A Comparison of Maximal and Submaximal Heart Rate and Oxygen Uptake in Combined Arm and Leg Bicycling and Rowing

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A COMPARISON OF MAXIMAL AND SUBMAXIMAL HEART RATE AND OXYGEN UPTAKE IN COMBINED ARM AND LEG BICYCLING AND ROWING

by

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>ACKNOWLEDGEMENTS</th>
<th>ii</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vii</td>
</tr>
</tbody>
</table>

## CHAPTER

### I. INTRODUCTION  1
- Statement of the Problem  1
- Need for the Study  2
- Delimitations  3
- Limitations  4
- Assumptions  4
- Hypothesis  5
- Definition of Terms  5

### II. REVIEW OF THE LITERATURE  8
- Heart Rate, Oxygen Consumption and Maximal Testing  8
- Effect of Muscle Mass on Maximal Heart Rate and Oxygen Uptake  12
- The Mechanics of Rowing  12
- The Physiology of Rowing  15
- The Mechanics of Bicycling  18
- The Physiology of Bicycling  19
- Rowing vs. Bicycling  21

### III. DESIGN AND METHODOLOGY  26
- Subject Selection  26

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Table of Contents—Continued

CHAPTER

Data Collection Procedures ...................... 27
Subjects ........................................ 27
Concept II Rowing Ergometer Test ........ 28
Schwinn Air-Dyne Bicycle Ergometer Test ....................... 29
Oxygen Uptake ................................... 30
Instrumentation .................................. 30
EKG Telemetry Monitor ........................... 30
Sphygmomanometer ............................... 30
Stethoscope ...................................... 31
Concept II Rowing Ergometer ..................... 31
Schwinn Air-Dyne Bicycle Ergometer .......... 31
Oxygen Analysis Equipment ....................... 32
Statistical Analysis .............................. 33

IV. RESULTS AND DISCUSSION .................... 34

Results ............................................. 35
Maximal Heart Rate .............................. 35
Maximal Oxygen Consumption .................... 36
Power Expressed as Percent of Maximal Heart Rate ....................... 38
Power Expressed as Percent of Maximal Oxygen Consumption ............... 44
Maximal Power Output ........................... 50
Discussion ........................................ 52
Maximal Heart Rate .............................. 52

iv

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
Table of Contents—Continued

CHAPTER

Maximal Oxygen Consumption ................. 54
Power Expressed as Percent of Maximal
Heart Rate ........................................ 58
Power Expressed as Percent of Maximal
Oxygen Consumption .............................. 63
Maximal Power Output .......................... 70

V. SUMMARY, FINDINGS, CONCLUSIONS AND
RECOMMENDATIONS .............................. 72
Summary .......................................... 72
Findings .......................................... 73
Conclusions ...................................... 74
Recommendations ................................. 75

APPENDICES

A. Health History ................................. 76
B. Informed Consent for Graded Exercise Test ..... 79
C. Raw Test Data .................................. 82
D. Table of Descriptive Statistics for Maximal
Heart Rate ....................................... 84
E. Table of Descriptive Statistics for Maximal
Oxygen Consumption ......................... 86
F. Table of Descriptive Statistics for Power at
Submaximal Heart Rate ..................... 88
G. Table of Descriptive Statistics for Power at
Submaximal Oxygen Consumption .......... 90
H. Table of Descriptive Statistics for Maximal
Power Output ................................. 92

BIBLIOGRAPHY .................................. 94

v

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
LIST OF TABLES

1. ANOVA Summary Table for Maximal Heart Rate ........ 36
2. ANOVA Summary Table for Maximal Oxygen Consumption ............................................. 37
3. ANOVA Summary Table for Power Expressed as Percent of Maximal Heart Rate ................. 39
4. ANOVA Summary Table of Simple Simple Main Effects Tests for Power Expressed as a Percentage of Maximal Heart Rate ................................................. 43
5. ANOVA Summary Table for Power Expressed as Percent of Maximal Oxygen Consumption .............. 46
6. ANOVA Summary Table of Simple Simple Main Effects Tests for Power Expressed as a Percentage of Maximal Oxygen Consumption ................................................. 49
7. ANOVA Summary Table for Maximal Power Output ....... 51
LIST OF FIGURES

1. Gender X Mode of Exercise Interaction for Maximal Oxygen Consumption ......................... 55

2. Gender X Mode of Exercise Interaction for Power Expressed as a Percentage of Maximal Heart Rate .............................................. 60

3. Percent Maximal Heart Rate X Gender Interaction for Power ........................................ 61

4. Mode of Exercise X Percent Maximal Heart Rate Interaction for Power ............................. 61

5. Gender X Mode of Exercise Interaction for Power Expressed as a Percentage of Maximal Oxygen Consumption ................................. 67

6. Percent Maximal Oxygen Consumption X Gender Interaction for Power ........................ 67

7. Mode of Exercise X Percent Maximal Oxygen Consumption for Power .......................... 68

8. Gender X Mode of Exercise Interaction for Maximal Power Output ................................. 71
CHAPTER I

INTRODUCTION

Currently in the United States there is an increasing interest to become physically fit. With this interest, a strong and competitive market for the production of exercise equipment to suit the consumer's needs is rising. Until recently, very few forms of exercise equipment have provided involvement of both the arms and the legs. The Schwinn Air-Dyne bicycle ergometer and the new Concept II rowing ergometer provide simultaneous arm and leg exercise. Each of these forms of combined arm and leg exercise have gained popularity, both in the health club setting, and in the more clinical cardiac rehabilitation environment. Research is lacking on the cardiovascular responses to each of these exercise devices. Even though the two have many similarities, they are very different with respect to the movements they command.

Statement of the Problem

The problem in this study was to determine the effect of exercise equipment on the cardiovascular system. Specifically, the Schwinn Air-Dyne bicycle ergometer and the Concept II rowing ergometer were studied by comparing
the respective maximal and submaximal heart rate and oxygen uptake they elicit.

Need for the Study

It has been well documented that the demand on the cardiovascular system varies with respect to the type of exercise performed. For example, a greater physiological strain will occur during arm exercise as compared to leg exercise performed at the same metabolic rate. As shown by the numerous number of heart attacks which have occurred while shoveling snow or performing other tasks with the arms, it is important to document further the effects that specific modes of exercise have on the cardiovascular system.

Rowing and bicycling are two very popular modes of exercise. The Schwinn Air-Dyne provides additional arm work to the traditional leg only method of bicycling. Rowing also provides a combination of arm and leg work. It is obvious that, despite their likenesses, the Air-Dyne and the Concept II incorporate very different muscular involvement. Because each modality is new and increasing in popularity, it is important to document how each mode stresses the human body.

In addition, both devices are very popular modes of stationary exercise in the cardiac rehabilitation setting. Since cardiac patients are considered to be
physiologically compromised and exercise is important to them, care must be taken to limit or eliminate any unnecessary dangers which may arise when too great a physiological strain is placed on the body. Any physiological data retrieved from this study of apparently healthy individuals can be applied to the cardiac population, so that safe measures of exercise are recommended.

Although many studies have compared the physiological responses to bicycling and rowing, none have compared the Air-Dyne and the Concept II rower. Since both devices are operated by wind resistance, are air-braked, and offer support for the weight of the body, a valuable comparison can be made between the two.

Delimitations

This study was delimited to the following characteristics:

1. Participants were between the ages of 23 and 35 years.

2. All subjects were actively involved in an aerobic exercise program and exercised at least three times per week prior to and throughout this study.

3. All subjects were apparently healthy individuals with no known cardiovascular problems.

4. None of the subjects were specifically trained on
the Schwinn Air-Dyne bicycle or the Concept II rower.

5. Maximal and submaximal heart rates were used as a measure of cardiovascular response.

6. Maximal and submaximal oxygen uptakes were used as a measure of cardiovascular response.

Limitations

This investigation was limited to the following:

1. The extreme flexed position that occurred just before the drive phase on the Concept II rowing ergometer may have interfered with pulmonary ventilation. True maximal efforts may have been inhibited.

2. It was difficult to maintain exact workloads on the Concept II rowing ergometer.

3. The subjects had to overcome localized muscular fatigue in all tests so that true maximal values could be reached.

Assumptions

This study was conducted under the following assumptions:

1. Participants revealed an accurate health and exercise history.

2. The Beckman Metabolic Cart and EKG instrumentation used for data collection were accurate and reliable.

3. The Schwinn Air-Dyne bicycle ergometer and the
Concept II rowing ergometer were accurately calibrated by their manufacturer.

4. A true maximal effort on both devices was put forth by each subject.

Hypothesis

This study was conducted to test the following hypotheses:

1. A higher maximal heart rate and oxygen uptake would be obtained during combined arm and leg exercise on the Schwinn Air-Dyne bicycle ergometer as compared to the Concept II rowing ergometer.

2. The Schwinn Air-Dyne bicycle ergometer would elicit higher submaximal workloads in power than would the Concept II rowing ergometer at equal percentages of maximal heart rate and oxygen consumption.

Definition of Terms

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

1. Maximal oxygen consumption (VO$_2$ max) - the greatest volume of oxygen used by the cells of the body per unit of time (Lamb, 1984).

2. Aerobic exercise - exercise during which the energy needed is supplied by the oxygen inspired (Thomas, 1985).
3. Anaerobic exercise - exercise during which the energy needed is provided without utilization of inspired oxygen (Thomas, 1985).

4. Pulmonary ventilation - the process by which favorable concentrations of alveolar oxygen and carbon dioxide are maintained to assure adequate aeration of the blood flowing through the lungs (McArdle, Katch and Katch, 1981).

5. Apparently healthy individuals - those individuals who have no major coronary risk factors (American College of Sports Medicine, 1986).

6. Catch phase - the phase in rowing in which the rower's knees and hips are flexed and the sliding seat is forward (Mahler, Nelson & Hagerman, 1984).

7. Drive phase - the phase in rowing where the rower fully extends the knees and hips, flexes the forearm muscles and the body moves backward on the sliding seat (Mahler et al., 1984).

8. Finish phase - the phase in rowing in which the body and the sliding seat come to a temporary stop after the drive phase and before the recovery phase (Mahler et al., 1984).

9. Recovery phase - the phase in rowing which begins as the hands move away from the body, the back flexes and the rower's body moves forward on the sliding seat (Mahler et al., 1984).
10. Flexion - when any body segment is moved in an antero-posterior plane so that its anterior or posterior surface approaches the anterior or posterior surface, respectively, of an adjacent body segment (Rasch & Burke, 1978).

11. Extension - moving from a flexed position back toward and/or beyond the anatomical position (Rasch & Burke, 1978).

12. Power - work performed per unit of time (Lamb, 1984).

13. Watts - a unit of power equivalent to one joule per second or one newton-meter per second (Lamb, 1984).

14. Kilopond meters per minute (kpm/min) - the energy necessary to lift a one kilogram mass one meter in one minute against the normal gravitational force (Wilson, Fardy and Froelicher, 1981).

15. METS (Metabolic Equivalents) - an expression of energy cost relative to an individual's resting energy expenditure. One MET is equivalent to 3.5 milliliters of oxygen per kilogram of body weight (Lamb, 1984).
CHAPTER XI

REVIEW OF LITERATURE

The cardiovascular response to different modes of exercise is apt to vary, depending on the parameter or variable being measured. Rowing and bicycling are two forms of exercise that have likenesses, yet are very different. In general, they are alike in that the body weight is supported by a seat, so that weight bearing is not a factor in either. However, a major difference between the two is the addition of arm work in rowing as compared to traditional bicycling. A great deal of research has been conducted comparing rowing to traditional cycling, with differing conclusions. The addition of arm work on the Schwinn Air-Dyne bicycle ergometer seems to lend itself to a more adequate comparison with rowing. However, the literature is lacking in this area.

This review of literature will discuss heart rate, oxygen consumption, and principles of maximal testing. In addition, it will discuss rowing and bicycling individually as stationary exercises, as well as rowing vs. bicycling from a research standpoint.

Heart Rate, Oxygen Consumption and Maximal Testing

Maximal and submaximal heart rate are very useful in
determining cardiovascular intensity. Due to the lack of expensive equipment to measure VO₂ in some testing facilities, the attainment of a predicted maximal heart rate is often sufficient evidence that a subject has achieved a maximal level of exertion. Predicted maximal heart rate is determined by subtracting age from 220 (McArdle et al., 1981). A submaximal heart rate measurement is useful in determining the adequacy of intensity during exercise. Most researchers believe that benefits occur from exercise if certain submaximal heart rates can be achieved. These heart rates are highly individualized and depend on age, cardiovascular and ambulatory limitations, resting and maximal heart rates.

Maximal oxygen uptake is the highest amount of oxygen that a person can extract from expired air while performing dynamic exercise using a large part of the total muscle mass (Wilson et al., 1981). Maximal oxygen uptake has become widely accepted as the best index of functional capacity and maximal cardiovascular function. Some factors influencing VO₂ max are: cardiovascular fitness and training, genetic endowment, age and sex, ambient oxygen concentration, the blood’s ability to carry oxygen, and the methodology for measurement.

In the most common method utilized to test for maximal functional capacity, increments of work gradually increase until the point at which a subject reaches
exhaustion. In apparently healthy populations, the decision whether to continue or discontinue an exercise test is made by the subject, unless unexpected abnormalities become evident. In some cases though, this decision is influenced by psychological or motivational factors and may not reflect true physiological strain (McArdle et al., 1981). Untrained subjects are less apt to tolerate the discomforts associated with strenuous exercise. This phenomenon should be kept in mind when untrained subjects are used in research studies.

With differing activities, the amount of oxygen consumed or heart rate achieved at maximal exercise may vary. Max VO₂ during bicycling has averaged 6.4% to 11.2% below values on the treadmill. On walking treadmill protocols, max VO₂ values averaged about 7% above values on the bicycle, but 5% below the average for the running test on the treadmill (McArdle et al., 1981).

Harrison, Brown and Cochrane (1980) compared maximal oxygen uptakes among three differing exercise protocols in male subjects. Each subject was maximally tested at two different speeds on a motorized treadmill (10 km/hr and 12 km/hr) as well as on a bicycle ergometer. They found no significant difference between VO₂ max measured at the two treadmill speeds. However, the VO₂ max measured on the bicycle was 20% lower than on the treadmill. This difference in maximal VO₂ between modes of exercise
could be due to several reasons.

First, the specificity of exercise principle refers to certain adaptations which occur metabolically and physiologically when a specific group of muscles are overloaded on a regular basis. McArdle et al. (1981) discussed this in a citation of a longitudinal study completed by Magel et al. on endurance swim training. Fifteen men trained for one hour per day, three days per week for 10 weeks. Pre and post maximal exercise tests were performed both for swimming and treadmill running. An 11% improvement was noted in VO₂ max for swimming compared to null improvement in the running. In this case, training did not transfer from one mode of exercise to another. Second, local discomfort could limit some individuals during maximal exercise testing. Certain modalities of exercise place a great deal of stress on relatively few muscles, causing localized fatigue in that area. This has been known to occur in both trained and untrained individuals during maximal exercise testing on the traditional stationary bicycle. True maximal heart rate and oxygen uptake are unattainable due to localized leg fatigue. Also, protocols which utilize arm cranking modalities to test maximal VO₂ are limited due to local muscular fatigue. In fact, Sawka (1986) recommended the use of intermittent protocols for arm crank ergometry. The effects of localized fatigue in the arms are minimized.
and, thus, maximal performance may be improved.

**Effect of Muscle Mass on Maximal Heart Rate and Oxygen Uptake**

It has been argued that maximal oxygen consumption is a function of the mass of muscle engaged in the exercise (Glesser, Horstman & Mello, 1974). These authors cited studies which reported that maximal work with one leg elicited a considerably lower \( VO_2 \) than that obtained during running or cycling. Glesser et al. (1974) studied 10 male subjects who exercised maximally on a bicycle ergometer using legs alone, and then with legs and arm work combined. The arm work was provided using a Quinton bicycle ergometer which was positioned at chest level. Maximal oxygen uptake was 10% higher with combined arm and leg work than with legs only \( (p < .002) \). Therefore, the amount and location of muscular effort should be considered when measuring maximal oxygen consumption. Maximal heart rate, however, did not significantly differ between legs only and combined arm and leg work.

**The Mechanics of Rowing**

Two of the most popular stationary rowing ergometers are the Gjessing Ergorow and The Concept II rowing ergometer. The Gjessing Ergorow is mechanically-braked and operated by fixed resistance. The Concept II rowing ergometer is air-braked and controlled by air-resistance,
which is variable depending on the effort being exerted. The Concept II ergometer utilizes a chain and pulley system and a sliding seat.

When testing for functional capacity on the Concept II rowing ergometer, repeatability and differences between machines are of primary concern. In an article in Ergo Update (Dreissigacker, 1983), a publication solely about the Concept II, these concepts were discussed. Research conducted by Concept II, Inc. revealed small variances between tests on the same and different rowing ergometers. However, the surroundings of the machine are believed to have a significant effect on test results. For example, a neighboring machine or a wall in close proximity of the ergometer has been shown to decrease the wind resistance on the flywheel, therefore making the ergometer easier to row. Dreissigacker (1983) emphasized the importance of consistency in equipment, location and surrounding conditions for each maximal test.

Secher (1983) pointed out that rowing is different from most other types of exercise because: the body is supported by a seat, it incorporates both arm and leg involvement, and the two legs are working in the same phase. This can be contrasted with running or bicycling during which one leg is predominantly active at a time. In addition, the arms in rowing are also participating in the same phase.
Mahler et al. (1984) described the rowing stroke as having four distinct yet interrelated phases. The first is the catch phase. In actual rowing, this phase would correspond to the hands lifting and the oar being placed into the water. In both actual and simulated rowing, the rower's knees and hips are flexed and the sliding seat is forward.

The next component, the drive phase, is subdivided into three parts: the leg drive, the back swing into the bow, and the hands drawing in towards the body. In this phase, the movement of the upper and lower body should be coordinated in order to stabilize the back and pelvis. The rower's body is thrust towards the bow on the sliding seat.

In the finish phase, the body and the sliding seat come to a temporary stop. In actual rowing, the major emphasis in this phase is to remove the oar from the water as cleanly as possible in order not to diminish the propulsion of the shell.

Finally, in the recovery phase, the hands move away from the body and the back is flexed. The rower's body moves forward on the sliding seat towards the stern of the boat, and the oar moves through the air to prepare for the catch phase.
The Physiology of Rowing

During rowing, the muscles of the thigh represent the major source of power according to Mahler et al. (1984). Specifically, during the drive phase, the contraction of the quadriceps are critical. Conversely, the hamstring muscles are important for the recovery phase.

In addition, muscle characteristics predominantly determine metabolic performance in rowing. Mahler et al. (1984) pointed out that highly trained rowers, men and women, have an increased percentage of Type I or slow-twitch muscle fibers. In fact, in two studies which compared the muscle composition of the vastis lateralis muscle in elite oarsmen to the same muscle in the normal population, the elite oarsmen had 60-88% slow twitch fibers compared to 50% in the normal population. This characteristic allows rowers to obtain a very high aerobic capacity.

Secher (1983) pointed out that when oarsmen extended both legs simultaneously during the drive phase, they developed a strength similar to or exceeding the sum of the strength in each of the two legs. However, in untrained subjects, the strength of the summed legs was approximately 13-25% less than expected from the strength measured in each leg. Secher's conclusions suggested that untrained individuals may be unable to utilize the slow twitch muscle fiber as much during maximal two-leg
exercise as during maximal one-leg exercise. Since trained oarsmen become accustomed to simultaneous leg extension, they may learn to mobilize slow twitch fibers equally during two-leg extension as during one-leg extension.

It was noted by Cunningham, Goode and Critz (1975) that the extreme flexed position of the body during the catch phase in rowing appeared to constrict the abdominal muscles so that their ability to aid in expiration was limited. Mahler, Andrea and Ward (1987) found higher ventilation values on a cycle ergometer as opposed to a rowing ergometer to support this notion. However, the investigators recognized that this higher ventilation may have been due to the greater intensity of exercise performed on the bicycle as opposed to the rower.

Other studies (Bassett, Smith & Getchell, 1984; Di Prampero, Cortili, Celentano & Cerretelli, 1971) have compared several other modes of exercise to rowing and have found no differences in the ventilation values. Secher (1983) also agreed that ventilation is not inhibited during rowing. In fact, he illustrated that ventilation increased linearly with oxygen uptake to approximately 30% of the maximum oxygen uptake.

Oxygen uptake values at maximal exercise were compared between treadmill work and rowing on the Concept II rowing ergometer (Bassett et al., 1984). VO\textsubscript{2 max} was 10%
lower on the rowing ergometer as compared to the treadmill (p < .01). In addition, maximal heart rate on the rowing ergometer averaged five beats per minute less than on the treadmill (p < .05).

In the study by Bassett et al. (1984), the 10 male subjects were of average fitness. The authors believed that the muscle groups in the upper body had insufficient endurance to meet the demands of rowing. In fact, the limiting factor during rowing was arm fatigue for several subjects.

In the second part of the Bassett et al. (1984) study, subjects were tested on the Concept II rowing ergometer at the following five submaximal velocities: 10, 15, 20, 25 and 30 miles per hour. A curvilinear relationship between VO$_2$ and velocity was discovered.

In a study conducted by Di Prampero et al. (1971), heart rate, oxygen uptake, lactic acid production and mechanical work performed were investigated during simulated rowing in a basin and during actual rowing on a racing shell. Heart rate and oxygen uptake were linearly correlated during both simulated rowing and actual rowing.

In addition, a linear relationship and high correlation were found between the actual work done and maximal oxygen uptake on the mechanically braked Gjessing Ergorow (Steinacker, Marx, Marx & Lormes, 1986). Heart rate also
increased as power increased. This study was conducted on 61 outstanding oarsmen.

The Mechanics of Bicycling

Stationary bicycling has been a very popular form of exercise for many years, in the cardiac rehabilitation setting, in the health club environment, and in the home. Two very popular models of stationary bicycles are the Monark ergometer and the Schwinn Air-Dyne ergometer. The Monark's wheel is braked mechanically by a belt around the rim. The Schwinn Air-Dyne ergometer is air-braked and the resistance is variable, depending on the amount of energy applied by the user. In addition, the Air-Dyne incorporates both arm and leg involvement, in an alternating fashion.

The contribution of the major muscle groups towards the total work done during traditional bicycling was analyzed by Ericson, Bratt, Nisell, Arborelius and Ekholm (1986). They concluded that the hip extensors contributed 27% of the total work done, while the hip flexors contributed 4%. The knee extensors and knee flexors contributed 39% and 10%, respectively, while the ankle plantar flexors contributed 20%. The distribution of work among major muscle groups during cycling on the Schwinn Air-Dyne is likely to differ extensively from the above example due to the addition of arm involvement.

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Traditionally, exercise tests performed on a bicycle ergometer have been characterized by a fixed resistance rather than an accommodating resistance. Often, localized fatigue limited these types of tests, and true maximal values were unattainable. The use of the Schwinn Air-Dyne lessens the likelihood of localized fatigue limiting performance, since alternating arm work can be included in the total work output.

For example, Hagan, Gettman, Upton, Duncan and Cummings (1983) conducted a study on the cardiorespiratory responses to progressive, incremental treadmill work, arm work alone, leg work alone, and combined arm and leg bicycling on the Schwinn Air-Dyne ergometer. Fifteen men and 15 women participated. In both the men and the women, maximal exercise values for heart rate, oxygen uptake and energy expenditure were progressively greater for combined arm and leg work compared to leg work, and for leg work compared to arm work. The maximal physiological values for combined arm and leg work were similar to the values on the treadmill test. This study justified the use of the Schwinn Air-Dyne in maximal exercise testing situations.

In order to determine the relative contribution of the arms and legs in eliciting the maximal oxygen uptake and heart rate, ten healthy males without experience in
upper or lower body exercise performed progressive exercise to exhaustion on the Schwinn Air-Dyne (Nagle, Richie & Giese, 1984). The exercise was done using arms only, legs only, and combinations of 10% arms/90% legs, 20% arms/80% legs, and 30% arms/70% legs. The results revealed that the maximal oxygen uptakes for the 10% arms/90% legs protocol and the 20% arms/80% legs protocol were not significantly different. However, eight of the subjects attained their highest \( VO_2 \) while performing the 10% arms/90% legs protocol and the other two subjects attained their highest \( VO_2 \) with the 20% arms/80% legs regimen. In addition, the highest power output (Watts) was from the 10% arms/90% legs protocol.

In addition, there was no difference between the maximal heart rate attained for the 100% legs, 10% arms/90% legs, and the 20% arms/80% legs protocols \((p > .05)\). However the maximal heart rate for the 10% arms/90% legs regimen was significantly greater than either the 100% arms or the 30% arms/70% legs protocols.

This study confirmed the findings of Gleser et al. (1974), which showed that the additional active muscle mass from arm cranking significantly increased \( VO_2 \) max. In the Nagle et al. (1984) study, \( VO_2 \) was significantly increased when 10 to 20% of the total power contribution was attributed to the push-pull activity on the Air-Dyne.
Rowing vs. Bicycling

There have been conflicting results regarding whether rowing or bicycling (generally traditional) elicits a higher maximal oxygen uptake. Cunningham et al. (1975) noted higher VO$_2$ max values on the bicycle ergometer (Monark) as compared to a fixed resistance rowing ergometer in eight oarsmen and five physical education students. This difference, however, was not statistically significant. They also reported consistently higher $V_E/VO_2$ ratios on the Monark than on the rowing ergometer at maximal exercise for all subjects. The authors attributed these results to a higher ventilation achieved on the bicycle, and concluded that rowing seriously impaired the breathing process. Maximal heart rate was similar on both modes of exercise.

Seventeen untrained female subjects and 12 collegiate women rowers participated in progressive, incremental exercise to exhaustion on the variable resistance Concept II rowing ergometer and on the traditional Monark ergometer (Mahler et al., 1987). Maximal heart rate was the same between the two types of exercise for both groups. Maximal oxygen consumption was significantly greater on the bicycle ergometer compared to the Concept II rowing ergometer, but only in the group of collegiate rowers. There was no difference in VO$_2$ max between the Monark and Concept II among the untrained subjects. The
results of this study seemed to contradict the principle of specificity.

In another comparison between the Concept II and Monark bicycle (Rosiello, Mahler & Ward, 1987), values for maximal and submaximal oxygen uptakes were examined. Progressive, incremental exercise tests were performed on eight male subjects on both devices. Maximal VO\(_2\) and heart rate were identical on the cycle and rowing ergometers. There were no significant difference in VO\(_2\) at three submaximal intensities of exercise between cycling and rowing.

As stated before, Mahler et al. (1987) found exercise ventilation to be consistently higher on the cycle ergometer in both the collegiate rowers and untrained subjects. This was probably due to the higher peak power output achieved while cycling, as opposed to any limitations caused by the rowing stroke.

Another experiment compared bicycling to rowing on the friction-braked Gjessing rowing ergometer (Steinacker et al., 1986). Ten well-trained oarsmen and six cyclists not experienced in rowing participated. One maximal exercise test with equal power output increments was performed on each ergometer in random order. The values for VO\(_2\) and heart rate were determined for each stage. In both the bicycling and the rowing group, VO\(_2\) at submaximal workloads was significantly higher on the rowing
ergometer than on the bicycle ergometer. Further, the VO\textsubscript{2} max on the rowing ergometer was 2.6% higher than on the bicycle ergometer in the group of oarsmen, but the difference was not significant.

These findings at maximal exercise contradicted the results of Mahler et al. (1987), who found VO\textsubscript{2} max to be significantly greater on the Monark bicycle ergometer than on the Concept II rowing ergometer in a group of collegiate rowers. Perhaps the specificity of exercise principle would account for the results obtained by Steinacker et al. (1986).

Bouckaert, Pannier and Vrijens (1983) compared maximal and submaximal parameters on an electromagnetically braked bicycle ergometer and on the Gjessing mechanically braked rowing ergometer. Nine well-trained oarsmen and nine physical education students participated. This study supported the notion that pulmonary ventilation is unaffected by the mechanics of the rowing stroke (Bassett et al., 1984; Secher, 1983). The authors found that submaximal pulmonary ventilation was slightly higher on the rowing ergometer than on the bicycle ergometer in both groups, although the difference was not significant. The differences in maximal ventilation were also not significant between rowing and bicycling. No evidence was found to indicate an impairment of pulmonary ventilation during maximal work on the rowing ergometer.
In addition, submaximal oxygen consumption at any given workload was higher during rowing than during bicycling for both the experienced rowers and control group (Bouckaert et al., 1983). The control subjects had considerably lower maximal oxygen uptakes on the rowing ergometer than on the bicycle ergometer \( (p < .01) \), while the oarsmen reached an almost identical VO\(_2\) max on both ergometers.

Several authors have investigated, in addition to VO\(_2\), submaximal and maximal heart rate when comparing bicycling to rowing. Steinacker et al. (1986) found mean maximal and submaximal heart rates to be higher in rowing (Gjessing Ergorow) than cycling. Although not significant, this was found in a group of ten oarsmen as well as six cyclists. Mahler et al. (1987), however, found no differences in maximal heart rates between rowing (Concept II) and cycling (Monark) in a group of 17 untrained subjects and another group of 12 collegiate rowers. Submaximal heart rate values were unavailable in this study.

Rosiello et al. (1987) found maximal heart rate to be similar between rowing (Concept II) and cycling (Monark), and found submaximal heart rates to be progressively higher during rowing than during cycling as the workloads increased. By measuring heart rate at three different submaximal levels of steady state exercise on the cycle and rowing ergometers, these investigators only
reached statistical significance at the higher submaximal workload.
CHAPTER III

DESIGN AND METHODOLOGY

The purpose of this study was to determine whether the Schwinn Air-Dyne bicycle ergometer or the Concept II rowing ergometer elicited higher maximal and submaximal heart rate and oxygen uptake values.

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

Subject Selection

The subjects in this study were between the ages of 23 and 35 years, and were exercising at the time of the study at least three times per week for a minimum of 30 minutes. Their exercise was aerobic, rhythmical and continuous in nature. However, none were specifically trained on the Concept II rower or the Schwinn Air-Dyne bicycle ergometer. Subjects were employees of the Institute for Cardiovascular Health at Borgess Medical Center in Kalamazoo, Michigan. In addition, subjects consisted of various male and female volunteers from the greater Kalamazoo area who fit the selection criteria.

A thorough health and exercise history form (Appendix A) was administered to all interested subjects until
ten male and ten female subjects were cleared to participate. From this form, activity level was verified, and a cardiovascular health history was made available. Those individuals with any cardiovascular abnormalities were eliminated from the study. Such abnormalities included a history of unusual shortness of breath due to pulmonary difficulties, a history of syncope or extreme lightheadedness with exercise, any known myocardial infarction or past positive stress test, and hypertension which was medically treated. Any other non-limiting abnormalities such as heart murmur were documented; however, subjects possessing such were allowed to participate in the study.

Data Collection Procedures

Subjects

The testing took place at the Institute for Cardiovascular Health, Borgess Medical Center, Kalamazoo, Michigan. Each subject performed a maximal graded exercise test on both the Air-Dyne and Concept II ergometers, no more than one week apart. The testing order was randomized. Before each test began, a consent form explaining the nature of the study and the possible risks involved was signed by each participant. The consent form appears in Appendix B.

The subjects wore loose, comfortable clothing for each maximal exercise test, including shorts, shirts and
exercise shoes. Body weight in kilograms, resting blood pressure and heart rate were among the baseline data collected before each test.

A three channel EKG monitoring system (Hewlett Packard) was used so that heart rate and rhythm could be documented at rest and throughout exercise. Three Dyna-trace silver/silver chloride electrodes were placed on the chests of the participants. One was placed just below the mid-clavicular line of the right clavicle, another below the mid-clavicular line of the left clavicle. The other electrode was located between the 6th and 7th intercostal space on the left mid-clavicular line. The American College of Sports Medicine Guidelines for Exercise Testing and Prescription (1986) were used to monitor heart rate and blood pressure response during each test.

After baseline data were taken, the subjects were instructed to perform a series of warm-up exercises to prepare the muscles for intense activity. Every subject warmed-up in a similar fashion. During the warm-up activity, the investigator provided a verbal explanation of the forthcoming procedure and answered questions from each participant.

**Concept II Rowing Ergometer Test**

The exercise protocol on the Concept II rower began
at 25 Watts, and increased by increments of 25 Watts every two minutes until exhaustion. Watts were read from the total workout display on the Concept II performance monitor. This display showed the average power production for the time the subject was rowing. At the end of each two minute stage, the investigator pushed the reset button. This allowed for all past power outputs to be cleared from the performance monitor so that only the present stage was averaged. After maximal efforts were achieved, the subjects continued to row at a very low intensity for four minutes to aid in the recovery period. Then the subjects sat in a chair for the remainder of the 10 minute recovery period. Heart rate and blood pressure were taken and recorded (Appendix C) at the end of every stage, at maximal exercise, immediate post exercise and every two minutes throughout recovery.

Schwinn Air-Dyne Bicycle Ergometer Test

The exercise protocol on the Schwinn Air-Dyne bicycle ergometer began with a 150 kp/min workload and was increased by 150 kp/min every two minutes until exhaustion. Subjects were required to use the arm handles throughout the exercise test. The workload was read from the computer console of the Air-Dyne. The subjects were asked to maintain the digital workload level at the specific workload requested by the investigator. After
maximal values were achieved, the subjects pedalled at a very low intensity for four minutes to aid in recovery. Thereafter, they sat in a chair for the remainder of the 10 minute recovery period. Heart rate and blood pressure were taken and recorded (Appendix C) at the end of every two minute stage, at maximal exercise, immediate post exercise, and every two minutes throughout recovery.

**Oxygen Uptake**

Oxygen uptake was analyzed beginning at the start of every test, and ended when the subject either reached volitional exhaustion, or when the subject was unable to maintain the appropriate workload. Oxygen was analysed every 30 seconds throughout the test.

**Instrumentation**

**EKG Telemetry Monitor**

A Hewlett-Packard EKG Monitoring System, model number 43110A, was used in this study. This instrument was recently purchased by Borgess Medical Center and has been maintained adequately.

**Sphygmomanometer**

A Pymah sphygmomanometer (Sommerville, New Jersey) was used to monitor blood pressure throughout this study.
Stethoscope

A Littman Dual-Headed Stethoscope was used to monitor blood pressure throughout this study.

Concept II Rowing Ergometer

A Concept II Rowing Ergometer, manufacturer date August 21, 1987, was used in this study. The workloads were based on the Electronic Performance Monitor. This monitor measures the flywheel speed and acceleration, and, with the moment of inertia of the flywheel, calculates the power applied to the wheel. Watts were measured as the specific form of work output. Foot straps were used to anchor both feet against the heel rest and foot block. The smaller of the two sprockets was utilized throughout this study.

Schwinn Air-Dyne Bicycle Ergometer

A Schwinn Air-Dyne Bicycle Ergometer, model number ex 800518, was used in this study. The seat height was adjusted for each subject so that the leg was almost straight on the pedal downstroke. This bicycle utilizes the resistance of the air to the wind vanes on the wheel to provide a wide range of workloads. The faster the wheel is turned by the pedals and arm levers, the greater the volume of air moved and the amount of work required to move it. The workloads, which were measured by the
work load indicator, were converted to kilopond meters per minute and then into Watts.

**Oxygen Analysis Equipment**

A Beckman Metabolic Measurement Cart, model number MMC 554336, was used to measure submaximal and maximal oxygen uptakes throughout each bicycle and rowing test. The metabolic cart was calibrated between tests according to manufacturer specifications. A Daniels Valve (R-Pel Company, Los Altos, California) was used for the mouthpiece, and nose plugs were used to prevent air from escaping through the nose.

To determine the validity over a wide range of metabolic levels (approximately two to 16 METS), the Beckman Metabolic Cart was simultaneously compared against a popular computerized system and a semiautomated system (Wilmore, Davis & Norton, 1976). Comparisons across the three systems demonstrated agreement, especially at higher MET levels. Some statistically significant differences were noted between the Beckman Metabolic Measurement Cart and the computerized system at the two lowest metabolic loads. This was believed to be the result of a calibration problem with the computerized system.
Statistical Analysis

Two split-plot factorial designs were used to interpret the maximal data collected during this study. The independent variables included: (a) gender with two levels, male and female; and (b) mode of exercise with two levels, the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer. The dependent variables included: (a) maximal heart rate, and (b) maximal oxygen consumption.

Two split plot factorial designs were also used to interpret the submaximal data collected during this study. The independent variables included: (a) gender with two levels, male and female; (b) mode of exercise with two levels, the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer; and (c) the percent of maximal heart rate or oxygen consumption with three levels, 50%, 70% and 85%. The dependent variables included: (a) power at three submaximal levels of maximal heart rate, and (b) power at three submaximal levels of maximal oxygen consumption. Simple Main Effects tests were used to interpret significant first and second order interaction effects.
CHAPTER IV

RESULTS AND DISCUSSION

This chapter includes the results and discussion of the differences found in the maximal heart rate and oxygen consumption among 20 subjects (10 male, 10 female) between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer. Also included in this chapter are results and discussion of the power output at three percentages (50%, 70% and 85%) of maximal heart rate and maximal oxygen consumption.

The purpose of this study was to determine maximal differences in heart rate and oxygen consumption and submaximal differences in power between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer.

Raw maximal and submaximal data were analyzed at Western Michigan University, using the computer program BMDP-2V. Two Analyses of Variance (ANOVA), Split Plot Factorial Designs, were used to determine the effects of the independent variables on the dependent variables for both maximal and submaximal data. Simple Simple Main Effects were used to interpret significant first and second order interaction effects.

Within the maximal data, the independent variables were: (a) gender with two levels, male and female; and
(b) mode of exercise with two levels, the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer. The dependent variables were: (a) maximal heart rate, and (b) maximal oxygen consumption. Within the submaximal data, the independent variables included: (a) gender with two levels, male and female; (b) mode of exercise with two levels, the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer; and (c) percent of maximal heart rate or oxygen consumption with three levels, 50%, 70% and 85%. The dependent variables were: (a) power at three submaximal levels of maximum heart rate, and (b) power at three submaximal levels of maximum oxygen consumption. This chapter is presented in two sections: (a) results, and (b) discussion.

Results

Maximal Heart Rate

Descriptive data for maximal heart rate, the dependent variable, were divided into cells by the independent variables, gender and mode of exercise. Cell means, standard deviations and marginal means were provided. These descriptive data are presented in Appendix D. An ANOVA was calculated using gender and mode of exercise as independent variables. The ANOVA (See Table 1) indicated the following:

1. There was no difference in maximal heart rate, F
2. There was a significant difference in maximal heart rate, $F = 6.34$, between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer ($F(1, 18) = 4.41, p < .05$).

3. There was no significant interaction, $F = 1.20$, between gender and mode of exercise regarding maximal heart rate ($F(1, 18) = 4.41, p < .05$).

Table 1
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>A (Gender)</td>
<td>0.02500</td>
<td>1</td>
<td>0.02500</td>
<td>0.00</td>
</tr>
<tr>
<td>Error</td>
<td>3016.45000</td>
<td>18</td>
<td>167.58056</td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B (Mode)</td>
<td>180.62500</td>
<td>1</td>
<td>180.62500</td>
<td>6.34*</td>
</tr>
<tr>
<td>A X B</td>
<td>34.22500</td>
<td>1</td>
<td>34.22500</td>
<td>1.20</td>
</tr>
<tr>
<td>Error</td>
<td>512.65000</td>
<td>18</td>
<td>28.48056</td>
<td></td>
</tr>
</tbody>
</table>

*$F(1, 18) = 4.41, p < .05$

Maximal Oxygen Consumption

Descriptive data for maximal oxygen consumption, the dependent variable, were divided into cells by the independent variables, gender and mode of exercise. Cell
means, standard deviations and marginal means were provided. These descriptive data are presented in Appendix E. An ANOVA was calculated using gender and mode of exercise as the independent variables. The ANOVA (see Table 2) indicated the following:

1. There was no significant difference in maximal oxygen consumption, $F = 2.30$, among gender ($F(1, 18) = 4.41, p < .05$).

2. There was a significant difference in maximal oxygen consumption, $F = 24.00$, between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer ($F(1, 18) = 4.41, p < .05$).

3. There was a significant interaction effect, $F = 5.23$, between gender and mode of exercise regarding maximal oxygen consumption ($F(1, 18) = 4.41, p < .05$).

Table 2
ANOVA Summary Table for Maximal Oxygen Consumption

<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>A (Gender)</td>
<td>317.53223</td>
<td>1</td>
<td>317.53223</td>
<td>2.30</td>
</tr>
<tr>
<td>Error</td>
<td>2480.36631</td>
<td>18</td>
<td>137.79813</td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B (Mode)</td>
<td>95.79024</td>
<td>1</td>
<td>95.79024</td>
<td>24.00*</td>
</tr>
<tr>
<td>A X B</td>
<td>20.88025</td>
<td>1</td>
<td>20.88025</td>
<td>5.23*</td>
</tr>
</tbody>
</table>
Table 2—Continued

<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>Error</td>
<td>71.84450</td>
<td>18</td>
<td>3.99136</td>
<td></td>
</tr>
</tbody>
</table>

*F(1, 18) = 4.41, p < .05

Power Expressed as Percent of Maximal Heart Rate

Descriptive data for power, the dependent variable, were divided into cells by the independent variables, percent of maximal heart rate, mode of exercise and gender. Cell means, standard deviations and marginal means were provided. These descriptive data are presented in Appendix F. An ANOVA was calculated using gender, mode of exercise and percent of maximal heart rate as independent variables. The ANOVA (see Table 3) indicated the following:

1. There was a significant difference in power, \( F = 39.62 \), between genders (*F*(1, 18) = 4.41, \( p < .05 \)).

2. There was a significant difference in power, \( F = 70.47 \), between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer (*F*(1, 18) = 4.41, \( p < .05 \)).

3. There was a significant interaction effect of power, \( F = 8.71 \), between gender and mode of exercise (*F*(1, 18) = 4.41, \( p < .05 \)).
4. There was a significant difference in power, $F = 538.19$, between the three percentages of maximum heart rate ($F(2, 36) = 3.32, p < .05$).

5. There was a significant interaction effect of power, $F = 29.02$, between gender and percent maximal heart rate ($F(2, 36) = 3.32, p < .05$).

6. There was a significant interaction effect of power, $F = 43.93$, between mode of exercise and percent maximal heart rate ($F(2, 36) = 3.32, p < .05$).

7. There was no significant interaction effect of power, $F = 0.16$, noted between gender, mode of exercise and percent of maximal heart rate ($F(2, 36) = 3.32, p < .05$).

Table 3

ANOVA Summary Table for Power Expressed as Percent of 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><strong>Between Subjects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Gender)</td>
<td>105448.82</td>
<td>1</td>
<td>105448.82</td>
<td>39.62*</td>
</tr>
<tr>
<td>Subj. w/in grps.</td>
<td>47903.19</td>
<td>18</td>
<td>2661.29</td>
<td></td>
</tr>
<tr>
<td><strong>Within Subjects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B (mode)</td>
<td>53333.31</td>
<td>1</td>
<td>53333.31</td>
<td>70.47*</td>
</tr>
<tr>
<td>A X B</td>
<td>6588.84</td>
<td>1</td>
<td>6588.84</td>
<td>8.71*</td>
</tr>
<tr>
<td>B X Subj. w/in grps.</td>
<td>13622.38</td>
<td>18</td>
<td>756.80</td>
<td></td>
</tr>
<tr>
<td>C (Percent Max H.R.)</td>
<td>246723.23</td>
<td>2</td>
<td>132361.62</td>
<td>538.19**</td>
</tr>
</tbody>
</table>
Table 3—Continued

<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>C X A</td>
<td>14275.21</td>
<td>2</td>
<td>7137.61</td>
<td>29.02**</td>
</tr>
<tr>
<td>C X Subj. w/in grps.</td>
<td>8853.83</td>
<td>36</td>
<td>245.94</td>
<td></td>
</tr>
<tr>
<td>B X C</td>
<td>5748.17</td>
<td>2</td>
<td>2874.09</td>
<td>43.93**</td>
</tr>
<tr>
<td>B X C X A</td>
<td>20.53</td>
<td>2</td>
<td>10.27</td>
<td>.16</td>
</tr>
<tr>
<td>B X C X Subj. w/in grps.</td>
<td>2355.06</td>
<td>36</td>
<td>65.42</td>
<td></td>
</tr>
</tbody>
</table>

*F(1, 18) = 4.41, p < .05
**F(2, 36) = 3.32, p < .05

For comparison of the power means for both groups associated with mode of exercise and percent of maximal heart rate, a Simple Simple Main Effects test was performed. This test determined significant differences between gender, the two modes of exercise and the three percentages of maximal heart rate. The Simple Simple Main Effects Test (see Table 4) indicated that:

1. There was no significant difference in power, F = .47, between men and women on the Concept II rowing ergometer at 50% of maximal heart rate (F(1, 18) = 4.41, p < .05).

2. There was a significant difference in power, F = 4.58, between men and women on the Concept II rowing ergometer at 70% of maximal heart rate (F(1, 18) = 4.41, p < .05).
3. There was a significant difference in power, $F = 8.73$, between men and women on the Concept II rowing ergometer at 85% of maximal heart rate ($F(1, 18) = 4.41$, $p < .05$).

4. There was no significant difference in power, $F = 3.95$, between men and women on the Schwinn Air-Dyne bicycle ergometer at 50% of maximal heart rate ($F(1, 18) = 4.41$, $p < .05$).

5. There was a significant difference in power, $F = 11.10$, between men and women on the Schwinn Air-Dyne bicycle ergometer at 70% of maximal heart rate ($F(1, 18) = 4.41$, $p < .05$).

6. There was a significant difference in power, $F = 18.65$, between men and women on the Schwinn Air-Dyne bicycle ergometer at 85% of maximal heart rate ($F(1, 18) = 4.41$, $p < .05$).

7. There was a significant difference in power, $F = 24.51$, between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer among men at 50% of maximal heart rate ($F(1, 18) = 4.41$, $p < .05$).

8. There was a significant difference in power, $F = 64.10$, between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer among men at 70% of maximal heart rate ($F(1, 18) = 4.41$, $p < .05$).

9. There was a significant difference in power, $F = 85.86$, between the Concept II rowing ergometer and the
Schwinn Air-Dyne bicycle ergometer among men at 85% of maximal heart rate ($F(1, 18) = 4.41, p < .05$).

10. There was no significant difference in power, $F = 1.11$, between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer among women at 50% of maximal heart rate ($F(1, 18) = 4.41, p < .05$).

11. There was a significant difference in power, $F = 19.67$, between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer among women at 70% of maximal heart rate ($F(1, 18) = 4.41, p < .05$).

12. There was a significant difference in power, $F = 26.77$, between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer among women at 85% of maximal heart rate ($F(1, 18) = 4.41, p < .05$).

13. There was a significant difference in power, $F = 131.72$, between the three percentages of maximal heart rate among men on the Concept II rowing ergometer ($F(2, 36) = 3.32, p < .05$).

14. There was a significant difference in power, $F = 212.79$, between the three percentages of maximal heart rate among men on the Schwinn Air-Dyne bicycle ergometer ($F(2, 36) = 3.32, p < .05$).

15. There was a significant difference in power, $F = 43.99$, between the three percentages of maximal heart rate among women on the Concept II rowing ergometer ($F(2, 36) = 3.32, p < .05$).
16. There was a significant difference in power, $F = 92.72$, between the three percentages of maximal heart rate among women on the Schwinn Air-Dyne bicycle ergometer ($F(2, 36) = 3.32, p < .05$).

Table 4

ANOVA Summary Table of Simple Simple Main Effects Tests for Power Expressed as a Percentage of 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>A (Gender)</td>
<td>105448.82</td>
<td>1</td>
<td>105448.82</td>
<td>39.62*</td>
</tr>
<tr>
<td>A (Concept II / 50%)</td>
<td>1260.24</td>
<td>1</td>
<td>1260.24</td>
<td>.47</td>
</tr>
<tr>
<td>A (Concept II / 70%)</td>
<td>12192.42</td>
<td>1</td>
<td>12192.42</td>
<td>4.58*</td>
</tr>
<tr>
<td>A (Concept II / 85%)</td>
<td>23218.71</td>
<td>1</td>
<td>23218.71</td>
<td>8.73*</td>
</tr>
<tr>
<td>A (Air-Dyne / 50%)</td>
<td>10511.57</td>
<td>1</td>
<td>10511.57</td>
<td>3.95</td>
</tr>
<tr>
<td>A (Air-Dyne / 70%)</td>
<td>29527.31</td>
<td>1</td>
<td>29527.31</td>
<td>11.10*</td>
</tr>
<tr>
<td>A (Air-Dyne / 85%)</td>
<td>49622.71</td>
<td>1</td>
<td>49622.71</td>
<td>18.65*</td>
</tr>
<tr>
<td>Error</td>
<td>47903.22</td>
<td>18</td>
<td>2661.29</td>
<td></td>
</tr>
<tr>
<td>B (Mode)</td>
<td>53333.31</td>
<td>1</td>
<td>53333.31</td>
<td>70.47*</td>
</tr>
<tr>
<td>B (Male / 50%)</td>
<td>7252.34</td>
<td>1</td>
<td>7252.34</td>
<td>24.51*</td>
</tr>
<tr>
<td>B (Male / 70%)</td>
<td>18964.79</td>
<td>1</td>
<td>18964.79</td>
<td>64.10*</td>
</tr>
<tr>
<td>B (Male / 85%)</td>
<td>25402.77</td>
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<td>25402.77</td>
<td>85.86*</td>
</tr>
<tr>
<td>B (Female / 50%)</td>
<td>328.86</td>
<td>1</td>
<td>328.86</td>
<td>1.11</td>
</tr>
<tr>
<td>B (Female / 70%)</td>
<td>5821.21</td>
<td>1</td>
<td>5821.21</td>
<td>19.67*</td>
</tr>
<tr>
<td>B (Female / 85%)</td>
<td>7920.60</td>
<td>1</td>
<td>7920.60</td>
<td>26.77*</td>
</tr>
<tr>
<td>Error</td>
<td>5325.84</td>
<td>18</td>
<td>295.88</td>
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Table 4—Continued

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<td>C (Percent)</td>
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<td>2</td>
<td>132361.62</td>
<td>538.19**</td>
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<tr>
<td>C (Male / Concept II)</td>
<td>77946.37</td>
<td>2</td>
<td>77946.37</td>
<td>131.72**</td>
</tr>
<tr>
<td>C (Male / Air-Dyne)</td>
<td>125921.62</td>
<td>2</td>
<td>62960.81</td>
<td>212.79**</td>
</tr>
<tr>
<td>C (Female / Concept II)</td>
<td>26033.60</td>
<td>2</td>
<td>13016.80</td>
<td>43.99**</td>
</tr>
<tr>
<td>C (Female / Air-Dyne)</td>
<td>54866.37</td>
<td>2</td>
<td>27433.19</td>
<td>92.72**</td>
</tr>
<tr>
<td>Error</td>
<td>5604.48</td>
<td>36</td>
<td>155.68</td>
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</tr>
</tbody>
</table>

*F*(1, 18) = 4.41, *p* < .05

**F*(2, 36) = 3.32, *p* < .05

Power Expressed as Percent of Maximal Oxygen Consumption

Descriptive data for power, the dependent variable, were divided into cells by the independent variables, percent of maximal oxygen consumption, mode of exercise and gender. Cell means, standard deviations and marginal means were provided. These descriptive data are presented in Appendix G. An ANOVA was calculated using gender, mode of exercise and percent maximal oxygen consumption as the independent variables. The ANOVA (see Table 5) indicated the following:

1. There was a significant difference in power, *F* = 45.27, between genders (*F*(1, 18) = 4.41, *p* < .05).
2. There was a significant difference in power, *F* =
173.39, between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer ($F(1, 18) = 4.41, p < .05$).

3. There was a significant interaction effect of power, $F = 12.09$, between gender and mode of exercise ($F(1, 18) = 4.41, p < .05$).

4. There was a significant difference in power, $F = 1016.39$, between the three percentages of maximum oxygen consumption levels ($F(2, 36) = 3.32, p < .05$).

5. There was a significant interaction effect of power, $F = 51.16$, between gender and percent maximal oxygen consumption ($F(2, 36) = 3.32, p < .05$).

6. There was a significant interaction effect of power, $F = 113.60$, between mode of exercise and percent maximal oxygen consumption ($F(2, 36) = 3.32, p < .05$).

7. There was a significant interaction effect of power, $F = 10.91$, between gender, mode of exercise and percent maximal oxygen consumption ($F(2, 36) = 3.32, p < .05$).
Table 5
ANOVA Summary Table for Power Expressed as Percent of Maximal Oxygen Consumption

<table>
<thead>
<tr>
<th>Source</th>
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</tr>
</thead>
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<tr>
<td><strong>Between Subjects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Gender)</td>
<td>142354.95</td>
<td>1</td>
<td>142354.95</td>
<td>45.27*</td>
</tr>
<tr>
<td>Subj. w/in grps.</td>
<td>56607.56</td>
<td>18</td>
<td>3144.86</td>
<td></td>
</tr>
<tr>
<td><strong>Within Subjects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B (mode)</td>
<td>116172.87</td>
<td>1</td>
<td>116172.87</td>
<td>173.39*</td>
</tr>
<tr>
<td>A X B</td>
<td>8103.04</td>
<td>1</td>
<td>8103.04</td>
<td>12.09*</td>
</tr>
<tr>
<td>B X Subj. w/in grps.</td>
<td>12060.37</td>
<td>18</td>
<td>670.02</td>
<td></td>
</tr>
<tr>
<td>C (Percent Max VO₂)</td>
<td>162093.94</td>
<td>2</td>
<td>81046.97</td>
<td>1016.39**</td>
</tr>
<tr>
<td>C X A</td>
<td>8158.68</td>
<td>2</td>
<td>4079.34</td>
<td>51.16**</td>
</tr>
<tr>
<td>C X Subj. w/in grps.</td>
<td>2870.63</td>
<td>36</td>
<td>79.74</td>
<td></td>
</tr>
<tr>
<td>B X C</td>
<td>6338.92</td>
<td>2</td>
<td>3169.46</td>
<td>113.60**</td>
</tr>
<tr>
<td>B X C X A</td>
<td>608.93</td>
<td>2</td>
<td>304.46</td>
<td>10.91**</td>
</tr>
<tr>
<td>B X C X Subj. w/in grps.</td>
<td>1004.41</td>
<td>36</td>
<td>27.90</td>
<td></td>
</tr>
</tbody>
</table>

* F(1, 18) = 4.41, p < .05
** F(2, 36) = 3.32, p < .05

For multiple comparisons of the power means for both groups associated with mode of exercise and percent of maximal oxygen consumption, a Simple Simple Main Effects test was performed. This test determined significant differences between gender, the modes of exercise
and the three percentages of maximal oxygen consumption. This Simple Main Effects test (see Table 6) indicated that:

1. There was no significant difference in power, $F = 2.31$, between men and women on the Concept II rowing ergometer at 50% of maximal oxygen consumption ($F(1, 18) = 4.41, p < .05$).

2. There was no significant difference in power, $F = 4.23$, between men and women on the Concept II rowing ergometer at 70% of maximal oxygen consumption ($F(1, 18) = 4.41, p < .05$).

3. There was a significant difference in power, $F = 7.28$, between men and women on the Concept II rowing ergometer at 85% of maximal oxygen consumption ($F(1, 18) = 4.41, p < .05$).

4. There was a significant difference in power, $F = 5.50$, between men and women on the Schwinn Air-Dyne bicycle ergometer at 50% of maximal oxygen consumption ($F(1, 18) = 4.41, p < .05$).

5. There was a significant difference in power, $F = 12.08$, between men and women on the Schwinn Air-Dyne bicycle ergometer at 70% of maximal oxygen consumption ($F(1, 18) = 4.41, p < .05$).

6. There was a significant difference in power, $F = 19.23$, between men and women on the Schwinn Air-Dyne bicycle ergometer at 85% of maximal oxygen consumption.
(\(F(1, 18) = 4.41, p < .05\)).

7. There was a significant difference in power, \(F = 57.71\), between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer among men at 50% of maximal oxygen consumption (\(F(1, 18) = 4.41, p < .05\)).

8. There was a significant difference in power, \(F = 149.15\), between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer among men at 70% of maximal oxygen consumption (\(F(1, 18) = 4.41, p < .05\)).

9. There was a significant difference in power, \(F = 199.27\), between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer among men at 85% of maximal oxygen consumption (\(F(1, 18) = 4.41, p < .05\)).

10. There was a significant difference in power, \(F = 21.32\), between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer among women at 50% of maximal oxygen consumption (\(F(1, 18) = 4.41, p < .05\)).

11. There was a significant difference in power, \(F = 50.35\), between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer among women at 70% of maximal oxygen consumption (\(F(1, 18) = 4.41, p < .05\)).

12. There was a significant difference in power, \(F = 64.59\), between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer among women at 85% of maximal oxygen consumption (\(F(1, 18) = 4.41, p < .05\)).

13. There was a significant difference in power, \(F = \)
176.90, between the three percentages of maximal oxygen consumption among men on the Concept II rowing ergometer \( (F(2, 36) = 3.32, p < .05) \).

14. There was a significant difference in power, \( F = 412.40 \), between the three percentages of maximal oxygen consumption among men on the Schwinn Air-Dyne bicycle ergometer \( (F(2, 36) = 3.32, p < .05) \).

15. There was a significant difference in power, \( F = 77.50 \), between the three percentages of maximal oxygen consumption among women on the Concept II rowing ergometer \( (F(2, 36) = 3.32, p < .05) \).

16. There was a significant difference in power, \( F = 156.33 \), between the three percentages of maximal oxygen consumption among women on the Schwinn Air-Dyne bicycle ergometer \( (F(2, 36) = 3.32, p < .05) \).

### Table 6

ANOVA Summary Table of Simple Main Effects Tests for Power Expressed as a Percentage of Maximal Oxygen Consumption

<table>
<thead>
<tr>
<th>Source</th>
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<th>df</th>
<th>M.S.</th>
<th>F</th>
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<tbody>
<tr>
<td>A (Gender)</td>
<td>142354.95</td>
<td>1</td>
<td>142354.95</td>
<td>45.27*</td>
</tr>
<tr>
<td>A (Concept II / 50%)</td>
<td>7251.19</td>
<td>1</td>
<td>7251.19</td>
<td>2.31</td>
</tr>
<tr>
<td>A (Concept II / 70%)</td>
<td>13303.51</td>
<td>1</td>
<td>13303.51</td>
<td>4.23</td>
</tr>
<tr>
<td>A (Concept II / 85%)</td>
<td>22907.65</td>
<td>1</td>
<td>22907.65</td>
<td>7.28*</td>
</tr>
<tr>
<td>A (Air-Dyne / 50%)</td>
<td>17292.49</td>
<td>1</td>
<td>17292.49</td>
<td>5.50*</td>
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Table 6--Continued

<table>
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<tr>
<td>A (Air-Dyne / 70%)</td>
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<td>1</td>
<td>37997.40</td>
<td>12.08*</td>
</tr>
<tr>
<td>A (Air-Dyne / 85%)</td>
<td>60473.60</td>
<td>1</td>
<td>60473.60</td>
<td>19.23*</td>
</tr>
<tr>
<td>Error</td>
<td>56607.48</td>
<td>18</td>
<td>3144.86</td>
<td></td>
</tr>
<tr>
<td>B (Mode)</td>
<td>116172.87</td>
<td>1</td>
<td>116172.87</td>
<td>173.39*</td>
</tr>
<tr>
<td>B (Male / 50%)</td>
<td>13962.97</td>
<td>1</td>
<td>13962.97</td>
<td>57.71*</td>
</tr>
<tr>
<td>B (Male / 70%)</td>
<td>36084.21</td>
<td>1</td>
<td>36084.21</td>
<td>149.15*</td>
</tr>
<tr>
<td>B (Male / 85%)</td>
<td>48210.31</td>
<td>1</td>
<td>48210.31</td>
<td>199.27*</td>
</tr>
<tr>
<td>B (Female / 50%)</td>
<td>5157.83</td>
<td>1</td>
<td>5157.83</td>
<td>21.32*</td>
</tr>
<tr>
<td>B (Female / 70%)</td>
<td>12181.55</td>
<td>1</td>
<td>12181.55</td>
<td>50.35*</td>
</tr>
<tr>
<td>B (Female / 85%)</td>
<td>15626.85</td>
<td>1</td>
<td>15626.85</td>
<td>64.59*</td>
</tr>
<tr>
<td>Error</td>
<td>4354.92</td>
<td>18</td>
<td>241.94</td>
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<tr>
<td>C (Percent)</td>
<td>162093.94</td>
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<td>1016.39**</td>
</tr>
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<td>C (Male / Concept II)</td>
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<td>176.90**</td>
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<td>77.50**</td>
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</tr>
<tr>
<td>Error</td>
<td>3875.04</td>
<td>36</td>
<td>107.64</td>
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*F(1, 18) = 4.41, p < .05

**F(2, 36) = 3.32, p < .05

Maximal Power Output

Descriptive data for maximal power output were

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divided into cells by the independent variables, gender and mode of exercise. Cell means, standard deviations and marginal means were provided. These descriptive data are presented in Appendix H. An ANOVA was calculated using gender and mode of exercise as the independent variables. The ANOVA (see Table 7) indicated the following:

1. There was a significant difference in maximal power output, $F = 53.18$, between the genders ($F(1, 18) = 4.41, p < .05$).

2. There was a significant difference in maximal power output, $F = 93.76$, between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer ($F(1, 18) = 4.41, p < .05$).

3. There was a significant interaction effect, $F = 6.83$, between gender and mode of exercise regarding maximal power output ($F(1, 18) = 4.41, p < .05$).

Table 7
ANOVA Summary Table for Maximal Power Output

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<td></td>
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<td>A (Gender)</td>
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<td>118265.62500</td>
<td>53.18*</td>
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<tr>
<td>Error</td>
<td>40031.250</td>
<td>18</td>
<td>2223.95833</td>
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<td>Within Subjects</td>
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<td></td>
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Table 7—Continued

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</thead>
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<tr>
<td>B (Mode)</td>
<td>62015.625</td>
<td>1</td>
<td>62015.62500</td>
<td>93.76*</td>
</tr>
<tr>
<td>A X B</td>
<td>4515.625</td>
<td>1</td>
<td>4515.62500</td>
<td>6.83*</td>
</tr>
<tr>
<td>Error</td>
<td>11906.250</td>
<td>18</td>
<td>661.45833</td>
<td></td>
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</table>

*F(1, 18) = 4.14, p < .05

Discussion

Maximal Heart Rate

For both male and female subjects, the Schwinn Air-Dyne bicycle ergometer produced higher maximal heart rates than did the Concept II rowing ergometer. The mean maximal heart rate (b/min) for both groups were: (a) men on the Concept II, 186.4; (b) men on the Schwinn Air-Dyne, 192.5; (c) women on the Concept II, 188.3; and (d) women on the Schwinn Air-Dyne, 190.7. The marginal heart rate mean for the Concept II was 187.35 b/min, compared to 191.6 b/min for the Schwinn Air-Dyne.

These results contradicted the results found by Cunningham et al. (1975) and Mahler et al. (1987) who found no difference in maximal heart rate between rowing and bicycling. It is important to note, though, that different variations of bicycling were used in the Cunningham and Mahler studies as opposed to this study. The
Monark bicycle ergometer, as mentioned before, is a popular bicycling apparatus used for maximal exercise testing. In this particular modality, subjects often experience localized muscular fatigue in the quadricep area. In the present study, the Schwinn Air-Dyne may have actually delayed muscular fatigue by incorporating arm movement, and allowing for a more maximal cardiovascular effort.

However, the work of Glesser et al. (1974) showed that maximal heart rate did not significantly differ between legs only and combined arm and leg work. Nagle et al. (1984) did not find a significant difference between maximal heart rate attained for 100% leg work, 10% arm/90% leg, and 20% arm/80% leg protocols.

Certainly, localized muscular fatigue in the upper or lower body could contribute to early or premature test termination on the Concept II, thus yielding lower maximal heart rates. Both the Schwinn Air-Dyne and the Concept II utilize the upper body to perform the work required. However, the modes differ in the way in which upper body work is done. On the Schwinn Air-Dyne, the arms and legs operate in an alternating pattern, giving rest or reprieve to each arm and leg. In contrast, the Concept II incorporates arm and leg movement in the same phase. At higher workloads, this involves a greater effort from the arms. The arms and upper body have a
relatively small amount of muscle mass compared to the legs and lower body. Therefore, fatigue, originating from the upper body or arms, may actually occur before maximal heart rate is achieved.

Since the upper body is characteristically weaker than the lower body, subjects could try to compensate by increasing muscular effort from the legs. Fatigue could originate from the muscles of the lower body: legs, buttock and/or back.

Maximal Oxygen Consumption

There was a significantly greater maximal VO\(_2\) attained on the Schwinn Air-Dyne bicycle ergometer compared to the Concept II rowing ergometer in this study. The difference appeared to be greater in the males compared to the female gender. Therefore, a significant interaction effect existed between gender and mode of exercise (see Figure 1). The mean maximal VO\(_2\) (ml/kg/min) was as follows: (a) men on the Concept II, 48.21; (b) men on the Schwinn Air-Dyne, 52.75; (c) women on the Concept II, 44.02; and (d) women on the Schwinn Air-Dyne, 45.67. The marginal mean for maximal oxygen consumption across gender on the Concept II was 46.12 ml/kg/min, compared to 49.21 ml/kg/min on the Schwinn Air-Dyne.
Figure 1. Gender X Mode of Exercise Interaction for Maximal Oxygen Consumption.

The literature supported the notion that a higher maximal VO\(_2\) can be demonstrated during traditional bicycling compared to rowing. For example, Cunningham et al. (1975), although not significant, found a higher VO\(_2\) while bicycling in trained and untrained men. Also, Mahler et al. (1987) demonstrated this phenomenon in 12 collegiate female rowers. Therefore, the literature supports the relationship found between maximal VO\(_2\) and mode of exercise across gender.

However, other investigators, such as Rosiello et al. (1987), determined that maximal VO\(_2\) remained the same between the Concept II rower and the traditional Monark bicycle. As with maximal heart rate, maximal VO\(_2\) can be affected by whether the arms are included in the
exercise. Since the Schwinn Air-Dyne does incorporate a
great degree of arm involvement, it was understandable
that this research study might have elicited different
results than traditional comparisons of bicycling and
rowing. In fact, Nagle et al. (1984) found a signifi-
cantly higher VO₂ when 10-20% of the total power contri-
bution was attributed to the push-pull activity of the
Air-Dyne.

Also, as with maximal heart rate, the way in which
the work is performed may actually affect maximal oxygen
consumption. For example, by participating in an alter-
nating phase on the Schwinn Air-Dyne, the arms and legs
are given short rests. On the Concept II, the arms and
legs participate in the same phase, both pulling and
resting together. Even though resting occurs during the
recovery phase, the work during the drive phase may actu-
ally be more intense and difficult.

This investigation did not monitor the amount of
work performed by the arms alone or the legs alone.

Since none of the subjects in this study were train-
ed rowers, it was suspected that Secher's (1983) con-
clusions were accurate. Basically, Secher identified an
increase in muscular strength during simultaneous leg
extension in trained oarsmen. Mahler et al. (1987) found
an increased percentage of slow twitch fibers in elite
oarsmen as compared to the normal population. In
untrained rowing subjects, however, the strength of both legs was lower than the strength measured in each leg, indicating an inability to utilize slow twitch muscle fiber during maximal two leg extension (Secher, 1983). If one can not utilize slow twitch muscle fiber, then the work is likely to be predominantly anaerobic, and oxygen consumption is affected.

The interaction effect of maximal VO$_2$ noted between gender and mode of exercise in this study may have been, in part, due to the subject selection process. Although all subjects tested were exercising three times per week for at least 30 minutes, perhaps the men in the study trained at higher intensities than some of the women subjects. This, therefore, may have enabled them to better extract oxygen from the blood to meet the demand of the muscles.

Also, although they were not specifically trained on the Schwinn Air-Dyne bicycle ergometer, at least one-half of the male subjects were predominantly cyclists. This may have more adequately prepared them for the cycling compared to female subjects. The women in the study, on the other hand, indicated on their history forms a more even distribution of cycling, running, aerobics and skiing.

Lastly, the significant interaction effect of maximal oxygen consumption between gender and mode of
exercise could be related to shoulder girdle strength differences between males and females.

**Power Expressed as Percent of Maximal Heart Rate**

In general, submaximal power (Watts) was significantly different between males ($M = 132.04$) and females ($M = 72.76$), and between the Concept II rowing ergometer ($M = 81.32$) and the Schwinn Air-Dyne bicycle ergometer ($M = 123.48$). Also, there was a significant difference between power at 50% ($M = 41.85$), 70% ($M = 109.01$) and 85% ($M = 156.33$) of maximal heart rate. Refer to Appendix F for the cell means, standard deviations and marginal means for this dependent variable.

Although the marginal means for maximal heart rate (b/min) across modes of exercise did not differ between men ($M = 189.45$) and women ($M = 189.5$), men achieved a significantly higher total power output ($M = 287.5$ Watts) than women ($M = 178.75$ Watts) on both ergometers. It is understandable that power taken as a percentage of maximal heart rate would be higher in men than in women. Due to the higher levels of muscular strength in men, significance between gender at submaximal power outputs would be expected in this study.

When comparing submaximal power outputs between the Concept II and the Schwinn Air-Dyne ergometers, one must again look at the differences in total power output.
Invariably, men and women achieved a higher marginal mean for maximal heart rate (b/min) on the Schwinn Air-Dyne (M = 191.6) as opposed to the Concept II (M = 187.35). Also, both genders achieved higher levels of total power (Watts) on the Schwinn Air-Dyne (M = 272.5) as compared to the Concept II (M = 193.75). Power at a percentage of maximal heart rate would be higher on the Schwinn Air-Dyne than on the Concept II. Mahler et al. (1987) found peak power output to be higher while cycling on the Monark compared to rowing on the Concept II which supported this investigation.

It was very difficult to compare submaximal heart rates at equal power outputs between the modes due to the large difference in total power achieved. By identifying a power at a given percentage of maximal heart rate from both devices, this comparison was possible. In summary, submaximal heart rates at equal power outputs were higher on the Concept II than on the Schwinn Air-Dyne. This was supported by Rosiello et al. (1987). This author found that submaximal heart rates were progressively higher during rowing than during cycling as workloads increased. Steinacker (1986) also found higher submaximal heart rates in rowing than in bicycling, although not significant.

The tremendous degree of significance in power noted between the three percentages of maximal heart rate was
expected in this study. Simply, power at 50%, 70% and 85% of the maximal heart rate are likely to vary from one another in any graded exercise test.

There was a significant interaction between gender and mode of exercise for power expressed as a percent of maximal heart rate (see Figure 2). An interaction existed between percent of maximal heart rate and gender (see Figure 3), as well as between mode of exercise and percent maximal heart rate (see Figure 4). To interpret these interactions, Simple Main Effects tests were used.

Figure 2. Gender X Mode of Exercise Interaction for Power Expressed as a Percentage of Maximal Heart Rate.
Figure 3. Percent Maximal Heart Rate X Gender Interaction for Power.

Figure 4. Mode of Exercise X Percent Maximal Heart Rate Interaction for Power.
As Table 4 depicts, there was no significance found in power between men and women on both the Concept II and the Air-Dyne at 50% of maximal heart rate (see Appendix F). However, there was a significant difference in power between gender on both modes of exercise at 70% and 85% of the maximal heart rate. The means were as follows: (a) for males on the Concept II at 70% of maximal heart rate, 109.77 Watts; (b) for females on the Concept II at 70% of maximal heart rate, 60.39 Watts; (c) for males on the Air-Dyne at 70% of maximal heart rate, 76.33 Watts; (d) for females on the Air-Dyne at 70% of maximal heart rate, 94.51 Watts; (e) for males on the Concept II at 85% of maximal heart rate, 162.63 Watts; (f) for females on the Concept II at 85% of maximal heart rate, 94.49 Watts; (g) for males on the Air-Dyne at 85% of maximal heart rate, 233.91 Watts; and (h) for females on the Air-Dyne at 85% of maximal heart rate, 134.29 Watts. Perhaps physiological strength differences between men and women did not become evident until 50% of the maximal heart rate was surpassed on the Concept II and Air-Dyne.

In comparing differences between modes of exercise, a significant difference in power (Watts) was found between the Concept II ($M = 38.24$) and Schwinn Air-Dyne ($M = 76.33$) among men at 50% of the maximal heart rate. However, the same comparison among women was not significant. This could be due to the superior cycling ability.
among some of the male subjects. Further, a significant difference was found in power between the Concept II and Schwinn Air-Dyne among both men and women at 70%, as well as 85%, of the maximal heart rate. The means were as follows: (a) Concept II at 70% of maximal heart rate for males, 109.77 Watts; (b) Air-Dyne at 70% of maximal heart rate for males, 171.36 Watts; (c) Concept II at 70% of maximal heart rate for females, 60.39 Watts; (d) Air-Dyne at 70% of maximal heart rate for females, 94.51 Watts; (e) Concept II at 85% of maximal heart rate for males, 162.63 Watts; (f) Air-Dyne at 85% of maximal heart rate for males, 233.91 Watts; (g) Concept II at 85% of maximal heart rate for females, 94.49 Watts; and (h) Air-Dyne at 85% of maximal heart rate for females, 134.29 Watts.

There was a significant difference in power at submaximal levels of maximal heart rate (50%, 70% and 85%) among men on both the Concept II and Air-Dyne. Similarly, the same was found in power between 50%, 70% and 85% of the maximal heart rate among women on both the Concept II and the Air-Dyne. In any graded exercise test, though, these results would be expected.

Power Expressed as Percent of Maximal Oxygen Consumption

Power at percentages of maximal oxygen consumption exhibited results similar to those found with percentages of maximal heart rate. In general, significant
differences were found for all tests. Refer to Appendix G for the cell means, standard deviations and marginal means for this dependent variable.

There was a significant difference in submaximal power (Watts) between men (M = 175.46) and women (M = 106.57). To explain this, marginal means for maximal oxygen consumption must be utilized. Men consistently achieved a higher level of maximal power (M = 287.5 Watts) on both modes of exercise than women (M = 178.75 Watts); they also exhibited a higher marginal mean (M = 50.48) across modes versus women (M = 44.85) for maximal oxygen consumption (ml/kg/min). Although this difference in maximal VO₂ was not significant, men had an 11% higher marginal mean for maximal VO₂. Therefore, the differences in power achieved between men and women at submaximal levels of maximal oxygen consumption could easily be accounted for.

Similarly, the same can apply to differences between modes of exercise. Maximal oxygen consumption (ml/kg/min) was higher for both men and women on the Schwinn Air-Dyne (M = 49.21) compared to the Concept II (M = 46.12). Also, a higher level of maximal power (Watts) was achieved on the Air-Dyne (M = 272.5) compared to the Concept II (M = 193.75) across gender. Mahler et al. (1987) also demonstrated higher peak power outputs on the Monark bicycle ergometer as opposed to the Concept II
rowing ergometer. Since submaximal power in this study was a function of maximal oxygen consumption and maximal power achieved, and since both of these were higher on the Schwinn Air-Dyne, it was concluded that the submaximal power achieved would be higher on this apparatus.

Because of the large difference in maximal power achieved between the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer, it was very difficult to compare submaximal oxygen consumption at equal power outputs. By identifying a submaximal power at a given percentage of the maximal VO$_2$ for each mode of exercise, this comparison was possible. For example, the marginal mean for power output (see Appendix G) on the Concept II at 85% of maximal VO$_2$ was 145.22 Watts, and the marginal mean for power on the Schwinn Air-Dyne at 85% of the maximal VO$_2$ was 222.27 Watts. Simple reasoning illustrates that 145.22 Watts for the Concept II is far less than the equivalent percent of VO$_2$ on the Schwinn Air-Dyne. In fact, it is actually somewhere between 50% and 70% of the maximal VO$_2$ on the Air-Dyne. Therefore, submaximal oxygen consumption is greater at equal power outputs on the Concept II rowing ergometer as compared to the Air-Dyne bicycle ergometer. Both Steinacker et al. (1986) and Bouckaert et al. (1983) found VO$_2$ at submaximal workloads significantly higher during rowing than during bicycling.
At percentages of maximal oxygen consumption, a significant difference between power at 50\%, 70\% and 85\% of the maximal \(\text{VO}_2\) existed. This phenomenon also occurred at percentages of submaximal heart rate. This difference was expected due to the graded protocols in the testing.

There was a significant interaction of submaximal power between gender and mode of exercise (see Figure 5). An interaction of submaximal power also occurred between percent maximal oxygen consumption and gender (see Figure 6). In addition, interactions occurred between mode of exercise and percent of maximal oxygen consumption (see Figure 7), as well as between all three of the independent variables, mode of exercise, percent of maximal \(\text{VO}_2\) and gender. To interpret these interactions, Simple Simple Main Effects tests were utilized.
Figure 5. Gender X Mode of Exercise Interaction for Power Expressed as a Percentage of Maximal Oxygen Consumption.

Figure 6. Percent Maximal Oxygen Consumption X Gender Interaction for Power.
As Table 6 depicts, there was no significant difference found in power between men and women on the Concept II rowing ergometer at 50% and 70% of the maximal oxygen consumption. A significance was found in power (Watts), however, between men (M = 179.05) and women (M = 111.37) on the Concept II at 85% of the maximal oxygen consumption. Perhaps differences in shoulder girdle strength could account for this difference. Men and women were significantly different in terms of power (Watts) on the Air-Dyne at 50% (M = 144.66 and M = 85.86, respectively), 70% (M = 222.45 and M = 135.27, respectively) and 85% (M = 277.25 and M = 167.28, respectively) of the maximal

Figure 7. Mode of Exercise X Percent Maximal Oxygen Consumption Interaction for Power.
\( \text{VO}_2 \). This was primarily due to the higher total power and maximal \( \text{VO}_2 \) achieved by the male gender. Also, since more of the men in this study were trained cyclists, an advantage over women existed.

Also due to the higher total power output achieved on the Schwinn Air-Dyne, significant differences were found in power (Watts) between the Air-Dyne and the Concept II at 50\% (\( M = 144.66 \) and \( M = 91.82 \), respectively), 70\% (\( M = 222.45 \) and \( M = 137.5 \), respectively) and 85\% (\( M = 277.25 \) and \( M = 179.06 \), respectively) of the maximal oxygen consumption for men. The same differences in power existed between the Schwinn Air-Dyne and the Concept II at 50\% (\( M = 85.85 \) and \( M = 53.73 \), respectively), 70\% (\( M = 135.27 \) and \( M = 85.91 \), respectively) and 85\% (\( M = 167.28 \) and \( M = 111.37 \), respectively) of the maximal oxygen consumption for women. The literature supports differing submaximal responses between these two modes.

A significant difference was found in power between 50\%, 70\% and 85\% of maximal oxygen consumption in men, both on the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer. Similarly, significance between power at 50\%, 70\% and 85\% of the maximal \( \text{VO}_2 \) was found in women on both the Concept II and the Schwinn Air-Dyne. Again, these significant differences were expected due to the nature of graded exercise testing procedures.
Maximal Power Output

Men produced significantly higher power outputs in Watts (M = 287.5) across modes of exercise compared to women (M = 178.75). This phenomenon usually will be true whenever men and women are compared on the same test. It is also possible that the men in this investigation trained at a higher intensity than women. A higher total power output may have resulted.

In addition, the Schwinn Air-Dyne (M = 272.5) produced significantly higher maximal power outputs (Watts) compared to the Concept II (M = 193.75) across gender. This was probably due to the alternating pattern of arm and leg movements. This may have prevented localized muscular fatigue from limiting the work performed.

Since the differences in maximal power output means were not consistent across gender and mode of exercise, a significant interaction effect was noted (see Figure 8). An interaction probably occurred due to the combination of two factors: (a) men trained at a higher intensity than women prior to this investigation, and (b) the men in the study were more experienced in cycling than the women, giving men an advantage on the Schwinn Air-Dyne.
Figure 8. Gender X Mode of Exercise Interaction for Maximal Power Output.
CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study was conducted to compare maximal heart rate and oxygen consumption between the Schwinn Air-Dyne bicycle ergometer and the Concept II rowing ergometer. In addition, power at submaximal levels of maximal heart rate and oxygen consumption were compared between the Schwinn Air-Dyne bicycle ergometer and the Concept II rowing ergometer. Twenty subjects, 10 men and 10 women, who exercised regularly, engaged in two maximal graded exercise tests in random order. One test was on the Schwinn Air-Dyne bicycle ergometer, and the other on the Concept II rowing ergometer. The tests were done no more than one week apart. Heart rate and blood pressure measurements were determined at rest and every two minutes throughout each test until exhaustion. Oxygen consumption was also analyzed every 30 seconds throughout each exercise bout. Heart rate and oxygen consumption were recorded for the appropriate level of power for each stage.

Raw data were coded and analyzed using the computer program BMDP-2V at Western Michigan University. Analysis of Variance, Split Plot Factorial Designs were used for
both the maximal and submaximal data. Simple Simple Main Effects tests were then used to interpret significant first and second order interaction effects. For the maximal data, the independent variables included: (a) gender with two levels, male and female; and (b) mode of exercise with two levels, the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer. The dependent variables included: (a) maximal heart rate, and (b) maximal oxygen consumption. For the submaximal data, the independent variables included: (a) gender with two levels, male and female; (b) mode of exercise with two levels, the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer; and (c) the percent of maximal heart rate or oxygen consumption with three levels, 50%, 70% and 85%. The dependent variables included: (a) power at three submaximal levels of maximal heart rate, and (b) power at three submaximal levels of maximal oxygen consumption.

Findings

Significance for the findings of this study was determined at the .05 level. The ANOVA and Simple Simple Main Effects tests indicated the following:

1. Maximal heart rate was higher on the Schwinn Air-Dyne bicycle ergometer compared to the Concept II rowing ergometer.
2. Maximal oxygen consumption was higher on the Schwinn Air-Dyne bicycle ergometer compared to the Concept II rowing ergometer.

3. Power at submaximal levels of maximal heart rate was higher on the Schwinn Air-Dyne bicycle ergometer compared to the same submaximal level of maximal heart rate on the Concept II rowing ergometer. Therefore, submaximal heart rates were greater on the Concept II rowing ergometer as opposed to the Schwinn Air-Dyne bicycle ergometer at equal power outputs.

4. Power at submaximal levels of maximal oxygen consumption was higher on the Schwinn Air-Dyne bicycle ergometer compared to the same submaximal level of maximal oxygen consumption on the Concept II rowing ergometer. Therefore, submaximal oxygen consumption was greater on the Concept II rowing ergometer as opposed to the Schwinn Air-Dyne bicycle ergometer at equal power outputs.

Conclusions

Maximal graded exercise tests done on the Schwinn Air-Dyne bicycle ergometer and the Concept II rowing ergometer led the investigator to suggest the following conclusions:

1. The Schwinn Air-Dyne bicycle ergometer and the Concept II rowing ergometer produce different heart rate
responses using protocols which increase in equal increments of power.

2. The Schwinn Air-Dyne bicycle ergometer and the Concept II rowing ergometer produce different oxygen consumption trends using protocols which increase in equal increments of power.

3. Equal power outputs on the Schwinn Air-Dyne bicycle ergometer and the Concept II rowing ergometer cannot be compared to one another. Each represents a different intensity of exercise.

Recommendations

Based on the results of this study comparing the cardiovascular responses to maximal exercise tests performed on the Concept II rowing ergometer and the Schwinn Air-Dyne bicycle ergometer, the following are recommendations for further research:

1. A larger sample size could be observed.

2. A more homogenous group of subjects could be observed. For example, one could delimit the subjects selected to cyclists or runners only.

3. Biomechanical analysis could be performed on both devices to determine similarities and differences.

4. Blood lactate levels could be drawn from the arms and legs while exercising on both devices to determine levels of anaerobic metabolism.
Appendix A

Health History
## APPENDIX A

### HEALTH HISTORY

<table>
<thead>
<tr>
<th>NAME</th>
<th>DATE</th>
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<th>CIGARS</th>
<th>NON-SMOKER</th>
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<tr>
<th>EXERCISE: TYPE</th>
<th>DURATION</th>
<th>DISTANCE</th>
<th>FREQUENCY</th>
<th>TIMES/WEEEK</th>
<th>INTENSITY</th>
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<tbody>
<tr>
<td></td>
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</table>

Have you exclusively trained on either the Schwinn Air-Dyne bicycle or the Concept II rower? **YES** **NO**

### PAST MEDICAL HISTORY

Have you ever had:

<table>
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<tr>
<th>PALPITATIONS</th>
<th>RHEUMATIC FEVER</th>
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<table>
<thead>
<tr>
<th>HEART ATTACK</th>
<th>OTHER HEART CONDITION</th>
<th>SPECIFY</th>
<th>HIGH BLOOD PRESSURE</th>
<th>HIGH CHOLESTEROL</th>
<th>HIGH TRIGLYCERIDES</th>
<th>JOINT/MUSCLE PROBLEMS</th>
<th>WHERE?</th>
<th>SWELLING IN LEGS/HANDS/ANKLES</th>
<th>ANY MAJOR SURGERIES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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MEDICAL HISTORY, CONT.

HAVE YOU EVER: 
- COUGHED UP BLOOD__________________________________________
- COUGHED UPON EXERTION________________________________________
- HAD A PREVIOUS MAXIMAL EXERCISE TEST__________________________

Have you experienced unusual shortness of breath at rest?

______________________________
WITH MILD ACTIVITY?

Have you experienced any chest discomfort at rest?

______________________________
WITH MILD ACTIVITY?

Have you had any light-headedness at rest?

______________________________
WITH MILD ACTIVITY?

In general, how do you feel lately?

______________________________

Do you have a family history of:

- STROKE
- HEART ATTACK
- CORONARY ARTERY DISEASE
- OTHER HEART PROBLEMS
- HIGH BLOOD PRESSURE
- DIABETES

The above information given is accurate and complete.

Signature: ____________________________

Phone number: ________________________

When are you most likely to be available for testing?

______________________________
Appendix B

Informed Consent for Graded Exercise Test
APPENDIX B

Informed Consent for Graded Exercise Test

1. Explanation of the Graded Exercise Test:

You will perform a graded exercise test on a Schwinn Air-Dyne bicycle ergometer and/or a Concept II rowing ergometer. The work levels will begin at a level which you can easily accomplish and will be advanced in stages, depending on your work capacity. We may stop the test at any time or you may stop the test because of excessive fatigue or discomfort. We do not wish you to exercise at a level which is abnormally uncomfortable for you.

2. Risks and Discomforts:

There exists the possibility of certain changes during the test. They include abnormal blood pressure response, fainting, disorders of the heart beat, and in very rare instances, heart attack. Given your regular activity level and the health information provided by your questionnaire, these risks would be very low. However, some discomfort is expected during your exercise test, such as muscular fatigue and shortness of breath. Every effort will be made to minimize danger through the preliminary examination, history and by observations made during the test. Emergency equipment and trained personnel are available to deal with unusual situations if they arise.

3. Benefits to be Expected:

The results obtained from your exercise test will be used in the investigator's research project. Results also may assist in evaluating what levels of activity you might carry out for maximum benefits on the Schwinn Air-Dyne and the Concept II.

4. Inquiries:

Any questions about procedures used in the graded exercise testing or in the measurement of functional capacity are welcome. If you have any doubts or questions, please ask us for further explanations.
5. Freedom of Consent:

Permission for you to perform this graded exercise test is voluntary. You are free to deny consent if you so desire.

Understand that the data and information obtained during these procedures will be used for research, publications and/or presentations. Further, understand that any information used for research purposes will maintain confidentiality and anonymity, and consent to its use in that fashion.

I have read this form and understand the procedures in which I will be engaged. I consent to participate in the evaluation.

____________________________________  ____________________________
Date                                      Signature of Subject

____________________________________
Signature of Witness
Appendix C

Raw Test Data
### Raw Test Data

**Name** ______________________  **Date** __________

**Test:** Concept II  **Predicted Max. Heart Rate** __________

**Air-Dyne**  **Last Meal** __________

**Weight** _______________ lb __________ kg

**Medications**

**Age** __________

**Resting HR** __________

**Resting BP** __________  **Taken today?**

**Caffeine today** __________ yes no

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<th>MINUTE</th>
<th>CONCEPT II AIR-DYNE HR BP VO₂</th>
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<tbody>
<tr>
<td>2</td>
<td>25 WATTS 150 KPM/MIN</td>
</tr>
<tr>
<td>4</td>
<td>50 WATTS 300 KPM/MIN</td>
</tr>
<tr>
<td>6</td>
<td>75 WATTS 450 KPM/MIN</td>
</tr>
<tr>
<td>8</td>
<td>100 WATTS 600 KPM/MIN</td>
</tr>
<tr>
<td>10</td>
<td>125 WATTS 750 KPM/MIN</td>
</tr>
<tr>
<td>12</td>
<td>150 WATTS 900 KPM/MIN</td>
</tr>
<tr>
<td>14</td>
<td>175 WATTS 1050 KPM/MIN</td>
</tr>
<tr>
<td>16</td>
<td>200 WATTS 1200 KPM/MIN</td>
</tr>
<tr>
<td>18</td>
<td>225 WATTS 1350 KPM/MIN</td>
</tr>
<tr>
<td>20</td>
<td>250 WATTS 1500 KPM/MIN</td>
</tr>
<tr>
<td>22</td>
<td>275 WATTS 1650 KPM/MIN</td>
</tr>
<tr>
<td>24</td>
<td>300 WATTS 1800 KPM/MIN</td>
</tr>
</tbody>
</table>

**I.P.E**

2' POST

4' POST

6' POST

8' POST

10' POST
Appendix D

Table of Descriptive Statistics for Maximal Heart Rate
### APPENDIX D

**Descriptive Statistics for Maximal Heart Rate**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Male</th>
<th>Female</th>
<th>Marginal Mean</th>
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<tbody>
<tr>
<td>Concept II Mean:</td>
<td>186.40000  188.30000</td>
<td>187.35000</td>
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</tr>
<tr>
<td>S.D.:</td>
<td>12.21293</td>
<td>10.55199</td>
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</tr>
<tr>
<td>Air-Dyne Mean:</td>
<td>192.50000  190.70000</td>
<td>191.60000</td>
<td></td>
</tr>
<tr>
<td>S.D.:</td>
<td>7.19954</td>
<td>8.93246</td>
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</tr>
<tr>
<td>Marginal Mean:</td>
<td>189.45000  189.50000</td>
<td>189.47500</td>
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Appendix E

Table of Descriptive Statistics for Maximal Oxygen Consumption
APPENDIX E

Descriptive Statistics for Maximal Oxygen Consumption

<table>
<thead>
<tr>
<th>Mode</th>
<th>Male</th>
<th>Female</th>
<th>Marginal Mean</th>
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<tbody>
<tr>
<td>Concept II</td>
<td>Mean: 48.21000</td>
<td>44.02000</td>
<td>46.11500</td>
</tr>
<tr>
<td></td>
<td>S.D.: 7.30562</td>
<td>8.18438</td>
<td></td>
</tr>
<tr>
<td>Air-Dyne</td>
<td>Mean: 52.75000</td>
<td>45.67000</td>
<td>49.21000</td>
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<tr>
<td></td>
<td>S.D.: 9.65462</td>
<td>8.36727</td>
<td></td>
</tr>
<tr>
<td>Marginal</td>
<td>Mean: 50.48000</td>
<td>44.84500</td>
<td>47.66250</td>
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Appendix F

Table of Descriptive Statistics for Power at Submaximal Heart Rate
APPENDIX F

Descriptive Statistics for Power at Submaximal Heart Rate

<table>
<thead>
<tr>
<th>Mode / Percent</th>
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<tbody>
<tr>
<td>Concept II / 50%</td>
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<tr>
<td></td>
<td>15.57908</td>
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<tr>
<td>70% Mean</td>
<td>109.77347</td>
<td>60.39186</td>
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<td>S.D.</td>
<td>20.41195</td>
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<tr>
<td>85% Mean</td>
<td>162.63474</td>
<td>94.48983</td>
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</tr>
<tr>
<td>S.D.</td>
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<td>20.39578</td>
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<tr>
<td>Air-Dyne / 50%</td>
<td>76.32939</td>
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<td>53.40352</td>
</tr>
<tr>
<td></td>
<td>27.29360</td>
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<tr>
<td>70% Mean</td>
<td>171.36043</td>
<td>94.51287</td>
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<tr>
<td>S.D.</td>
<td>39.47157</td>
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<tr>
<td>85% Mean</td>
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<td>S.D.</td>
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<tr>
<td>Marginal Mean</td>
<td>132.04241</td>
<td>72.75530</td>
<td>102.39885</td>
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Appendix G

Table of Descriptive Statistics for Power at Submaximal Oxygen Consumption
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<th>Mode / Percent</th>
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<td></td>
<td>Mean:</td>
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<tr>
<td></td>
<td>11.91299</td>
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<td>Air-Dyne / 50%</td>
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<td>85.85533</td>
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<td>85% Mean:</td>
<td>277.25361</td>
<td>167.27841</td>
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<td>48.34173</td>
<td>26.62519</td>
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<tr>
<td>Marginal Mean</td>
<td>175.45690</td>
<td>106.57174</td>
<td>141.01432</td>
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Appendix H

Table of Descriptive Statistics for Maximal Power Output
APPENDIX H

Descriptive Statistics for Maximal Power Output

<table>
<thead>
<tr>
<th>Mode</th>
<th>Male</th>
<th>Female</th>
<th>Marginal Mean</th>
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<tr>
<td>Concept II</td>
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<tr>
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<tr>
<td>Marginal Mean</td>
<td>287.50</td>
<td>178.75</td>
<td>233.125</td>
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BIBLIOGRAPHY


