptake and Maximal Heart Rate

Trained vs. Untrained Individuals

Results from maximal graded exercise testing have often been compared between trained and untrained individuals. Miyamura et al. (1978) studied 9 untrained and 11 trained subjects who performed maximal work on a motorized treadmill and a Monarch bicycle ergometer. The trained subjects were members of collegiate cross country, cross country ski or crew teams and exercised five to six days per week. The untrained subjects were not involved in any regular conditioning. After subjects familiarized themselves with the equipment and testing procedures, they were randomly assigned to the two tests. Maximal oxygen uptake values were significantly higher (p<.005) for the trained subjects compared to the untrained subjects in both the treadmill and bicycle ergometer tests. No significant differences were found for maximal heart rates for trained or untrained subjects between the treadmill or bicycle ergometer tests.
Pannier et al. (1980) reported that subjects who were involved in distance running had significantly higher maximal oxygen uptake and maximal heart rate values (p<.01 and p<.02, respectively) for maximal tests on a treadmill compared to values obtained on bicycle ergometer tests. The control subjects, however, had maximal oxygen uptake and heart rate values that did not differ significantly when results from treadmill and bicycle ergometer tests were compared. It was suggested that the specificity of exercise for the trained subjects influenced the results of their maximal tests.

Trained and untrained women performed maximal exercise tests in a study by Pollock et al. (1982). A treadmill and bicycle ergometer were used. Maximal oxygen uptake values were significantly higher (p<.05) for each of the two treadmill tests which utilized two different protocols, compared to the bicycle ergometer test. There were 20 trained women and 29 untrained women; testing order was randomized. The untrained group averaged 1.9 to 3.6 ml/kg/min higher on the two treadmill tests compared to the bicycle ergometer test. The trained group averaged 2.9 to 4.6 ml/kg/min higher on the two treadmill tests compared to the bicycle ergometer test.

The total group (49 women) had significantly higher maximal heart rates on the two treadmill tests compared to the bicycle ergometer test (p<.01). The untrained group averaged 5 beats/minute higher on the treadmill tests compared to the bicycle ergometer test. The trained group averaged 2 to 4 beats/minute higher on the two treadmill tests compared to the bicycle ergometer test.

Mostardi and Gandee (1981) studied eleven healthy but sedentary
men who performed maximal exercise tests on a Monarch bicycle ergometer. After a six-week conditioning program, all subjects were retested. The investigators found a 12% increase in mean maximal oxygen uptake and no significant difference in mean maximal heart rate. Five of the men had trained three days per week on bicycle ergometers, covering three miles per session at 80 to 90% of each subject's maximal heart rate. The session was broken down to a series of rides of one to five minutes in duration. Six of the subjects performed arm and leg work on a bicycle ergometer and an adapted Fleisch ergostat ergometer. Training sessions were conducted in the same manner as the leg group sessions. Both groups improved maximal oxygen uptake performance, regardless of the type of conditioning.

Men vs. Women

A majority of investigators have studied men exclusively, in tests designed to elicit maximal oxygen uptake and maximal heart rate. However, some studies have involved both men and women, making comparisons between the two groups possible.

Taguchi et al. (1974) studied 45 men and 33 women who performed maximal exercise tests on a Monarch bicycle ergometer and a treadmill. Testing order was randomly assigned and subjects were healthy but not involved in any training. The mean maximal oxygen uptake values for the men were 7.2 and 9.4 ml/kg/min higher compared to the women for the treadmill and bicycle ergometer, respectively. Mean maximal heart rate values for the men were one beat/minute
higher compared to the women for the bicycle ergometer test but one beat/minute lower compared to the women for the treadmill test.

In 1982 Kitamura et al. studied 13 students, six of them men. Subjects performed maximal exercise tests on a Monarch bicycle ergometer. Each subject performed one test using legs alone, one test using an elevated ergometer to use arms alone and one test using a combination of ergometers to work arms and legs together. Mean maximal oxygen uptake values for the men were 7.9, 7.7 and 11.5% higher compared to the women for the leg tests, arm tests and combined arm and leg tests, respectively. Kitamura et al. (1982) suggested that lower maximal oxygen uptake values for the women were due to the women's smaller muscle mass. Mean maximal heart rates for the men were 1, 5 and 2 beats/minute higher compared to the women for the leg tests, arm tests and combined arm and leg tests, respectively.

Testing Protocols

Treadmill

A variety of protocols have been used with the treadmill for maximal graded exercise testing. In an effort to assist investigators in the selection of appropriate protocols, the ACSM developed guidelines for exercise testing protocols.

The exercise test should be graded according to energy requirements in METS. One MET is equal to the amount of oxygen consumed while a subject is in a sitting position, approximately 3.5
ml/kg/min. The MET cost of treadmill exercise is independent of body weight. Tables have been developed to use as guidelines in the estimation of achieved METS, but direct measure of the oxygen consumed is more precise (ACSM, 1980).

ACSM members Pollock, et al. (1978) recommended that:

1. Maximal tests should be graded, with the initial workload not exceeding 2 to 3.5 METS.
2. The progressive increases in workload should not exceed 2 to 3 METS per increase.
3. Each workload should be performed for at least one minute before increasing to the next workload.
4. Subjects should recover in a supine position or by walking slowly on the treadmill at 2 mph, 0% grade.

The Bruce protocol (Bruce, 1974) meets the above criteria. Pollock et al. (1978) noted that the Bruce protocol has been used successfully with groups of varying ability, body type, age and health status. Stewart and Ellestad (1980) surveyed 1400 exercise testing centers and found the treadmill to be the most popular testing mode (71%). The Bruce protocol was the most widely used at 65.5%.

Pollock (1976) compared four protocols (Astrand, Balke, Bruce, and Ellestad) used for maximal testing on a treadmill. The time duration differed significantly between tests, but the final result, maximal oxygen uptake, was approximately the same for 51 men, aged 35 to 55 years. The Bruce test averaged 13 minutes, while the Balke test averaged 24 minutes. Pollock et al. (1978) noted that the
biggest criticism of the Balke test is the time involved, while the Bruce test is criticized for its abrupt changes in workloads. The Astrand test was another one of the protocols tested. It does not meet ACSM guidelines for diagnostic testing because the initial workload is too high. Subjects using the Ellstad protocol averaged 12 minutes. It is not as popular as the Bruce protocol, primarily because the speed increases at a faster rate throughout the test than the Bruce test. Maximal heart rates were similar for all four protocols.

Pollock et al. (1982) studied 49 women who performed maximal exercise using the Bruce and Balke protocols. Mean maximal oxygen uptake was significantly higher (p<.05) for the Bruce protocol compared to the Balke protocol. Mean maximal heart rate values were not significantly different.

**Monarch Bicycle Ergometer**

A variety of protocols have also been used with the Monarch bicycle ergometer (Stewart and Ellestad, 1980). The same guidelines set forth by Pollock et al. (1978) for treadmill testing apply to bicycle ergometer testing with the exception of the recovery procedure. During recovery, subjects should recover in a supine position or by pedalling 60 rpm at little or no resistance.

The most popular protocol for bicycle ergometer testing is one adapted from Astrand (Pollock et al. 1978). Each 150 kpm/min increase represents an increase in energy requirement of 1.67 METS (Morehouse and Miller, 1967). This is slightly less than the 2 to 3
MET increment suggested in the ACSM guidelines; however, a 300 kpm/min increase would represent an increase of over 3 METS. The protocol meets all other ACSM guidelines without exception.

McArdle et al. (1973) compared a continuous and discontinuous protocol using a Monarch bicycle ergometer. Subjects performed maximal tests using each protocol and testing order was randomized. The continuous protocol used two-minute stages and workloads were increased at rates similar to the Astrand protocol. Mean maximal oxygen uptake and maximal heart rate values were not significantly different between the two tests. The disadvantage of a discontinuous test is the longer total test time. Hoyt et al. (1973) used a protocol similar to the one adapted from Astrand. The only difference was the use of a one-minute stage for each workload. This protocol also meets the ACSM guidelines.

Schwinn Air-Dyne Ergometer

Because the workload increments of the Schwinn Air-Dyne ergometer are identical to those on the Monarch bicycle ergometer, it would be possible to use the same protocol for the two ergometers. Hagen et al. (1983) used the Schwinn Air-Dyne ergometer to test 15 men and 15 women. For the men, the workload started at 150 kpm/min and increased 150 kpm/min for five minutes and then increased 300 kpm/min every fifth minute until exhaustion. For the women, the workload started at 150 kpm/min and increased 150 kpm/min every fifth minute until exhaustion. All subjects pedalled at 150 kpm/min during recovery. Women and men were not compared; however, each subject's
performance on the Air-Dyne was compared with a maximal graded exercise test on a treadmill.
CHAPTER III
DESIGN AND METHODOLOGY

The purpose of this study was to determine which of three exercise modes: (a) a motorized treadmill, (b) a Monarch bicycle ergometer, or (c) a Schwinn Air-Dyne ergometer, would produce the highest maximal values for oxygen consumption and heart rate when subjects performed maximal graded exercise tests on each mode of exercise.

This chapter includes four sections: (a) Subject Selection, (b) Testing Procedures, (c) Instrumentation, and (d) Statistical Analysis.

Subject Selection

The subjects in this study were chosen from the general population of the greater Kalamazoo area. There were ten men and ten women, ranging in age from 22 to 34 years. Subjects were divided into a trained group and an untrained group. Trained individuals were classified as those who were exercising on a regular basis three or more times per week, for 30 or more minutes per exercise session. Their exercise was aerobic, rhythmic and maintained continuously. The intensity of each exercise session was such that their heart rates were between 60 and 90% of their maximal heart rates or 50 to 80% of their maximal oxygen uptake values. Untrained individuals were those who did not meet one or more of the criteria used to classify trained individuals. The trained group included 5 men and 5
women. The untrained group included 5 men and 5 women. The general characteristics of the subjects are presented in Table 1. See Table 2 for descriptive data for trained and untrained subjects.

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
</table>

### Descriptive Analysis by Weight, Height and Age for Gender

<table>
<thead>
<tr>
<th>Sex</th>
<th>Weight X</th>
<th>SD</th>
<th>Height X</th>
<th>SD</th>
<th>Age X</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>57.13</td>
<td>7.13</td>
<td>161.1</td>
<td>6.06</td>
<td>28.0</td>
<td>4.08</td>
</tr>
<tr>
<td>Males</td>
<td>75.82</td>
<td>14.68</td>
<td>172.4</td>
<td>8.41</td>
<td>27.6</td>
<td>3.03</td>
</tr>
</tbody>
</table>

**Note.** Weight is in kg. Height is in cm. Age is in years.

### Table 2

### Descriptive Analysis by Weight, Height and Age for Level of Fitness

<table>
<thead>
<tr>
<th>Group</th>
<th>Weight X</th>
<th>SD</th>
<th>Height X</th>
<th>SD</th>
<th>Age X</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trained</td>
<td>53.66</td>
<td>3.70</td>
<td>158.2</td>
<td>6.18</td>
<td>28.4</td>
<td>4.39</td>
</tr>
<tr>
<td>Untrained</td>
<td>60.60</td>
<td>8.40</td>
<td>164.0</td>
<td>4.85</td>
<td>27.6</td>
<td>4.22</td>
</tr>
<tr>
<td>Males</td>
<td>70.98</td>
<td>8.98</td>
<td>168.8</td>
<td>3.90</td>
<td>28.0</td>
<td>3.94</td>
</tr>
<tr>
<td>Untrained</td>
<td>80.66</td>
<td>18.59</td>
<td>176.0</td>
<td>10.56</td>
<td>27.2</td>
<td>2.17</td>
</tr>
</tbody>
</table>

**Note.** Weight is in kg. Height is in cm. Age is in years.
Testing Procedures

Subjects

Testing took place at The Institute for Cardiovascular Health in Kalamazoo, Michigan. Each subject was tested during a six-week period, with a minimum of six days between each test. A consent form which explained the nature of the study and the possible risks involved was signed by each subject before each test, in addition to a general consent form which was signed before any tests took place. The consent forms appear in Appendices A and B. Subjects were allowed to become familiar with each exercise mode and the oxygen analysis apparatus. All procedures were explained. The subjects reported to the testing room wearing loose, comfortable clothing and exercise shoes. They were instructed to perform warm-up exercises before each test. ACSM guidelines for exercise testing (1980) were used to monitor heart rate and blood pressure response during each exercise test. Due to the use of a repeated measures statistical design, subjects were randomly assigned a testing order to minimize the effect of an ordered pattern in data collection procedures.

Motorized Treadmill Test

The maximal exercise test on the treadmill was performed using the Bruce protocol with three-minute stages. Subjects were allowed to use the handrail for balance and were instructed to walk close to the front of the treadmill.
Monarch Bicycle Ergometer Test

The maximal exercise test on the Monarch bicycle ergometer began with a 150 kpm/min workload and increased another 150 kpm/min at the end of each three-minute stage, to follow a protocol adapted from Astrand (Pollock et al. 1978). Pedal rate was 60 rpm. Subjects were cued by a metronome and verbally encouraged to maintain the correct pedal rate. After reaching volitional exhaustion or localized muscle fatigue, the subjects pedalled at a 150 kpm/min workload to aid recovery. After four minutes of recovery pedalling, the subjects were allowed to sit in a chair to complete the ten-minute recovery period.

Schwinn Air-Dyne Ergometer Test

The maximal exercise test on the Schwinn Air-Dyne ergometer began with a 150 kpm/min workload and increased another 150 kpm/min at the end of each three-minute stage. Pedal rate was maintained at each workload by verbal encouragement and monitored throughout the test. Since the pedal rate changed at each successive workload, a metronome was not used. Subjects were required to use the arm handles during the entire test. After reaching volitional exhaustion or localized muscle fatigue, the subjects pedalled at a 150 kpm/min workload to aid recovery. After four minutes of recovery pedalling, the subjects were allowed to sit in a chair to complete the ten-minute recovery period.
Oxygen Analysis

Oxygen analysis began in the final stages of each test, starting at the time each subject perceived the workload as "somewhat hard". The tests were discontinued when each subject reached volitional exhaustion, localized muscle fatigue or was unable to maintain the appropriate workload. All subjects were verbally encouraged to achieve their highest level of work on each test.

Instrumentation

Each piece of equipment was calibrated according to manufacturer specifications before each test.

Quinton Motorized Treadmill

A Quinton motorized treadmill, model number 18-49-C, was used in this study. Subjects were instructed to walk at the front of the treadmill and use the handrail for balance.

Monarch Bicycle Ergometer

The Monarch bicycle ergometer used in this was model number 666. Seat height adjustments were made so that the leg was almost straight when the ball of the foot was placed on a pedal in the downstroke position (Hartley, 1973).
Schwinn Air-Dyne Ergometer

A Schwinn Air-Dyne ergometer, model AD-3, was used. Seat height adjustments were made so that a subject's leg was almost straight on the pedal downstroke (Hartley, 1973).

Oxygen Analysis Equipment

A Beckman Metabolic Measurement Cart, model number MMC 554336, was used to analyze the amount of oxygen used by each subject at the peak workload. Expired air was collected through a flexible plastic tube attached to the metabolic cart. A Daniels valve (R-Pel Company, Los Altos, California) was used for the mouthpiece. Nose plugs were used to prevent air escape through the nose.

Electrocardiographic Equipment

A Viagraph Auto Test Recorder was used to monitor heart rates throughout each maximal exercise test. ACSM guidelines for exercise testing were followed, whereby heart rates were measured during the last thirty seconds of each stage and every two minutes throughout the ten-minute recovery period.

Blood Pressure Equipment

Blood pressure response was monitored throughout exercise; measurements were read prior to each heart rate measurement. A PyMah sphygmomanometer (Trimline, PyMah Corp., Somerville, New Jersey) was used.
Statistical Analysis

Raw data were coded and then computer analyzed, using the Computer Program BMDP. An Analysis of Variance, Split Plot Factorial Design was used. Tukey's HSD Multiple Range Comparison Test was used to determine significant differences between means. The independent variables included: (a) mode of exercise with three levels, a motorized treadmill, a Monarch bicycle ergometer and a Schwinn Air-Dyne ergometer; (b) sex with two levels, women and men, and (c) activity with two levels, trained and untrained. This study included two dependent variables: maximal oxygen uptake and maximal heart rate.
CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to determine which of three exercise modes would produce the highest maximal values for oxygen consumption and heart rate. Subjects performed maximal graded exercise tests using: (a) a motorized treadmill, (b) a Monarch bicycle ergometer, and (c) a Schwinn Air-Dyne ergometer.

An Analysis of Variance, Split Plot Factorial Design was used to determine the effects of the independent variables on the dependent variables. The independent variables included: (a) fitness with two levels, trained and untrained; (b) sex with two levels, women and men; and (c) mode of exercise with three levels, a motorized treadmill, a Monarch bicycle ergometer, and a Schwinn Air-Dyne ergometer. The two dependent variables were maximal oxygen consumption and maximal heart rate. This chapter is presented in two sections: (a) Results and (b) Discussion.

Results

Maximal Oxygen Uptake

An ANOVA was calculated using mode of exercise, gender and level of fitness as independent variables. Maximal oxygen uptake served as the dependent variable. The ANOVA (see Table 3) indicated the following:

1. Mean maximal oxygen uptake values were significantly
different, $F = 19.31$, for the trained vs. untrained subjects at the .01 level of significance, ($F(1,16) = 8.53, p<.01$).

2. A significant difference in mean maximal oxygen uptake, $F = 12.97$, was found for gender, ($F(1,16) = 8.53, p<.01$).

3. No difference in mean maximal oxygen uptake, $F = .16$, was found for the gender X level of fitness interaction, ($F(1,16) = 8.53, p<.01$).

4. For mean maximal oxygen uptake, modes of exercise were found to be significantly different, $F = 11.08$, ($F(2,82) = 5.39, p<.01$).

5. No difference in mean maximal oxygen uptake was found for first order interactions (a) level of fitness X modes, $F = .36$, and (b) modes X gender, $F = .79$, and the second order interaction, mode X level of fitness X gender, $F = .17$, ($F(2,32) = 5.39, p<.01$).

Table 3

ANOVA Summary Table for Maximal Oxygen Uptake

<table>
<thead>
<tr>
<th>Source</th>
<th>S.S.</th>
<th>df</th>
<th>M.S.</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3467.52</td>
<td>59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trained (T)</td>
<td>2980.35</td>
<td>19</td>
<td>192.60</td>
<td>19.31*</td>
</tr>
<tr>
<td>Gender (G)</td>
<td>789.89</td>
<td>1</td>
<td>789.89</td>
<td>12.97*</td>
</tr>
<tr>
<td>T X G</td>
<td>9.68</td>
<td>1</td>
<td>9.68</td>
<td>.16</td>
</tr>
<tr>
<td>Subj. w. Groups</td>
<td>988.18</td>
<td>16</td>
<td>61.76</td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td>487.17</td>
<td>40</td>
<td>12.18</td>
<td></td>
</tr>
<tr>
<td>Modes (M)</td>
<td>190.16</td>
<td>2</td>
<td>95.08</td>
<td>11.08**</td>
</tr>
<tr>
<td>T X M</td>
<td>6.11</td>
<td>2</td>
<td>3.06</td>
<td>.36</td>
</tr>
<tr>
<td>M X G</td>
<td>13.56</td>
<td>2</td>
<td>6.78</td>
<td>.79</td>
</tr>
<tr>
<td>M X T X G</td>
<td>2.86</td>
<td>2</td>
<td>1.43</td>
<td>.17</td>
</tr>
<tr>
<td>M X Subj. w. Groups</td>
<td>274.48</td>
<td>32</td>
<td>8.58</td>
<td></td>
</tr>
</tbody>
</table>

* $F(1,16) = 8.53, p<.01$.

** $F(2,32) = 5.39, p<.01$. 

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The means and standard deviations for the maximal oxygen uptake values for gender, level of fitness and modes of exercise are presented in Table 4. An analysis of gender and level of fitness indicates the following:

1. A significant difference between means for trained and untrained subjects was indicated. The mean for trained subjects was 43.84 ml/kg/min and the mean for untrained subjects was 34.92 ml/kg/min, a difference of 8.92 ml/kg/min.

2. A significant difference between means for gender was indicated. The mean for male subjects was 43.01 ml/kg/min and the mean for female subjects was 35.75 ml/kg/min, a difference of 7.26 ml/kg/min.
Table 4

Descriptive Analysis by Level of Fitness, Gender and Mode of Exercise for Maximal Oxygen Uptake

<table>
<thead>
<tr>
<th>Mode</th>
<th>Trained X</th>
<th>SD</th>
<th>Untrained X</th>
<th>SD</th>
<th>Marginal X</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monarch</td>
<td>38.58</td>
<td>4.24</td>
<td>29.56</td>
<td>5.69</td>
<td>34.07</td>
</tr>
<tr>
<td>Air-Dyne</td>
<td>40.12</td>
<td>4.38</td>
<td>31.42</td>
<td>4.22</td>
<td>35.77</td>
</tr>
<tr>
<td>Treadmill</td>
<td>40.72</td>
<td>3.24</td>
<td>34.10</td>
<td>2.47</td>
<td>37.41</td>
</tr>
<tr>
<td>Marginal X</td>
<td>39.81</td>
<td></td>
<td>31.69</td>
<td></td>
<td>35.75</td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monarch</td>
<td>45.74</td>
<td>2.84</td>
<td>35.68</td>
<td>6.15</td>
<td>40.71</td>
</tr>
<tr>
<td>Air-Dyne</td>
<td>47.12</td>
<td>3.54</td>
<td>37.48</td>
<td>7.94</td>
<td>42.30</td>
</tr>
<tr>
<td>Treadmill</td>
<td>50.74</td>
<td>4.69</td>
<td>41.28</td>
<td>8.26</td>
<td>46.01</td>
</tr>
<tr>
<td>Marginal X</td>
<td>47.87</td>
<td></td>
<td>38.15</td>
<td></td>
<td>43.01</td>
</tr>
<tr>
<td><strong>Combined</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monarch</td>
<td>42.16</td>
<td></td>
<td>32.62</td>
<td></td>
<td>37.39</td>
</tr>
<tr>
<td>Air-Dyne</td>
<td>43.62</td>
<td></td>
<td>34.45</td>
<td></td>
<td>39.04</td>
</tr>
<tr>
<td>Treadmill</td>
<td>45.73</td>
<td></td>
<td>37.69</td>
<td></td>
<td>41.71</td>
</tr>
<tr>
<td>Marginal X</td>
<td>43.84</td>
<td></td>
<td>34.92</td>
<td></td>
<td>39.38</td>
</tr>
</tbody>
</table>

For the comparison of the means associated with modes of exercise, Tukey's HSD Multiple Range Test was used to locate significant differences between the three modes. The means for the three modes, shown in Table 4, were 37.39 ml/kg/min, 39.04 ml/kg/min and 41.71 ml/kg/min for the Monarch, Air-Dyne and treadmill, respectively. The analysis of mean differences for modes of exercise are presented in Table 5. Those differences indicate that:
1. No significant difference, \( R = 1.65 \), existed between the two bicycle ergometers, the Monarch and the Air-Dyne, \( (HSD = 2.55, \ p < .01, \ R = 2) \).

2. Both bicycle ergometers were significantly different from the treadmill. The range for the Monarch and treadmill was 4.32, \( (HSD = 2.91, \ p < .01, \ R = 3) \). The range for the Air-Dyne and the treadmill was 2.67, \( (HSD = 2.55, \ p < .01, \ R = 2) \).

These results indicate effects of the independent variables: (a) mode of exercise, (b) gender, and (c) level of fitness upon the dependent variable, maximal oxygen uptake. This supports the hypothesis which stated that maximal oxygen uptake values of subjects using the Air-Dyne ergometer were not significantly different from values obtained when subjects used the Monarch bicycle ergometer. These results do not support the hypothesis which stated that maximal oxygen uptake values of subjects using the Air-Dyne ergometer were not significantly different from values obtained when subjects used a motorized treadmill.

Table 5

<table>
<thead>
<tr>
<th>Modes</th>
<th>Monarch</th>
<th>Air-Dyne</th>
<th>Treadmill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monarch</td>
<td>-</td>
<td>1.65</td>
<td>4.32*</td>
</tr>
<tr>
<td>Air-Dyne</td>
<td>-</td>
<td>-</td>
<td>2.67**</td>
</tr>
<tr>
<td>Treadmill</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*HSD = 2.91, \( p < .01, \ R = 3 \).
**HSD = 2.55, \( p < .01, \ R = 2 \).
Maximal Heart Rate

An ANOVA was calculated using mode of exercise, gender and level of fitness as independent variables. Maximal heart rate served as the dependent variable. The ANOVA (see Table 6) indicates the following:

1. Mean maximal heart rate values were not significantly different, $F = 1.02$, for trained versus untrained subjects at the .01 level of significance, $(F(1,16) = 8.53, p < .01)$.

2. No significant difference in mean maximal heart rate was found, $F = .30$, for gender, $(F(1,16) = 8.53, p < .01)$.

3. No significant difference in mean maximal heart rate was found, $F = 2.33$, for the gender X level of fitness interaction, $(F(1,16) = 8.53, p < .01)$.

4. For mean maximal heart rate, modes of exercise were not significantly different, $F = 3.03$, $(F(2,32) = 5.39, p < .01)$.

5. No difference in mean maximal heart rate was found for first order interactions (a) level of fitness X modes, $F = 1.77$, and (b) modes X gender, $F = .08$, and the second order interaction, mode X level of fitness X gender, $F = 1.07$, $(F(2,32) = 5.39, p < .01)$. 

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Table 6

ANOVA Summary Table for Maximal Heart Rate

<table>
<thead>
<tr>
<th>Source</th>
<th>S.S.</th>
<th>df</th>
<th>M.S.</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trained (T)</td>
<td>81.67</td>
<td>1</td>
<td>81.67</td>
<td>1.02</td>
</tr>
<tr>
<td>Gender (G)</td>
<td>24.07</td>
<td>1</td>
<td>24.07</td>
<td>.30</td>
</tr>
<tr>
<td>T X G</td>
<td>187.27</td>
<td>1</td>
<td>187.27</td>
<td>2.33</td>
</tr>
<tr>
<td>Subj. w. Groups</td>
<td>1286.93</td>
<td>16</td>
<td>80.43</td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td>999.99</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modes (M)</td>
<td>138.13</td>
<td>2</td>
<td>69.07</td>
<td>3.03</td>
</tr>
<tr>
<td>T X M</td>
<td>80.53</td>
<td>2</td>
<td>40.27</td>
<td>1.77</td>
</tr>
<tr>
<td>M X G</td>
<td>3.73</td>
<td>2</td>
<td>1.87</td>
<td>.08</td>
</tr>
<tr>
<td>M X T X G</td>
<td>48.53</td>
<td>2</td>
<td>24.27</td>
<td>1.07</td>
</tr>
<tr>
<td>M X Subj. w. Groups</td>
<td>729.07</td>
<td>32</td>
<td>22.78</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2579.93</td>
<td>59</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*\(F(1,16) = 8.53, p<.01\).  
**\(F(2,32) = 5.39, p<.01\).

The means and standard deviations for the maximal heart rate values for gender, level of fitness and modes of exercise are presented in Table 7. An analysis of gender and level of fitness indicates the following:

1. No significant difference between means for trained and untrained subjects was indicated. The mean for trained subjects was 184.80 beats/minute (b/min) and the mean for untrained subjects was 187.13 b/min, a difference of 2.33 b/min.

2. No difference between means for gender was indicated. The mean for male subjects was 185.34 b/min and the mean for female subjects was 186.60 b/min, a difference of 1.26 b/min.

3. No difference between the means associated with modes of exercise was indicated. The means for the three modes, shown in
exercise was indicated. The means for the three modes, shown in Table 7, were 183.90 b/min, 186.50 b/min and 187.50 b/min for the Monarch, Air-Dyne and treadmill, respectively.

Table 7

Descriptive Analysis for Level of Fitness, Gender and Mode of Exercise for Maximal Heart Rate

<table>
<thead>
<tr>
<th>Mode</th>
<th>Trained X</th>
<th>Trained SD</th>
<th>Untrained X</th>
<th>Untrained SD</th>
<th>Marginal X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monarch</td>
<td>185.20</td>
<td>6.42</td>
<td>184.00</td>
<td>2.83</td>
<td>184.60</td>
</tr>
<tr>
<td>Air-Dyne</td>
<td>188.40</td>
<td>6.23</td>
<td>185.20</td>
<td>6.42</td>
<td>186.80</td>
</tr>
<tr>
<td>Treadmill</td>
<td>188.00</td>
<td>6.78</td>
<td>188.80</td>
<td>4.15</td>
<td>188.40</td>
</tr>
<tr>
<td>Marginal X</td>
<td>187.20</td>
<td></td>
<td>186.00</td>
<td></td>
<td>186.60</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monarch</td>
<td>182.80</td>
<td>8.67</td>
<td>183.60</td>
<td>5.55</td>
<td>183.20</td>
</tr>
<tr>
<td>Air-Dyne</td>
<td>182.80</td>
<td>9.01</td>
<td>189.60</td>
<td>3.29</td>
<td>186.20</td>
</tr>
<tr>
<td>Treadmill</td>
<td>181.60</td>
<td>8.17</td>
<td>191.60</td>
<td>6.84</td>
<td>186.60</td>
</tr>
<tr>
<td>Marginal X</td>
<td>182.40</td>
<td></td>
<td>188.27</td>
<td></td>
<td>185.34</td>
</tr>
<tr>
<td>Combined</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monarch</td>
<td>184.00</td>
<td></td>
<td>183.80</td>
<td></td>
<td>183.90</td>
</tr>
<tr>
<td>Air-Dyne</td>
<td>185.60</td>
<td></td>
<td>187.40</td>
<td></td>
<td>186.50</td>
</tr>
<tr>
<td>Treadmill</td>
<td>184.80</td>
<td></td>
<td>190.20</td>
<td></td>
<td>187.50</td>
</tr>
<tr>
<td>Marginal X</td>
<td>184.80</td>
<td></td>
<td>187.13</td>
<td></td>
<td>185.97</td>
</tr>
</tbody>
</table>

These results show the effects of the independent variables: (a) mode of exercise, (b) gender, and (c) level of fitness upon the dependent variable, maximal heart rate. This supports the hypotheses
which stated that: (a) maximal heart rate values of subjects using the Air-Dyne ergometer were not significantly different from values obtained when subjects used the Monarch bicycle ergometer, and (b) maximal heart rate values of subjects using the Air-Dyne ergometer were not significantly different from values obtained when subjects used a motorized treadmill.

Discussion

Maximal Oxygen Uptake

The significantly higher maximal oxygen uptake values seen in trained subjects compared to untrained subjects were in agreement with studies by Miyamura et al. (1978), Pannier, et al. (1980), Pollock et al. (1982) and Mostardï and Gandee (1981). Body weight for the trained women averaged 53.66 kg compared to 60.60 kg for the untrained women. Body weight for the trained men averaged 70.98 kg compared to 80.66 kg for the untrained men (see Table 2). The higher maximal oxygen uptake values for the trained men could be due to greater muscle mass per kg of body weight. Pannier et al. (1980) also reported lower weights for trained subjects compared to control subjects. Miyamura et al. (1978) assumed that trained subjects were able to maintain a higher venous return to the heart compared to untrained subjects during treadmill and bicycle ergometer exercise. It was suggested that: (a) a trained muscle consumes more oxygen per unit of blood flow compared to an untrained muscle, and (b) the higher maximal oxygen uptake values for trained subjects may result
from higher cardiac output due to a larger stroke volume and/or higher arterio-venous oxygen difference, due to the greater oxygen extraction ability compared to untrained subjects.

Maximal oxygen uptake values that were significantly higher for men compared to women were consistent with results from studies by Taguchi et al. (1974) and Kitamura et al. (1982). Less total muscle mass or less muscle mass per kg of body weight could explain the lower values for the women compared to the men. Since the Air-Dyne ergometer enables a subject to utilize more muscle mass at a given workload than a traditional bicycle ergometer (i.e. Monarch), it was expected that maximal oxygen uptake values would be significantly higher for the Air-Dyne compared to the Monarch. The results indicate that there was no difference in maximal oxygen uptake for the two different modes. This suggests the following possible explanations:

1. The number of subjects in this study was too small to elicit a significant difference between modes.
2. Subjects preferred the Monarch to the Air-Dyne ergometer.
3. The longer test time for the Air-Dyne compared to the Monarch test caused subjects to fatigue in a different manner than the Monarch test.
4. The arms did not make a significant contribution to the total work being done by the subject on the Air-Dyne.
5. Subjects did not attain true maximal oxygen uptake values on the Air-Dyne ergometer.

It was also expected that maximal oxygen uptake values for the
treadmill and the Air-Dyne would be similar. As noted earlier, there was a significant difference between the Air-Dyne and the treadmill. The possible reasons for this include:

1. Subjects preferred the treadmill compared to the Air-Dyne.

2. The longer test time for the Air-Dyne compared to the treadmill caused subjects to fatigue in a different manner than the treadmill test.

3. Subjects did not attain true maximal oxygen uptake values on the Air-Dyne.

4. Subjects were more familiar with walking and running compared to riding.

**Maximal Heart Rate**

Maximal heart rate values for trained and untrained subjects were not found to be significantly different in this study. Mostardi and Gandee (1981) reported similar results for untrained subjects who trained for six weeks and were retested. Pollock et al. (1978) stated that regular aerobic exercise may cause a decrease or no change in maximal heart rate.

Mean maximal heart rates did not differ significantly between men and women. This was expected, since all subjects were in a relatively small age range and the average ages for men and women were similar. Taguchi et al. (1974) reported similar results in a study that involved 45 men and 33 women who performed maximal exercise tests. The lack of significance in maximal heart rate
values between the three exercise modes was not in agreement with results of studies by Deutsch and Knowlton (1980), McArdle and Magel (1970), Miyamura et al. (1978), Taguchi et al. (1974), and Pannier et al. (1980). These investigators reported significantly higher maximal heart rate values on a treadmill compared to a bicycle ergometer. However, Pannier et al. (1980) did not find a significant difference between the two modes for control subjects in a study that involved trained and untrained subjects. Hagan et al. (1983) reported similar values for maximal heart rate for subjects who used a treadmill and an Air-Dyne. Bergh et al. (1976) reported significantly higher maximal heart rate values on a treadmill compared to combined arm and leg work and also compared to a bicycle ergometer. Similar values for maximal heart rate between exercise modes in this study may be due to the ability of all three exercise modes to elicit a maximal heart rate.
CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study was conducted to determine which of three exercise modes would elicit the highest values for maximal oxygen uptake and maximal heart rate. Twenty healthy adults, ten women and ten men, were divided into two groups according to fitness level. Five of the women and five of the men were classified as trained, and the remaining ten subjects were classified as untrained. All subjects were between 22 and 34 years of age. They performed maximal graded exercise tests using: (a) a motorized treadmill, (b) a Monarch bicycle ergometer, and (c) a Schwinn Air-Dyne ergometer. Testing order was randomized to minimize the effect of an ordered pattern in data collection procedures. Subjects were instructed to continue each test until they reached volitional exhaustion, experienced localized muscle fatigue or were unable to maintain the appropriate workload. Due to the use of a repeated measures statistical design, subjects served as their own control. Heart rate and oxygen consumption values were determined at maximal workloads.

Raw data were coded and analyzed using the Computer Program BMDP. An Analysis of Variance, Split Plot Factorial design was used. Tukey's HSD Multiple Range Comparison Test was used to determine significant differences between means. The independent variables included: (a) mode of exercise with three levels, a motorized
treadmill, a Monarch bicycle ergometer, and a Schwinn Air-Dyne
ergometer; (b) sex with two levels, women and men; and (c) activity
with two levels, trained and untrained. This study included two
dependent variables, maximal oxygen uptake and maximal heart rate.

Findings

Significance was determined at the .01 level. The ANOVA used to
determine the effects of the independent variables on the dependent
variables indicated the following:

1. Mean maximal oxygen uptake values were significantly higher
   for the trained subjects compared to the untrained subjects.

2. Mean maximal oxygen uptake values were significantly higher
   for the men compared to the women.

3. Mean maximal oxygen uptake values were significantly higher
   when subjects used the treadmill, compared to the Monarch and the
   Air-Dyne.

4. No difference in mean maximal oxygen uptake was found for
   first order interactions: (a) level of fitness X modes, and (b)
   modes X gender and the second order interaction, mode X level of
   fitness X gender.

5. No significant difference in mean maximal heart rate was
   found between trained and untrained subjects.

6. No significant difference in mean maximal heart rate was
   found between men and women.

7. No significant difference in mean maximal heart rate was
   found between modes of exercise.
Conclusions

The effects of the independent variables on maximal oxygen uptake and maximal heart rate led the investigator to suggest the following conclusions:

1. Higher values for maximal oxygen uptake in trained subjects compared to untrained subjects may be due to greater muscle mass per kg of body weight.

2. Higher values for maximal oxygen uptake in men compared to women may be due to greater total muscle mass or greater muscle mass per kg of body weight.

3. Higher values for maximal oxygen uptake when subjects used the treadmill compared to the Monarch and the Air-Dyne may be due to: (a) a preference by subjects for the treadmill compared to the Monarch and the Air-Dyne, (b) failure of the subjects to attain a true maximal oxygen uptake on the Monarch or the Air-Dyne, and (c) the longer test time for the Monarch and the Air-Dyne caused subjects to fatigue in a different manner than the treadmill test.

4. Similar values for maximal heart rate in trained and untrained subjects and in women and men may indicate the failure of these independent variables to affect maximal heart rate values.

5. Similar values for maximal heart rate between modes of exercise may be due to the ability of all three modes to elicit a maximal heart rate.
Recommendations

Based on the results of this study, the Schwinn Air-Dyne can be recommended for use in maximal graded exercise tests designed to elicit a maximal heart rate. The Air-Dyne could be used to test women or men and trained or untrained subjects. Further studies should include the following changes:

1. The testing protocol used for the Air-Dyne should be modified to include more progressive increments of work and/or shorter workload stages.

2. The sample size for trained and untrained women and men should be larger than the sample size of this study.

3. Subjects should be tested using both the Air-Dyne and the treadmill in exercise tests designed to elicit a maximal oxygen uptake and results should be compared.
APPENDIX A

CONSENT FORM

I have agreed to be a participant in a thesis study conducted by Elaine Jason Naegele. I understand that the information obtained from the three maximal graded exercise tests I will undergo will be kept confidential. The information will be coded to protect individual identity. It will be used with information obtained from similar tests which 19 other people will perform.

Average values for maximal heart rate, maximal oxygen uptake, age, weight and height will be determined. I will receive a summary of the results when all data is in and results have been compiled. My test data will then be handed over to me for personal use. I understand that there are emergency personnel available in the event of a problem during or after each test. Trained assistants (basic cardiac life support) will be present during each test. An on-call emergency code team will also be available. Any assistance which may be needed will be provided at no cost to me. I am aware that Dr. E. Enrique Leguizamon, M.D., (Medical Director for the Institute of Cardiovascular Health and Rehabilitation) has approved all procedures for this study. ACSM Exercise Testing Guidelines will be followed.

I have read and understand the above information. I agree to perform the three maximal graded exercise tests using three different modes of exercise. I understand that there are potential risks involved and know that emergency help is available, if needed.
APPENDIX B

INFORMED CONSENT

Explanation:

You will perform maximal exercise on a treadmill, Monarch bicycle ergometer or a Schwinn Air-Dyne ergometer. The exercise will start at very low levels and increase at regular intervals until you reach exhaustion or wish to discontinue for another reason. We may also stop the test if a problem develops. We would like you to give us a maximal effort on the test, however you may stop the test at any time because of fatigue or discomfort.

Risks:

There is a possibility of certain changes occurring during the test. They include: abnormal blood pressure responses, dizziness, irregular heart beats and in very rare cases, a heart attack. Every effort will be made to minimize any risks by preliminary questioning and observation during the test. Emergency equipment and trained personnel are available if any situations should arise.

Purpose:

The purpose of this investigation is to determine which mode of exercise will elicit the highest values for maximal oxygen uptake and maximal heart rate. The order of testing will be randomized.

Inquiries:

Any questions about testing procedures are welcome. You will be given information throughout the test and all procedures will be explained.
Freedom of consent:

Your participation in this test is voluntary. If you do not wish to participate, please inform the investigator. The data from this test will be used with other data to complete a thesis by Elaine Jason Naegele to earn a degree at Western Michigan University.

I HAVE READ THIS FORM AND UNDERSTAND THE PROCEDURE I WILL BE INVOLVED IN. I AGREE TO PARTICIPATE IN THIS TEST.

Date: __________  Signature: _____________________________

Witness: _____________________________


McArdle, K., & Magel, J.R. (1970). Physical work capacity and max-
imum oxygen uptake in treadmill and bicycle exercise. Medicine and Science in Sports, 2, 118-123.


