The goal of this study was to determine if the cardiorespiratory adaptations to an eight-week circuit weight training program are better measured with a biokinetic swim-bench test versus a standard treadmill test. The working hypothesis of the study was that since standard circuit weight training programs stress the upper body considerably more than the lower body, then the physiological adaptations to the program would be more evident in an upper body test of cardiorespiratory responses than a lower body of the same capacity.

Twelve college-aged subjects participated in an eight-week circuit weight training program. Prior to the program, each subject was tested for cardiorespiratory responses by both a treadmill test and a biokinetic swim bench test. At the conclusion of the circuit weight training program, the subjects were re-tested to assess the physiological adaptations that had occurred over the course
of the program. The test re-test reliability for the swim bench protocol developed for use in this study was $r = .85$.

Results of the post-test showed no significant changes in maximum oxygen uptake, heart rate, or respiratory rate for either the swim-bench or the treadmill test. There was a significant increase in ventilatory equivalent for both the swim bench and the treadmill tests, and also a significant increase in max Ve for the treadmill test ($p < .05$). A significant increase in dynamic muscular endurance occurred in all subjects ($p < .01$).

'It was concluded that although the results from the study were for the most part not significant, a replication of the study using a longer training program may produce the results that were originally hypothesized.
Cardiorespiratory Responses to Circuit Weight Training as Measured by a Biokinetic Swim-Bench Test and a Treadmill Run Test

by

Jasson Chiang

A THESIS

submitted to

Oregon State University

In partial fulfillment of the requirement for the degree of

Doctor of Philosophy

Completed April 28, 1988

Commencement June 1989
APPROVED:

Redacted for Privacy
Professor of Physical Education in charge of major

Redacted for Privacy
Chair of Department of Physical Education

Redacted for Privacy
Dean of School of Education

Redacted for Privacy
Dean of Graduate School

Date thesis is presented April 28, 1987
Acknowledgements

I would like to express my deepest appreciation to Dr. John Patrick O'Shea for his guidance, encouragement, and patience throughout the course of this study.

Appreciation is also extended to my committee members, Dr. Richard F. Irvin, Dr. Clara C. Pratt, Dr. Gilbert J. Knapp, and Dr. Carvel W. Wood for their inspiration and guidance.

Thanks are also extended to Dr. Christian Zauner, Dr. Anthony Wilcox, and my friends Steve Auferoth, Mike Climstein, and Karen Shake for their great effort in assisting in the data collection. I am also grateful to Dr. David R. Thomas and Dr. Terry M. Wood for their assistance in utilizing an appropriate statistical treatment of this study.

A very special thanks is in order for Dr. Thomas N. Tillman and Nancy Edi for their friendship and assistance in editing the manuscript. This thesis could not have been possible without the effort of Dr. Randy Hyllegard.

Finally, I would like to dedicate this thesis to my wife Li-Yun, and my son Li-Ming, and my family for their neverending love and encouragement.
# TABLE OF CONTENTS

## CHAPTER I
### INTRODUCTION
- Statement of the Problem.  
  Page 3
- Purpose of the Study.  
  Page 4
- Significance of the Study.  
  Page 4
- Research Hypotheses.  
  Page 5
- Delimitations of the Study.  
  Page 7
- Limitation of the Study.  
  Page 8
- Definition of Terms.  
  Page 8

## CHAPTER II
### REVIEW OF LITERATURE
- Introduction  
  Page 11
- The Development of Circuit Weight Training.  
  Page 11
- Circuit Weight Training and the Development of Muscular Strength and Endurance.  
  Page 13
- The Development of Swim Bench Strength Training.  
  Page 17
- The Swim Bench and the Development of Strength and Power.  
  Page 19
- Cardiorespiratory Effects of Circuit Weight Training.  
  Page 21
- Cardiorespiratory Responses to Swim Bench Strength Training.  
  Page 25
- Specificity of Training Responses Measured by Peak VO₂ and Heart Rate.  
  Page 26
- Expectations Based on the Literature Review.  
  Page 29

## CHAPTER III
### METHODS AND PROCEDURES
- Subjects.  
  Page 32
- Circuit Weight Training Program.  
  Page 34
- Strength Endurance Testing.  
  Page 34
- Treadmill Test.  
  Page 35
Biokinetic Swim Bench Testing. 37
Swim-Bench Test Protocol Reliability. 39
Experimental Design. 40
Data Analysis. 41

CHAPTER IV
RESULTS AND DISCUSSION,
Analysis of the Data. 42
Discussion. 62
Strength Adaptations to Circuit Weight Training. 62
Cardiorespiratory Adaptations to Circuit Weight Training. 64
Minute Ventilation. 67
Ventilatory Equivalent. 68
Heart Rate. 69
Respiratory Rate. 70

CHAPTER V
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS 71
Summary. 71
Conclusions. 73
Recommendations. 74

REFERENCES 76

APPENDIX A  Informed Consent Release 84
APPENDIX B  Weight Training Circuit 85
APPENDIX C  Weight Calculation 86
APPENDIX D  Summary of Results 87
APPENDIX E  Peak VO₂ Swim Bench Test Reliability 88
APPENDIX F  Peak VO₂ Pre-and Post-Test 89
APPENDIX G  Heart Rate Pre-and Post-Test 90
APPENDIX H  Respiratory Rate Pre-and Post-Test 91
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The Swim Bench Testing Equipment</td>
<td>37</td>
</tr>
<tr>
<td>2.</td>
<td>Swim Bench Reliability Test.</td>
<td>40</td>
</tr>
<tr>
<td>3.</td>
<td>Peak VE,BTPS Pre-Post Test Differences for the Treadmill Test</td>
<td>47</td>
</tr>
<tr>
<td>4.</td>
<td>Peak VE/VO₂ Pre-Post-Test Changes for the Swim Bench Test.</td>
<td>50</td>
</tr>
<tr>
<td>5.</td>
<td>Peak VE/VO₂ Pre-Post-Test Changes for the Treadmill Test.</td>
<td>51</td>
</tr>
<tr>
<td>6.</td>
<td>Mean Strength Endurance Tests Pre-Test and Post-Test Results</td>
<td>59</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age and Physical Characteristics of the Subjects.</td>
<td>32</td>
</tr>
<tr>
<td>2. Swim Bench Reliability Test.</td>
<td>40</td>
</tr>
<tr>
<td>3. Pre-Test and Post-Test Measurements: Mean, Standard Deviations, t-test, and Percent Change.</td>
<td>43</td>
</tr>
<tr>
<td>4. Peak ( \dot{V}O_2 ) Measurements During the Swim-Bench and the Treadmill Test.</td>
<td>44</td>
</tr>
<tr>
<td>5. Peak ( \dot{V}O_2 ) Measurement Differences for the Swim-Bench versus the Treadmill Test.</td>
<td>45</td>
</tr>
<tr>
<td>6. Peak ( \dot{V}E, \text{BTPS} ) Measurements During the Swim Bench and the Treadmill Test.</td>
<td>46</td>
</tr>
<tr>
<td>7. Peak ( \dot{V}E, \text{BTPS} ) Measurement Differences for the Swim Bench versus the Treadmill Test.</td>
<td>48</td>
</tr>
<tr>
<td>8. Peak ( \dot{V}E/\dot{V}O_2 ) Measurements during the Swim Bench Test and the Treadmill Test.</td>
<td>49</td>
</tr>
<tr>
<td>9. Peak ( \dot{V}E/\dot{V}O_2 ) Measurement Differences for the Swim Bench Test versus the Treadmill Test.</td>
<td>52</td>
</tr>
<tr>
<td>10. Heart Rate Measurements for the Swim Bench Test and the Treadmill Test.</td>
<td>53</td>
</tr>
<tr>
<td>11. Heart Rate Measurement Differences for the Swim Bench Test versus the Treadmill Test.</td>
<td>53</td>
</tr>
<tr>
<td>12. Respiratory Rate Measurements for the Swim Bench Test and the Treadmill Test.</td>
<td>54</td>
</tr>
<tr>
<td>13. Respiratory Rate Measurement Differences for the Swim Bench versus the Treadmill Test.</td>
<td>54</td>
</tr>
<tr>
<td>14. Mean Scores on the Pre-Test and Post-Test Strength Endurance Tests for all Subjects.</td>
<td>57</td>
</tr>
<tr>
<td>15. Differences Between Mean Scores on the Pre-Test and Post-Test Strength Endurance Tests for all the Female Subjects.</td>
<td>58</td>
</tr>
<tr>
<td>16. Differences Between Mean Scores on the Pre-Test and Post-Test Strength Endurance Tests for all the Male Subjects.</td>
<td>58</td>
</tr>
</tbody>
</table>
17. Cardiorespiratory Measurements for the Female and the Male Subjects for Pre-and Post-Test Differences.
CHAPTER I

INTRODUCTION

Since the 1970s, considerable research has been directed toward the physiological effects of weight training. Among the various weight training programs, circuit weight training programs have been utilized for the development of physical fitness. Circuit weight training refers to performing several repetitions using a moderate amount of weight, moving from station to station in a continuous fashion, with minimal rest between stations (Gettman et al., 1979).

Studies have shown that circuit weight training increases strength (Brown et al., 1987; Harris and Holly, 1987; Rains et al., 1987; Messier and Dill, 1985; Reid et al., 1987), power (Jun, 1987; Ward, 1984), and endurance (Gettman and Pollack, 1982). However, controversy still exists concerning the effect of circuit weight training programs for the development of cardiorespiratory function. A significant improvement in maximal oxygen uptake ($\dot{V}O_2$ max) was reported by Harris and Holley (1987), Messier and
Dill (1985), Girandola and Katch (1973), and Reid et al (1987). While little or no improvement was observed by Allen et al (1976), Hempel (1982), Gettman et al (1980), and Bradshaw (1984). Previous research has shown that training intensity, duration, and frequency (Gettman et al, 1980), and investigative devices employed (Bonen et al, 1980; Holmer et al, 1974; Magel et al, 1978) may contribute to the conflicting results.

Although there is not total agreement, physical fitness has most often been defined in terms of the maximum level of physical work capacity. Physical work capacity is a measure of aerobic capacity and is usually expressed in milliliters of maximum oxygen consumption (\(\dot{V}O_2\) max) per kilogram of body weight per minute while performing in the laboratory on devices such as the treadmill, the cycle ergometer, the biokinetic swim-bench, or the arm-crank ergometer. Treadmill running generally produces the highest \(\dot{V}O_2\) values, followed by the bicycle ergometer, swim-bench, and arm-crank ergometer (Bonen et al, 1980; Holmer et al, 1974; Magel et al, 1978).

Examination of previous investigations indicate that when an exercise task makes use of previously trained muscles instead of exercise with an untrained muscle group there are significant decreases in submaximal heart rate (Clausen and Trap-Jensen, 1970; Saltin, 1976), minute ventilation (Rasmussen et al, 1975), and blood lactate
(Klausen et al, 1974). Similarly, improvements in peak \( \dot{V}O_2 \) are best demonstrated when there is a close similarity between the exercise test and the form of training used to train the cardiorespiratory system. This is supported by research evidence from bicycle ergometry, biokinetic swim-bench, arm-crank ergometry, and run training which suggests that a large component of the aerobic training response exists in peripheral adaptations that are highly specific to the trained muscles (Gergley et al, 1984).

**Statement of the Problem**

One of the primary principles of exercise physiology is that muscles tend to adapt to the specific nature of the exercise stress (O'Shea, 1976). Strength training programs should, therefore, stress the working muscles in a manner similar to the task that they are to perform. An accurate test outcome can best be produced by utilizing a device by which the task can be performed in a way similar to the weight lifting exercises. The difficulty however, is that most of the weight training programs and especially circuit weight training are upper body in nature. Past studies conducted to measure the effect of circuit weight training for the development of cardiorespiratory functions have mostly used a treadmill run or a bicycle ergometer test.
These types of exercise tests are simply not specific enough to weight lifting which may explain why conflicting evidence has been reported in previous circuit weight training studies.

To properly evaluate the effect of circuit weight training on cardiovascular functions it appears desirable to determine maximal oxygen uptake as measured on a biokinetic swim-bench in place of a treadmill run.

The primary question examined by this study was to see if peak VO$_2$ as measured by the biokinetic swim-bench was significantly different from that as measured by a treadmill run following the completion of an eight-week circuit weight training program.

**Purpose of the Study**

The main purpose of this study was to compare the cardiorespiratory changes, if any, due to eight weeks of circuit weight training as measured by a biokinetic swim bench and a treadmill run.

**Significance of the Study**

Although the study on the subject of the effect of circuit weight training on cardiorespiratory function is voluminous, none of these studies have been conducted to compare the effects of circuit weight training on maximal
oxygen uptake as measured by the treadmill run versus the swim-bench ergometer. In addition, conflicting evidence exists concerning the effect of circuit weight training for the development of cardiorespiratory functions. This may be due to specificity which plays an important role in aerobic testing and training. Local adaptations in the skeletal muscles play an important role in contributing to improvements in peak VO₂. A better testing outcome may be obtained by utilizing a device by which the task can be performed in a way similar to circuit weight training exercises.

Investigating the specificity of circuit weight training and peak VO₂ will be helpful in providing a better understanding of results from many previous and future research studies on cardiorespiratory responses to circuit weight training. A need for the study, therefore, is apparent.

**Research Hypotheses**

This study hypothesized that following an eight-week circuit weight training program, there will be no significant difference in the cardiorespiratory measurements during either the biokinetic swim-bench test or during a treadmill run test.

The following is the primary hypothesis tested in this
Ho 1: There will be no significant pre-and post-test difference between the mean peak V\(_{02}\) measurements during a swim-bench test or during a treadmill run test following an eight week circuit weight training program.

The following are the secondary hypotheses tested in this study:

Ho 2: There will be no significant pre-and post-test difference between the mean peak VE,BTPS measurements during the swim-bench test or during treadmill run test following an eight week circuit weight training program.

Ho 3: There will be no significant pre-and post-test difference between the mean peak ventilation equivalent measurements during the swim-bench test or during the treadmill run test following an eight week circuit weight training program.

Ho 4: There will be no significant pre-and post-test difference between the mean heart rate measurements during the swim-bench test or during the treadmill run test following an eight week circuit weight training program.

Ho 5: There will be no significant pre-and post-test difference between the mean respiratory rate measurements during the swim-bench test or during the treadmill run test following an eight week circuit weight training program.

Ho 6: There will be no significant pre- and post-test difference in mean number of repetitions as measured by a
two-minute bench squat strength endurance test following an eight week circuit weight training program.

Ho 7: There will be no significant pre- and post-test difference in mean number of repetitions as measured by a regular grip bench press strength endurance test following an eight week circuit weight training program.

Ho 8: There will be no significant pre- and post-test difference in mean number of repetitions as measured by a two-minute sit-up strength endurance test following an eight week circuit weight training program.

Ho 9: There will be no significant difference for the mean change in peak $\dot{V}O_2$, peak $\dot{V}E,BTPS$, peak $\dot{V}E/\dot{V}O_2$, heart rate, and breath rate measurements during the swim-bench and treadmill tests for the male subjects.

Ho 10: There will be no significant difference for the mean change in peak $\dot{V}O_2$, peak $\dot{V}E,BTPS$, peak $\dot{V}E/\dot{V}O_2$, heart rate, and breath rate measurements during the swim-bench and treadmill tests for the female subjects.

**Delimitations of the Study**

The study was delimited to the following parameters:

1. The subjects selected for this study were thirteen healthy male and/or female student volunteers from among the students registered in an intermediate weight training class. They were not selected randomly from a larger
population.

2. The subjects were trained two days a week for a period of eight weeks.

3. Control of physical activities or diet outside of the class was not possible.

4. Those who were not runners were requested to not start a running program.

5. Subjects who had been running regularly were asked to run no more than five miles per week.

Limitations of the Study

The study was subject to the following limitations:

1. The eight-week circuit weight training program was the major component of the ten-week intermediate weight training class. Since the students received a grade for the class, a relatively high motivation level was expected.

2. The post-tests were conducted during the week of final exams. Academic pressures may have affected the subjects' final performance.

Definition of Terms

Circuit weight training: Stations are assigned for specific exercises. The individual rotates from station to station during the exercise period. Variables in circuit weight
training include: number of repetitions, amount of weight, number of stations, and total exercise time.

Maximal oxygen consumption ($\dot{V}O_2$ max): The highest oxygen uptake a subject can obtain during physical work while breathing air at sea level. This is often measured as oxygen uptake in liters per minute ($l\cdot min^{-1}$) or in milliliters per kilogram of body weight per minute ($ml/kg\cdot min^{-1}$).

Peak $\dot{V}O_2$: The highest attained oxygen consumption value for the biokinetic swim bench and treadmill tests.

Isometric (static) contraction: When a muscle develops tension but does not shorten.

Isotonic (dynamic) contraction: A shortening of the muscle fiber length caused by fiber contraction.

Isokinetic contraction: A dynamic contraction involving limb movement at a predetermined speed thus allowing for maximal force generation (100% overload) throughout the full range of motion.

Biokinetic swim-bench ergometer: A type of variable resistance device designed to incorporate partial accommodation, so the resistive force varies automatically, so that it remains proportional to (though not equal to) the applied muscular force. In the present study, biokinetic swim-bench and isokinetic swim-bench refer to the same device.

Repetition: One complete cycle of the exercise movement.
**Set**: A particular number of cycles of the same exercise usually ranging from 6 to 15 repetitions.

**Strength**: The capacity of a muscle to exert force.

**Endurance (skeletal muscle)**: The ability of a muscle to do more than one repetition of an exercise.

**Minute ventilation (VE, BTPS)**: Minute volume of expired breath - BTPS conditions (normal body temperature 37° C, ambient pressure, saturated with water vapor).

**Ventilatory equivalent (VE/V̇O₂)**: The ratio of minute ventilation to oxygen consumption.

**a-\(\bar{V}_{O₂}\) difference**: The difference in oxygen content in arterial and venous blood.

**Response**: Any behavior of a living organism that results from an external or internal stimulus, e.g. the cardio-respiratory or muscular responses to circuit weight training programs.
CHAPTER II

REVIEW OF THE LITERATURE

Introduction

A review of the related research revealed that this study was distinct from previous studies. Although the literature on the subject of the effect of circuit weight training on cardiovascular function is voluminous, none of these studies have been conducted to compare the effect of circuit weight training on \( \dot{V}O_2 \) max responses by utilizing both the treadmill run and the biokinetic swim-bench.

This review will attempt to focus on early and current research related to five areas: 1) The development of circuit weight training; 2) the development of biokinetic swim-bench strength training; 3) the cardiorespiratory effects of circuit weight training; 4) the specificity of training responses as measured by \( \dot{V}O_2 \) max and heart rate, and; 5) expectations based on the literature review.

The Development of Circuit Weight Training

Background

Conventional strength training has long been considered a form to enhance muscular endurance and strength (Berger, 1962a). This type of strength training
employs a medium to heavy resistance with short bursts of exertion, followed by rest with no requirements for a continuous high-energy state, is categorized as an anaerobic physical activity. It contributes little or no improvement in the cardiorespiratory system (Reid et al, 1987). Circuit weight training was therefore developed in an attempt to tax the cardiorespiratory system and bring about a significant improvement in its function (O'Shea, 1976).

Circuit weight training technique involves high repetitions using a moderate intensity exercise performed in a continuous fashion while moving from one station to another with minimal rest between stations (Gettman et al, 1979). The trainee exercises in short, all-out bursts of 45-60 seconds in duration, then rests for one minute or less between stations. The total number of repetitions executed during the 45 seconds should be set at a minimum of 15 and a maximum of 20. Once the trainee reaches this upper limit, the load is increased. A circuit of eight or more stations is established with a specific exercise executed at each station. Exercises are selected so that all muscles groups are worked. The exercises are arranged in an alternating order between upper body and lower body (O'Shea, 1976).

Morgan and Addmeon (1961) reported that circuit weight training provides three advantages over conventional weight
training: 1) circuit weight training aims at the development of muscular and cardiorespiratory fitness; 2) circuit weight training applies the principal of progressive overload, and; 3) circuit weight training enables large numbers of trainees to work simultaneously. In addition, O'Shea (1976) reported that one of the benefits of circuit weight training is that it enables the performer to push to the point of psychological exhaustion and thus permitting the entire body to be brought close to actual physical exhaustion.

**Circuit Weight Training and the Development of Muscular Strength and Endurance.**

Dynamic strength is considered a foundation of muscular abilities essential to specific athletic performance. It was defined by O'Shea (1976) as:

The ability of muscles to exert force through a wide range of multiple joints, to repeat maximum or near maximum contractions, to contract the muscles in proper sequence with other muscle groups, and to allow mobility of multiple joint action (p.15).

Muscular endurance, on the other hand, refers to the muscle's ability to generate and or sustain tension over a prolonged period of time, and is best demonstrated by lifting a certain resistance many times (Delorme, 1952). There is no doubt that weight training can lead to

The development of muscular strength is a reflection of changes in the size of the affected muscle fibers and in their protein content. This increase in fiber size is called hypertrophy. Recent research reported that the increase in strength may also be induced by muscle cell hyperplasia. Gonyea (1980), Ho et al (1980), and Edgerton (1978) reported that fiber splitting (longitudinal division of muscle fibers resulting in a new muscle cell) as well as hypertrophy (increased fiber size) may all contribute to an increase in strength.

More specifically, muscular strength gain may be due to local muscular adaptations to training. Cellular alterations include an increase in the number of mitochondria and oxidative enzymes which may result in an improvement in the oxidative capacity of the muscle (Lamb, 1984). This adaptation, in fact, was found in various metabolites (lactate, glycerol, triglycerides, and β-OH-butyrate) and hormones (norepinephrine and epinephrine). (Guezennec et al, 1986).

Gettman and Pollack (1982) reported that circuit
weight training programs increased leg press and bench press strength ranging from 7% to 27% and 8% to 32% respectively. This provided evidence that circuit weight training can lead to increases in muscular strength and endurance. One of the pioneer investigators who introduced the progressive overload principle was Delorme (1952). His study indicated that one to three repetitions in three to four sets with maximum loads are best for the development of strength. This principle became the foundation of strength training programs.

Berger (1962a) compared nine different weight training programs to determine which were more effective in improving strength. The experiment was conducted with the bench press lift for a period of 12 weeks with approximately 20 subjects in each weight training program. The subjects were tested for 1 RM on the bench press at the beginning of training and at three-week intervals. Training took place three times weekly with the variations in programs involving one, two, and three sets, and two, six, and ten repetitions per set. The results showed that three sets and six repetitions per set were best for improving strength. This study suggested that the intensity of the training program based upon the selection of the number of repetitions, sets, and load utilized for each exercise is the most important requirement for the development of strength.
O'Shea (1966) conducted a study to determine the effects of a six-week progressive weight training program on the development of strength and muscle hypertrophy, using one exercise, the deep knee bend, with various repetitions. Thirty subjects were divided into three groups, one group performing three sets of 10RM, the second groups performing three sets of 5RM, and the third group performing three sets of 2RM. No significant differences were found between the three groups, however, all groups made statistically significant gains in static and dynamic strength.

O'Shea (1980) has summarized the research in strength training which indicates three types of programs are utilized to develop strength and endurance. These programs are: 1) three sets of one to three repetitions at 90% of 1RM for maximum strength development, 2) four to five sets of four to ten repetitions at 75 to 85% of 1RM for strength and endurance development, and 3) five to seven sets of eight to twelve repetitions at 60-75% of 1RM for the development of endurance.

Stone (1982) examined eleven previous studies and suggested a theoretical model for strength and power training. The four phases in the model were hypertrophy, basis strength, strength and power, and peaking or maintenance. The recommended intensities of training programs were low intensity for hypertrophy, moderate
volume at high intensity for basic strength, low volume at high intensity for strength and power, and very low intensity for peaking or maintenance.

O'Shea and Wegner (1981) further recommended a three-cycle program for the development of dynamic strength. The program is divided into four weekly periods of heavy, light, and medium training utilizing a varying percentage of 1 RM for a given number of repetitions and sets. The cycle program includes: 1) four to five sets of one to three repetitions at 85-100% of 1 RM for heavy training, 2) three to four sets of four to five repetitions at 60-75% of 1 RM for light training, and 3) four to five sets of four to five repetitions at 70-85% of 1 RM for medium training.

The frequency and duration of the training programs vary. The frequency of training greatly depends upon the sports event. Studies suggest that at least two to three days a week and a minimum of five weeks is required for physiological adaptations to take place (Hellebrant, 1958; O'Shea, 1980; Razor, 1966; Stone et al, 1982).

The Development of Swim-Bench Strength Training

Background

Until the 1970's, dryland strength training had been considered an effective way to improve swimming
There were several modes or types of strength training that were in use. Pipes (1978) described that the modes of training generally fell into two categories: static (isometric), and dynamic (isotonic). The latter is further divided into three other categories: 1) constant resistance, 2) accommodating resistance, and 3) variable resistance. Each of these three, while isotonic in nature, impose a different type of resistance on the contracting muscles while at the same time fixing limb velocity independent of force.

There are variable-resistance devices which attempt to incorporate partially, or isokinetic resistance. Heusner (1980) reported that isokinetic resistance seems to combine the best features of both variable and accommodating resistance. Resistive force varies automatically so that it remains proportional to (though not equal to) the applied muscular force permitting accelerations similar to actual athletic activity. It is apparent that strength training effect can be best obtained when specificity of exercise is employed. This indicates that the athlete should train with movements as similar as possible to the actual activity.

Counsilman (1968) reported that since swimmers contract their muscles in a manner that is more like isokinetic movements than to either isometric or isotonic when pulling the arms through the water, that to receive a maximum transfer effect, the swimmer should perform
training exercises isokinetically. The biokinetic (bio=life, kinetic=action) swim-bench was designed to duplicate as closely as possible to the accelerations characteristics found in swimming (Counselman, 1979). In the present study, the terms biokinetic swim-bench and isokinetic swim-bench refer to the same device.

**The Swim-Bench and the Development of Strength and Power**

Conventional isotonic (concentric) contraction is by far the most frequently utilized form of strength training. The disadvantage of isotonic training is that the muscles do not contract to the same degree at every position throughout the range of motion (Fleck, 1979). This is due to changes in leverage combined with changes in direction of the resistance in relation to the line of gravity. Isokinetic exercise is a form of isotonics with an added device that automatically adjusts the resistance depending on the force applied to it at every angle throughout the full range of motion.

There have been several studies examining the use of the biokinetic swim-bench for strength development. Pipes and Wilmore (1975) examined the changes in strength, body composition, anthropometric measurements, and selected motor performance tasks between subjects trained isotonically and isokinetically. They found isokinetic
training was superior in all aspects as compared to isotonic training. They also found that high-speed isokinetics was a more effective training technique than low-speed isokinetics (Pipes and Wilmore, 1975 has been discredited).

Pipes (1978) studied isokinetic strength training in 20 competitive swimmers. After an eight-week training program, Pipes concluded that high-speed isokinetic strength training was an effective means of gaining strength. The improvement in strength was positively correlated with improved swimming performance.

Thistle et al (1967) compared isokinetic training versus isotonic and isometric training. Following an eight-week program, they found that the isokinetic group increased 35% in quadricep strength as compared to 27% for the isotonic group and 9% for the isometric group. The control group showed a decrease of 9% over the eight-week period.

Van Oteghen (1975) studies the effect of two speeds of isokinetic exercise on vertical jump performance and found that both low speed and high speed training significantly improved jump ability over an eight-week period. Of the two speeds, high-speed was the most effective of the two.

Costill et al (1980) studied the relationship between various distances of swimming and maximal power as measured on the biokinetic swim-bench. They found that there was a
close relationship (r=.93) between maximum power on the swim-bench and sprint time for the 25 yard freestyle. They further examined if the improvement in sprint swimming accompanied the gains in muscular strength and reported that the swimmers increased power on average of 28% while their sprint speed improved 3.6%. When compared with the rate that the swimmers became fatigued during the test they found little relationship with swimming performance or peak power(r=.11). It was concluded that the repeated maximal pulls was not an efficient means for the evaluation of muscular endurance.

Cardiorespiratory Effects of Circuit Weight Training

The effects of circuit weight training on cardiorespiratory functions has received considerable attention by researchers. Early studies indicated that cardiorespiratory endurance showed improvement following circuit weight training; however, these results are in conflict.

One of the pioneer studies concerning the effect of circuit weight training on cardiorespiratory functions was directed by Capen (1949). Fourty-two subjects were trained twice a week on a fourteen free-weight circuit over a period of eleven weeks. A 300 yard shuttle run was used as a measure of cardiorespiratory endurance. Capen concluded
that there was no significant improvement in cardiorespiratory endurance after an 11-week circuit weight training program. However, there remains a question as to whether the 300 yard run was a direct and valid measure of cardiorespiratory endurance.

Allen et al (1976) investigated the effects of a high resistance, low repetition circuit weight training program on cardiorespiratory function. The 66 male subjects were trained on a six-station universal strength training gym over a twelve-week period at a frequency of three times a week. No significant cardiorespiratory function improvements were found. Allen concluded that high resistance, low repetition circuit weight training did not improve cardiorespiratory function.

A similar result was reported by Gettman et al (1978). The 20 week study was based on the assumption that improvement in cardiorespiratory functions would be observed following a longer period of circuit training. Seventy subjects were randomly assigned to one of three groups: circuit weight training, running, and control. The circuit weight training consisted of 10 exercises performed in 2 sets of 15 repetitions with 20 to 25 second rests between exercises. It was concluded that the circuit weight training program was effective in improving strength and body composition, but produced only a small aerobic effect as measured on the treadmill run.
Conflicting results were reported by Gettman and his colleagues in a later study (1979); this study examined the training effects of eight weeks of circuit weight training followed by eight weeks of jogging and then eight weeks of either circuit weight training or continuous jogging. It was found that both groups improved in cardiorespiratory function equally well for the subsequent eight weeks.

Gettman et al (1980) investigated physiological changes after 20 weeks of isotonic and isokinetic circuit weight training. Training was directed three days a week, with 12 repetitions at 50% of maximum strength and 30 second rest periods between sets. Gettman reported that both groups improved significantly in VO₂ max, 7% in the isotonic group and 8% in the isometric group.

Girandola and Katch (1973) studied the effects of a nine week circuit training program on aerobic capacities. Twenty-nine college students were trained three times a week. VO₂ max was measured on a Monark bicycle ergometer. A significant improvement was found in VO₂ max. The authors concluded that VO₂ max is better measured by ml/kg·min⁻¹ rather than l·min⁻¹ due to the fact that an increase in lean body weight can effect VO₂ max measurements. This conclusion was supported by Allen et al (1976), Wilmore et al (1980), and Gettman et al (1978). Theoretically, changes in muscular strength affect body composition by increasing lean body weight. Lean body
weight is correlated with \( \dot{V}O_2 \text{ max} \), thus aerobic changes would not be independent of body composition changes produced through circuit weight training.

Messier and Dill (1985) studied the effects of a Nautilus circuit weight training program on muscular strength and \( \dot{V}O_2 \text{ max} \) by comparing these effects to those produced by adhering to either a free weight strength training program or a running program. All groups participated in their respective programs three days a week for 10 weeks. The study found that the running and Nautilus circuit weight training groups experienced significant (p<.01) increases in \( \dot{V}O_2 \text{ max} \) as expressed in \( 1\cdot \text{min}^{-1} \), \( \text{ml/kg} \cdot \text{min}^{-1} \), and \( \text{ml/kg LBW} \cdot \text{min}^{-1} \) when compared to the free weight group. There were no significant differences between the Nautilus and running groups. It was concluded that for a training period of short duration, Nautilus circuit weight training appears to be an equally effective alternative to standard free weight and aerobic training programs for the untrained individual.

Reid et al. (1987) compared four constant-resistant weight training programs on muscular strength, endurance, body composition, and cardiorespiratory functioning. Forty-five men (18-35 yrs) were randomly assigned to one of four programs: endurance (2 sets of 15 repetitions of 1 RM; explosive (1 set of 15 RM); strength 1 (3 sets of 6 RM) strength 2 (1 set of 10 RM twice weekly and 1 set of 3 RM
once weekly). All groups showed significant increases in strength. \( \dot{V}O_2 \text{ max (ml/kg·min}^{-1} \) improved significantly in the endurance and strength 2 groups.

Cardiorespiratory Responses to Swim-Bench Strength Training

Studies have revealed that maximum oxygen uptake for arm exercise is considerably lower than for leg exercises (Holmer et al., 1972, 1974; McArdle et al., 1971). Presumably, cardiorespiratory responses to exercises are significantly influenced by the quantity of active musculature (Lewis et al., 1983). Treadmill running generally produces the highest values for oxygen uptake, followed by cycle ergometry, swimming bench, and arm-crank ergometry (Bonen et al., 1980; Holmer et al., 1974; Magel et al., 1978).

Gergley et al. (1984) evaluated 25 college-aged male recreational swimmers. The subjects were divided into two groups, a non-training control group and a standard swim-bench pulley system group. For all subjects prior to training, tethered swimming peak \( \dot{V}O_2 \) averaged 19% below treadmill values (p<.01). Significant increases in peak \( \dot{V}O_2 \) in tethered swimming and swim-bench were observed for the swim-bench trained group (p<.01), while the swimming-trained group improved on both the tethered swimming and swim-bench tests, respectively (p<.01). Comparisons between training groups indicated that although
both groups improved to a similar extent when measured on the swim-bench, the 0.53 l·min⁻¹ improvement in tethered swimming peak \( \dot{V}O_2 \) for the swim-trained group was greater than the 0.32 l·min⁻¹ increase for the swim-bench trained group (p<.05). It was concluded that the peak \( \dot{V}O_2 \) measured by the swim-bench was about 90% of peak \( \dot{V}O_2 \) during swimming.

**Specificity of Training Response Measured by \( \dot{V}O_2 \) max and Heart Rate**

Maximal oxygen uptake has been established as an objective evaluation of the specificity of training responses to exercise because it is considered to be a valid indicator of overall maximal cardiorespiratory response to physical performance. Current research concerning this area has been fruitful.

Sharp et al (1982) may have best demonstrated the importance of specificity that exists between lab evaluation and actual exercise performance. The study examined the relationship between power and sprint freestyle swimming. The results showed that muscular forces, as measured on a biokinetic similar type biokinetic swim-bench, showed a strong relationship between sprint swimming performance. They concluded that improvements in strength on the machine correlated with improved with swimming performance.
Gergley et al (1984) investigated specificity of arm training on aerobic power during swimming and running. \( \dot{V}O_2 \) max was measured during tethered-swimming, treadmill running, and biokinetic swim-bench. The comparisons between swim-bench and swimming versus treadmill exercises supported the specificity of aerobic improvement with training, and suggested that local adaptations contribute significantly to improvements in \( \dot{V}O_2 \) max. The authors concluded that swim-bench exercise activated a considerable portion of the musculature involved in swimming, and that aerobic improvements with the swim-bench training are directly transferred to swimming.

Bouchard et al (1979) investigated specificity of maximal aerobic power. Thirty moderately active men were tested for \( \dot{V}O_2 \) max on five different work tasks; cycling supine; cycling sitting; alternating arm cranking, bench stepping, and treadmill walking. A significant difference (\( p < .01 \)) for maximum heart rate (max HR) and \( \dot{V}O_2 \) (l.min\(^{-1}\)) and (ml/kg.min\(^{-1}\)) between the 5 types of work tests was observed. Correlation between the 5 \( \dot{V}O_2 \) max tests revealed a common variance ranging from 36% (seated cycling and alternating arm cranking) to 76% (seated cycling and treadmill walking). It was concluded that a substantial amount of task specific variation existed based on \( V_O_2 \) max measurements.

Pechar et al (1974) studied specificity of
cardiorespiratory adaptations to bicycle and treadmill training. Sixty subjects were assigned to one of three groups: bicycle ergometer training, treadmill training and, a control group. The training was conducted 20 minutes per day, 3 times a week, for eight weeks at 85% of the subject's maximal heart rate. Results showed a mean VO2 max improvement for the treadmill trained group of 6.8% and 6.9% for the treadmill and the bicycle ergometer tests respectively, compared with improvements of 2.6% and 7.8% for the bicycle ergometer trained group. The mean difference between treadmill and bicycle ergometer VO2 max for the bicycle ergometer group after training was significantly greater than the mean difference between the treadmill trained group. It was concluded that the treadmill training produced a general VO2 max improvement, whereas a specific training effect was observed with bicycle ergometer training.

Clausen and Trap-Jenson (1970) investigated the effects of training on heart rate during arm and leg exercise. Four subjects trained on an arm ergometer while four other subjects trained on a leg ergometer. The workouts took place twice a day for a period of 4 weeks. Results showed that the arm trained group significantly reduced submaximal heart rate response during arm ergometer testing by 21.5 beats/min (p<.01). The heart rates during the leg exercises showed a non-significant decrement of 3.5
beats/min. The mean submaximal heart rate during leg exercise for the leg trained group was significantly lower by 16.5 beats/min (p<.01) after training, while the heart rate during arm exercise was only slightly reduced by 5.5 beats/min. The authors concluded that arm and leg ergometer training caused a reduction in the heart rate only during the special type of training employed. It is well recognized that sport activities require upper and lower body strength and endurance for optimal performance and that it is important to contrast the cardiorespiratory adaptations from such training. These findings were supported by other studies (Clausen et al, 1973; McKenzie et al, 1978; Saltin, 1976) and suggests that a substantial component of the aerobic training response resides in peripheral adaptations that are highly specific to the trained muscles. This means that resistive muscular training will result in cardiorespiratory changes only when the specifically trained muscle groups are involved in the testing procedure for VO₂ max.

**Expectations Based on the Literature Review**

1. The review indicated that weight training does improve strength.

2. Conventional high-resistance, low-repetition weight training has little effect on cardiorespiratory fitness.

3. The frequency and duration of the circuit weight
training program depends upon the sports event. It is suggested that at least two to three days per week and a minimum of five weeks is required for physiological adaptations to take place.

4. Circuit weight training may be beneficial to the deconditioned individual for the development of endurance but will show little or no improvement in cardiorespiratory function as determined by treadmill run, bicycle, or arm-crank ergometer tests.

5. Conflicting evidence exists concerning the effect of circuit weight training for the development of cardiorespiratory functions. This may be due to lack of specificity in aerobic testing and training. Local adaptations in skeletal muscles contribute to improvement in cardiorespiratory \( \dot{V}O_2 \) max.

6. An extensive review of the literature indicated that the biokinetic swim-bench has not been used as a testing mode to measure \( \dot{V}O_2 \) max in weight training.

7. The swim-bench ergometer provided an effective means of exercise for improving aerobic capacity during swimming (Gergley et al, 1984).

8. Based on the specificity principle, the swim bench may be a legitimate and superior method of measuring \( \dot{V}O_2 \) max in swimmers or others who use primarily the upper body in performance.

The present study hypothesizes that circuit weight
training is mainly upper body in nature so it appears desirable to determine maximum oxygen uptake measurements while performing on a swim-bench ergometer instead of while performing on a treadmill or a bicycle ergometer. No research was found which examined this hypothesis, and a need for research in this area was apparent.

9. The primary hypothesis tested was that mean measurements of peak $\dot{\text{VO}}_2$ during biokinetic swim-bench tests would be greater than during treadmill run tests following an eight week circuit weight training program.
CHAPTER III

METHODS AND PROCEDURES

The main purpose of this study was to compare the cardiovascular changes, if any, due to eight weeks of circuit weight training as measured by a biokinetic swim bench and a treadmill run. All training and testing was conducted in the weight room and Human Performance Laboratory of the College of Health and Physical Education, Oregon State University.

Subjects

Four female and nine male students from Oregon State University participated as subjects in this study. The subjects were volunteers from among the students who were registered in an intermediate weight training class during the fall term of 1987.

The physical characteristics of the individuals who served as subjects in the study are presented in Table 1.

Table 1. Age and Physical Characteristics of the Subjects

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Subjects</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Age (yrs.)</td>
<td>21.63 ±2.46</td>
<td>21.43 ±3.12</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>70.69 ±12.19</td>
<td>59.64 ±6.87</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177.59 ±7.84</td>
<td>169.55 ±7.86</td>
</tr>
</tbody>
</table>
The use of human subjects for the study was approved by the Human Subjects Board at Oregon State University. Informed consent forms were completed by each subject (Appendix, A). The subjects were screened for cardiorespiratory health history and there were no reported problems. Initially, thirteen subjects volunteered for the study, however one subject dropped out after the pre-test due to illness.

Although the subjects were selected from an intermediate circuit weight training class, safety procedures were established assuming the subjects were untrained so that the chances of injury would be minimal. The following procedures were followed during the entire experimental period: 1) the subjects warmed-up prior to the workout and cooled-down at the completion of the program; 2) correct techniques were taught for all exercises; 3) the subjects worked in pairs to act as spotters; 4) a 10 cm wide leather belt was required to be worn during all high intensity lifts.

One minor injury was reported during the study. A female subject strained her lower back on Tuesday of the eighth week of the program. The subject's post-test was delayed one week. A male subject also postponed his post-test for one week due to an upper respiratory illness.
Circuit Weight Training Program

The circuit weight training consisted of a twelve-station circuit which included exercises in the following order: front dumbbell raise; bench press (regular grip); bent-over row; arm/shoulder extensions with elastic tubes; front lat pull-downs; parallel bar dips; dumbbell curls; squats; bench press (narrow grip); leg extension and, sit-ups (Appendix B).

Training resistance selected for the subjects was based on a percent of body weight (Appendix C). Each exercise was executed in short, all-out bursts, of 45 seconds in duration followed by a one minute recovery period.

Strength Endurance Testing

A dynamic endurance oriented strength test was administered for the evaluation of strength changes prior to and after the eight week circuit weight training program. The test consisted of; 1) bench press (regular grip) with an intensity load of 50% of body weight for the males and 30% for the females; 2) bench squats (3/4 squat) at 75% of body weight for males and 50% for females and; 3) sit-ups at 10% of body weight for males and 5% for females with the weight held on the upper chest and performed flat
on the floor.

Each of the three tests were performed for two minutes utilizing correct technique with the total number of repetitions recorded for the evaluation of strength endurance changes.

The first two weeks of the term were a conditioning period for the subjects. The pre-test was conducted during the third week of the term. The post-test was conducted eight weeks after the pre-test.

Treadmill Test

Cardiorespiratory functions were determined using a graded-incremental treadmill test. The modified treadmill peak VO$_2$ protocol, as described by Thoden et al (1980), was administered to each subject to derive direct measurements of peak VO$_2$ and related respiratory function.

Metabolic determinations were made each minute via open circuit spirometry. The subjects breathed through a Daniel's type low-resistance two-way valve with the volume of inspired air being measured by a Parkinson-Cowan CD-4 dry gas meter. The expired air then passed through a 5 liter mixing chamber with a sample being drawn off continuously at a rate of 500 cc. per minute. This sample then passed through a Beckman LB-2 infrared carbon dioxide (CO$_2$) analyzer and an Applied Electrochemistry S-3A oxygen
(O_2) analyzer. The gas analyzers were calibrated against gases of known concentration before and after the tests. Oxygen consumption (peak \( \dot{V}O_2 \)), minute ventilation (peak \( \dot{V}E, BTPS \)), ventilatory equivalent (peak \( \dot{V}E/\dot{V}O_2 \)), heart rate (HR), and the respiratory rate (RR) were calculated immediately via an automatic computer system (Rayfield Electronics, Chicago, Ill.)

The subject's heart rates were monitored using a Physio-Control Lifepak (Physio-Control Corp.) in order to measure heart rate responses during the tests.

Peak values for oxygen uptake and heart rate were determined when the subject met one of the three following criteria: 1) when the highest value for peak \( \dot{V}O_2 \) was indicated either a increase of less than 2.1 ml/kg·min\(^{-1} \) (Taylor et al, 1955), 2) when the respiratory exchange ratio exceeded 1.1, 3) when the heart rate value was greater than the age adjusted maximal heart rate, or 4) the subject declared fatigue.

Maximum oxygen uptake was expressed in milliliters of oxygen per kilogram of body weight per minute (ml/kg·min\(^{-1} \)) and in liters of oxygen per minute (l·min\(^{-1} \)). Buskirk and Taylor (1957) reported that these terms represent the subject's ability to perform maximal work in relative and absolute terms.

In the present study, peak \( \dot{V}O_2 \) values obtained by either the treadmill or the biokinetic swim-bench were
expressed in both absolute terms (1·min⁻¹) and relative terms (ml/kg·min⁻¹).

**Biokinetic Swim-Bench Testing**

The biokinetic swim bench may be described as a semi-accommodating resistance device which allows the subject to preset a regulation speed that provides a constant amount of acceleration in proportion to the force applied by the subject (Heusner, 1980). A swim bench test protocol developed for measuring peak VO₂ by O'Shea and Chiang (1987) was employed in this study.

During the test, the subjects were secured in a prone position on the bench with an elastic wrap around the hips. In the start position, the subjects grasped the stroke paddles with both arms in an extended horizontal position (Figure 1). During the test an arm sweep of 90° was required with each stroke.

Figure 1. The Swim Bench Testing Equipment.
The swim bench test protocol called for progressively increasing resistance with arm stroke velocity constant at 60 strokes per minute. For example, with the swim bench resistance set at 8 the workload was $3.92 \pm 0.05 \text{ m.s}^{-1}$, at 7 - $3.63 \pm 0.05 \text{ m.s}^{-1}$, at 6 - $3.34 \pm 0.05 \text{ m.s}^{-1}$, etc (Sharpe et al, 1982). Thus, as the speed in meters per second decreased, the resistance increased, with the arm velocity constant. This is analogous to a progressive treadmill test where the elevation is gradually increased with the running velocity kept constant.

Prior to each test a four-minute warm-up was given at a workload of 8. During the warm-up all subjects attained a heart rate of 140 to 160 bpm. A four minute recovery followed. Following the recovery period, the graded swim-bench test was administered. The work load started at 7 and was increased every two minutes and continued until the conclusion of the test.

The tests were terminated when the subjects reached one of the three following criteria: 1) when the highest value for peak VO$_2$ by either a change of less than 2.1 ml/kg·min$^{-1}$. (Taylor et al, 1955); or, 2) when the respiratory exchange ratio exceeded 1.1; or, 3) when the stroke rate dropped to 50 strokes per minute for 10 seconds and/or the subject could no longer continue the test.
Swim-Bench Test Protocol Reliability

A test-retest procedure was utilized to determine the reliability of the swim bench test in measuring peak $\dot{V}O_2$. Eleven volunteer subjects (mean age = 22.5 ± 3.2 yrs.) were selected for testing based upon the sample size power test (Courtney, 1984):

$$H_0 : \mu_D = 0 \; ; \; H_a : \mu_D = \Delta ;$$

$$\alpha = .05, \; \beta = .1$$

$$n = \frac{\alpha \mu^2}{\Delta^2} \left( \frac{z_{\alpha/2} + z_\beta}{\mu} \right)^2$$

$$n = \left( \frac{\alpha \mu}{\Delta} \right)^2 \left( \frac{1.96 + 1.28}{\mu} \right)^2$$

$$n = (10.5)^2$$

Pearson's correlation coefficient analysis was employed to test the reliability of the swim bench protocol. Table 1 presents the results of the first and second test for reliability. There was a three day recovery period between the pre-test and the post-test. The peak $\dot{V}O_2$ values as measured by a swim bench test were found to be reliable ($r=0.85$) between the pre- and the post-test (Figure 2).
Table 2. Swim Bench Test Reliability Test. (N=10)

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Wt (kg)</th>
<th>peak VO₂ I</th>
<th>peak VO₂ II</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.5 ±3.2</td>
<td>68.53 ±12.92</td>
<td>1.41 ±.51</td>
<td>1.59 ±.60</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Figure 2. Swim Bench Reliability Test.

\[ r = 0.85 \]

Experimental Design

The experimental design was a two-factor, within subjects design using a pre-test and a post-test for the
cardiorespiratory variables measured. The dependent variables were peak oxygen uptake (peak $\dot{V}O_2$), minute ventilation (peak $\dot{V}E$, BTPS), ventilatory equivalent (peak $\dot{V}E/\dot{V}O_2$), heart rate (HR), and respiratory rate (RR). The independent variables were the biokinetic swim-bench and the treadmill run tests.

An alpha level of .05 was used throughout as the minimum acceptable error probability for rejection level of the null hypothesis.

**Data Analysis**

Statistical analyses of the data were performed using the STATVIEW II package for the Macintosh computer. Paired T-Tests were used to test for differences between the pre-test and post-test scores for hypotheses 1 through 10. A test - retest procedure was utilized to determine the reliability of peak $\dot{V}O_2$ values during the swim bench test.
CHAPTER IV

RESULTS AND DISCUSSION

This study investigated the effect of an eight-week circuit weight training program on cardiovascular measurements during a biokinetic swim bench test and during a treadmill run test. The measurements were completed prior to the initiation of the training program and immediately following the program. The results from the study will be presented in the following order: 1) swim-bench versus treadmill pre-and post-test results; 2) the strength endurance test results; and, 3) comparisons between females and males on pre- and post-test results.

Analysis of the Data

The following table presents a summary of the pre-and post-test means, t-test results, and percent change for the measurements taken during the study (Table 3).
Table 3. Pre-Test and Post-Test Measurements: Mean, Standard Deviation, t-test, and Percent Change.

<table>
<thead>
<tr>
<th>Test</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>t</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB ( \dot{V}O_2 ) (ml/kg·min(^{-1}))</td>
<td>21.15 ±4.90</td>
<td>19.99 ±3.59</td>
<td>-.51</td>
<td>-5%</td>
</tr>
<tr>
<td>TM ( \dot{V}O_2 ) (ml/kg·min(^{-1}))</td>
<td>49.40 ±5.75</td>
<td>49.39 ±5.90</td>
<td>-.50</td>
<td>0%</td>
</tr>
<tr>
<td>SB ( \dot{V}E ) (l·min(^{-1}))</td>
<td>58.80 ±22.44</td>
<td>59.32 ±20.09</td>
<td>.21</td>
<td>+1%</td>
</tr>
<tr>
<td>TM ( \dot{V}E ) (l·min(^{-1}))</td>
<td>87.96 ±16.37</td>
<td>94.15 ±13.94</td>
<td>1.97*</td>
<td>+7%</td>
</tr>
<tr>
<td>SB ( \dot{V}E/\dot{V}O_2 ) (l·min(^{-1}))</td>
<td>36.46 ±8.45</td>
<td>42.25 ±7.32</td>
<td>1.99*</td>
<td>+16%</td>
</tr>
<tr>
<td>TM ( \dot{V}E/\dot{V}O_2 ) (l·min(^{-1}))</td>
<td>25.72 ±3.48</td>
<td>28.46 ±4.38</td>
<td>2.15*</td>
<td>+11%</td>
</tr>
<tr>
<td>SB ( HR ) (beats/min)</td>
<td>153.33 ±24.58</td>
<td>152.33 ±23.27</td>
<td>-.63</td>
<td>-1%</td>
</tr>
<tr>
<td>TM ( HR ) (beats/min)</td>
<td>188.75 ±6.68</td>
<td>192.67 ±6.11</td>
<td>1.75</td>
<td>+2%</td>
</tr>
<tr>
<td>SB ( RR ) (breaths/min)</td>
<td>46.79 ±8.29</td>
<td>48.00 ±4.84</td>
<td>.67</td>
<td>+3%</td>
</tr>
<tr>
<td>TM ( RR ) (breaths/min)</td>
<td>46.50 ±9.24</td>
<td>47.92 ±10.09</td>
<td>1.60</td>
<td>+3%</td>
</tr>
<tr>
<td>Squat (# of reps)</td>
<td>46.38 ±8.32</td>
<td>58.83 ±10.24</td>
<td>6.63**</td>
<td>+26%</td>
</tr>
<tr>
<td>Bench (# of reps)</td>
<td>40.17 ±13.55</td>
<td>47.25 ±16.85</td>
<td>2.86**</td>
<td>+18%</td>
</tr>
<tr>
<td>Sit-up (# of reps)</td>
<td>41.25 ±11.66</td>
<td>57.17 ±12.97</td>
<td>6.76**</td>
<td>+39%</td>
</tr>
</tbody>
</table>

* p < .05  SB = Biokinetic Swim Bench Test  
** P < .01  TM = Treadmill Run Test
The following are the results of the hypotheses tested in this study.

**HO 1**: \( \mu_{sb} = \mu_{tm} \)

where,

- \( \mu_{sb} \) = the mean change peak in \( \dot{V}O_2 \) measurements during the swim-bench test,
- \( \mu_{tm} \) = the mean change in peak \( \dot{V}O_2 \) measurements during the treadmill test,

**HA 1**: \( \mu_{sb} \geq \mu_{tm} \)

The results of a paired t-test showed that there was no significant difference in the mean pre- and post-test peak \( \dot{V}O_2 \) measurements between the swim-bench and the treadmill tests. Therefore, the test failed to reject the null hypothesis. Swim-bench peak \( \dot{V}O_2 \) measurements to the eight-week circuit weight training program were not greater than the treadmill peak \( \dot{V}O_2 \) measurements to the same program (Table 4 and Table 5).

### Table 4. Peak \( \dot{V}O_2 \) Measurements during the Swim Bench Test and the Treadmill Test (ml/kg·min\(^{-1}\)).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre Mean (X)</th>
<th>s</th>
<th>Post Mean (Y)</th>
<th>s</th>
<th>Y-X</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB ( \dot{V}O_2 )</td>
<td>21.15</td>
<td>4.90</td>
<td>19.99</td>
<td>3.59</td>
<td>-1.16</td>
<td>-.51</td>
<td>&gt;.1</td>
</tr>
<tr>
<td>TM ( \dot{V}O_2 )</td>
<td>49.40</td>
<td>5.75</td>
<td>49.39</td>
<td>5.90</td>
<td>-0.01</td>
<td>-.50</td>
<td>&gt;.1</td>
</tr>
</tbody>
</table>
Table 5. Peak $\dot{V}O_2$ Measurement Differences for the Swim Bench Test versus the Treadmill Test (ml/kg·min$^{-1}$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>SB Diff.</th>
<th>TM Diff.</th>
<th>X-Y</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\dot{V}O_2$</td>
<td>-1.16</td>
<td>.03</td>
<td>-1.19</td>
<td>-.58</td>
<td>&gt;.1</td>
</tr>
</tbody>
</table>

**H0 2:** $\mu_{sb} = \mu_{tm}$

where,

$\mu_{sb} =$ the mean change in peak $\dot{V}E,BTPS$ measurements during the swim-bench test,

$\mu_{tm} =$ the mean change in peak $\dot{V}E,BTPS$ measurements during the treadmill test,

**HA 2:** $\mu_{sb} \geq \mu_{tm}$

The results of paired t-tests show that there was no significant difference in the mean changes in peak $\dot{V}E,BTPS$ measurements for the swim-bench tests. However, there was a significant increase for the treadmill swim-bench peak $\dot{V}E,BTPS$ measurements (Table 6). The treadmill peak $\dot{V}E,BTPS$ measurement showed a 7% increase in the pre-test versus the post-test (Table 7) (Figure 3).
Table 6. Peak VE, BTPS Measurements for the Swim Bench Test and the Treadmill Test (l·min⁻¹).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre Mean (X)</th>
<th>s</th>
<th>Post Mean (Y)</th>
<th>s</th>
<th>Y-X</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB peak VE</td>
<td>58.80</td>
<td>22.44</td>
<td>59.32</td>
<td>20.09</td>
<td>0.52</td>
<td>.21</td>
<td>&gt;.4</td>
</tr>
<tr>
<td>TM peak VE</td>
<td>87.96</td>
<td>16.37</td>
<td>94.15</td>
<td>13.94</td>
<td>6.19</td>
<td>1.97</td>
<td>&lt;.05</td>
</tr>
</tbody>
</table>
Figure 3. Peak VE, BTPS Pre- and Post-Test Measurements for the Treadmill Test (l·min⁻¹).
Table 7. Peak \( \dot{V}E, \text{BTFS} \) Measurement Differences for the Swim Bench Test versus the Treadmill Test ( \( 1\cdot\text{min}^{-1} \)).

<table>
<thead>
<tr>
<th>Variable</th>
<th>SB Diff.</th>
<th>TM Diff.</th>
<th>Y-X</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>peak VE</td>
<td>0.52</td>
<td>6.19</td>
<td>5.67</td>
<td>1.20</td>
<td>&gt;.1</td>
</tr>
</tbody>
</table>

**HO 3:** \( \mu_{sb} = \mu_{tm} \)

where,

\( \mu_{sb} = \) the mean change in peak ventilatory equivalent measurements as during the swim-bench test,

\( \mu_{tm} = \) the mean change in peak ventilatory equivalent measurements as during the treadmill test,

**HA 3:** \( \mu_{sb} \geq \mu_{tm} \)

The results of paired t-tests show that there was no significant difference in the mean changes in peak ventilatory equivalent measurements between the swim-bench and the treadmill tests. Therefore, the test failed to reject the null hypothesis. Swim-bench peak ventilatory equivalent measurements following the eight-week circuit weight training program were not greater than the treadmill peak ventilatory equivalent measurements to the same program (Table 8). However, there was a significant
difference in the pre-and post-test peak ventilatory equivalent for both the swim bench test and the treadmill test (p<.05). The percent increase in the post-test swim bench test was 16%, while the percent increase in the post-test treadmill test was 11%. (Table 3) (Figure 4).

Table 8. Peak VE/VO₂ Measurements during the Swim Bench Test and the Treadmill Test (l·min⁻¹).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre Mean (X)</th>
<th>s</th>
<th>Post Mean (Y)</th>
<th>s</th>
<th>Y-X</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB peak VE/VO₂</td>
<td>36.46</td>
<td>8.45</td>
<td>42.25</td>
<td>7.32</td>
<td>5.79</td>
<td>1.99</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>TM peak VE/VO₂</td>
<td>25.72</td>
<td>3.48</td>
<td>28.46</td>
<td>4.38</td>
<td>2.74</td>
<td>2.15</td>
<td>&lt;.05</td>
</tr>
</tbody>
</table>
Figure 4. Peak $\dot{V}E/\dot{V}O_2$ Pre-Post-Test Changes for the Swim Bench Test ($l\cdot min^{-1}$).
Figure 5. Peak $\dot{V}E/\dot{V}O_2$ Pre-Post-Test Changes for the Treadmill Test.
Table 9. Peak $\dot{V}E/\dot{V}O_2$ Measurements Differences for the Swim Bench Test versus the Treadmill Test (1·min$^{-1}$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>SB Diff. (X)</th>
<th>TM Diff. (Y)</th>
<th>Y-X</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>peak $\dot{V}E/\dot{V}O_2$</td>
<td>5.79</td>
<td>2.74</td>
<td>-3.05</td>
<td>-0.95</td>
<td>&gt;.1</td>
</tr>
</tbody>
</table>

**HO 4:** $\mu_{sb} = \mu_{tm}$

where,

$\mu_{sb} =$ the mean change in heart rate measurements during the swim-bench test,

$\mu_{tm} =$ the mean change in heart rate measurements during the treadmill test,

**HA 4:** $\mu_{sb} \geq \mu_{tm}$

The results of a paired t-test showed that the mean differences in heart rate between the swim-bench test and the treadmill test were not significantly different. Therefore, the test failed to reject the null hypothesis. There was no difference between the pre-and post-test heart rate values achieved during the swim-bench measurements following the eight-week circuit weight training program were no different than the treadmill heart rate measurements to the same program (Table 10 and Table 11).
Table 10. Heart Rate Measurements for the Swim Bench Test versus the Treadmill Test (beats/min.).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre Mean (X)</th>
<th>s</th>
<th>Post Mean (Y)</th>
<th>s</th>
<th>Y-X</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB</td>
<td>153.33</td>
<td>24.58</td>
<td>152.33</td>
<td>23.27</td>
<td>-1.00</td>
<td>-0.63</td>
<td>p&gt;.4</td>
</tr>
<tr>
<td>TM</td>
<td>188.75</td>
<td>6.68</td>
<td>192.67</td>
<td>6.11</td>
<td>3.92</td>
<td>1.75</td>
<td>p&gt;.1</td>
</tr>
</tbody>
</table>

Table 11. Heart Rate Measurement Differences for the Swim Bench Test versus the Treadmill Test (beats/min.).

<table>
<thead>
<tr>
<th>Variable</th>
<th>SB Diff. (X)</th>
<th>TM Diff. (Y)</th>
<th>X-Y</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td>-1.00</td>
<td>3.92</td>
<td>2.92</td>
<td>.82</td>
<td>p&gt;.1</td>
</tr>
</tbody>
</table>

**HO 5:** \( \mu_{sb} = \mu_{tm} \)

where,

\( \mu_{sb} \) = the mean change in respiratory rate measurements during the swim-bench test,

\( \mu_{tm} \) = the mean change in respiratory rate measurements during the treadmill test,

**HA 5:** \( \mu_{sb} \geq \mu_{tm} \)

The results of a paired t-tests shows that the mean
differences in respiratory rate between the swim-bench test and the treadmill test were not significantly different. Therefore, the test failed to reject the null hypothesis. Swim-bench respiratory rate measurements for the eight-week circuit weight training program were no different than the treadmill respiratory rate measurements to the same program (Table 12 and Table 13).

Table 12. Mean Respiratory Rate Measurements for the Swim Bench Test and the Treadmill Test (breaths/min).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre Mean (X)</th>
<th>s</th>
<th>Post Mean (Y)</th>
<th>s</th>
<th>Y-X</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB</td>
<td>46.79</td>
<td>8.29</td>
<td>48.00</td>
<td>4.84</td>
<td>1.25</td>
<td>0.67</td>
<td>p&gt;.1</td>
</tr>
<tr>
<td>TM</td>
<td>46.5</td>
<td>9.24</td>
<td>47.92</td>
<td>10.09</td>
<td>1.42</td>
<td>1.60</td>
<td>p&gt;.05</td>
</tr>
</tbody>
</table>

Table 13. Respiratory Rate Differences for the Swim Bench Test versus the Treadmill Test (breaths/min).

<table>
<thead>
<tr>
<th>Variable</th>
<th>SB Diff. (X)</th>
<th>TM Diff. (Y)</th>
<th>Y-X</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory Rate</td>
<td>1.25</td>
<td>1.42</td>
<td>0.17</td>
<td>0.08</td>
<td>p&gt;.4</td>
</tr>
</tbody>
</table>
**HO 6:** $\mu_{\text{post}} = \mu_{\text{pre}}$

where,

$\mu_{\text{pre}} = \text{pre-test mean number of repetitions for squat strength endurance}$

$\mu_{\text{post}} = \text{post-test mean number of repetitions for squat strength endurance}$

**HA 6:** $\mu_{\text{post}} \geq \mu_{\text{pre}}$

The results of a paired t-test showed that the mean number of post-test repetitions was significantly greater than the mean number of pre-test repetitions for the standard squat test. Therefore, the alternative hypothesis was accepted: the mean number of post test repetitions for the squat strength endurance test was greater than the mean number of repetitions for the pre-test. These results showed that there was an increase in strength endurance over the eight-week circuit weight training program as measured by the squat strength endurance test.

**HO 7:** $\mu_{\text{post}} = \mu_{\text{pre}}$

where,

$\mu_{\text{pre}} = \text{pre-test mean repetitions for bench press strength endurance test}$

$\mu_{\text{post}} = \text{post-test mean repetitions for bench press strength endurance test}$

**HA 7:** $\mu_{\text{post}} \geq \mu_{\text{pre}}$
The results of a paired t-test showed that the mean number of post-test repetitions was significantly greater than the mean number of pre-test repetitions for the standard bench press strength endurance test. Therefore, the alternative hypothesis was accepted: the mean number of post test repetitions for the bench press strength endurance test was greater than the mean number of repetitions for the pre-test. These results showed that there was an increase in strength endurance over the eight-week circuit weight training program as measured by the bench press strength endurance test.

**HO 8:** \( \mu_{\text{post}} = \mu_{\text{pre}} \)

where,

- \( \mu_{\text{pre}} \) = pre-test mean repetitions for sit-up strength endurance test
- \( \mu_{\text{post}} \) = post-test mean repetitions for sit-up strength endurance test

**HA 9:** \( \mu_{\text{post}} \geq \mu_{\text{pre}} \)

The results of a paired t-test showed that the mean number of post-test repetitions was significantly greater than the mean number of pre-test repetitions for the sit-up strength endurance test. Therefore, the alternative hypothesis was accepted: the mean number of post test repetitions for the sit-up strength endurance test was
greater than the mean number of repetitions for the pre-test. These results showed that there was an increase in sit-up strength endurance test over the eight-week circuit weight training program as measured by the sit-up strength endurance test. Table 14 presents the results of the squat, bench-press, and sit-up tests for all subjects. Tables 15 and 16 present the same results for the female and male subjects, respectively.

Table 14. Mean Scores on the Pre-and Post-Test Strength Endurance Tests for all Subjects.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre Mean (X)</th>
<th>Pre Mean s</th>
<th>Post Mean (Y)</th>
<th>Post Mean s</th>
<th>Y-X</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squat</td>
<td>46.83</td>
<td>8.32</td>
<td>58.83</td>
<td>10.24</td>
<td>12.00</td>
<td>6.63</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Bench Press</td>
<td>40.17</td>
<td>13.55</td>
<td>47.25</td>
<td>16.85</td>
<td>7.08</td>
<td>2.86</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Sit-Up</td>
<td>41.25</td>
<td>11.66</td>
<td>57.17</td>
<td>12.97</td>
<td>15.92</td>
<td>6.76</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>
### Table 15. Difference between Mean Scores on the Pre- and Post-Test Strength Endurance Tests for the Female Subjects.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre Mean (X)</th>
<th>s</th>
<th>Post Mean (Y)</th>
<th>s</th>
<th>Y-X</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squat</td>
<td>39.75</td>
<td>5.5</td>
<td>57.0</td>
<td>9.59</td>
<td>17.25</td>
<td>6.65</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Bench Press</td>
<td>30.25</td>
<td>4.92</td>
<td>34.5</td>
<td>4.20</td>
<td>4.25</td>
<td>5.67</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Sit-Up</td>
<td>54.25</td>
<td>3.94</td>
<td>68.25</td>
<td>5.12</td>
<td>14.0</td>
<td>19.80</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>

### Table 16. Difference between Mean Scores on the Pre- and Post-Test Strength Endurance Tests for the Male Subjects.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre Mean (X)</th>
<th>s</th>
<th>Post Mean (Y)</th>
<th>s</th>
<th>Y-X</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squat</td>
<td>50.38</td>
<td>7.27</td>
<td>62.25</td>
<td>6.94</td>
<td>11.88</td>
<td>9.12</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Bench Press</td>
<td>45.13</td>
<td>13.95</td>
<td>53.63</td>
<td>17.29</td>
<td>8.53</td>
<td>6.63</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Sit-Up</td>
<td>34.75</td>
<td>7.80</td>
<td>51.63</td>
<td>12.15</td>
<td>16.88</td>
<td>6.76</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>
Figure 6. Mean Strength Endurance Pre-Test and Post-Test Results.
The results from the female subjects (N=4) and the male subjects (N=8) were tested separately to find if there was a difference in responses to the circuit weight training program between the male and female subjects.

**HO 9:** \( \mu_{sb} = \mu_{tm} \)

where,

\( \mu_{sb} = \) the mean change in peak \( \dot{V}O_2 \), peak \( \dot{V}E \), BTPS, peak \( \dot{V}E/\dot{V}O_2 \), heart rate, and respiratory rate measurements during the swim-bench test for the females,

\( \mu_{tm} = \) the mean change in peak \( \dot{V}O_2 \), peak \( \dot{V}E \), BTPS, peak \( \dot{V}E/\dot{V}O_2 \), heart rate, and respiratory rate measurements during as measured by the treadmill test for the females,

**HA 9:** \( \mu_{sb} \geq \mu_{tm} \)

**HO 10:** \( \mu_{sb} = \mu_{tm} \)

where,

\( \mu_{sb} = \) the mean change in peak \( \dot{V}O_2 \), peak \( \dot{V}E \), BTPS, peak \( \dot{V}E/\dot{V}O_2 \), heart rate, and respiratory rate measurements during the swim-bench test for the males,

\( \mu_{tm} = \) the mean change in peak \( \dot{V}O_2 \), peak \( \dot{V}E \), BTPS, peak \( \dot{V}E/\dot{V}O_2 \), heart rate, and respiratory rate measurements during the treadmill test for the males,

**HA 10:** \( \mu_{sb} \geq \mu_{tm} \)
The results of the paired t-tests showed that neither the female nor the male subjects responded significantly differently between the pre-test and the post-test in the cardiorespiratory measurements during the swim-bench test and the treadmill test (Table 17).

Table 17. Cardiorespiratory Measurements for the Female and the Male Subjects for Pre-and Post-Test Differences.

<table>
<thead>
<tr>
<th>Variable</th>
<th>SB Diff. (X)</th>
<th>TM Diff. (Y)</th>
<th>Y-X</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\dot{V}O_2$</td>
<td>1.96</td>
<td>-2.35</td>
<td>4.31</td>
<td>1.45</td>
<td>&gt;.1</td>
</tr>
<tr>
<td>$VE_{BTPS}$</td>
<td>0.73</td>
<td>12.11</td>
<td>11.38</td>
<td>1.32</td>
<td>&gt;.1</td>
</tr>
<tr>
<td>$VE/\dot{V}O_2$</td>
<td>4.96</td>
<td>3.31</td>
<td>-1.66</td>
<td>-0.29</td>
<td>&gt;.1</td>
</tr>
<tr>
<td>HR</td>
<td>4.0</td>
<td>-6.5</td>
<td>-10.50</td>
<td>-0.92</td>
<td>&gt;.1</td>
</tr>
<tr>
<td>RR</td>
<td>-7.25</td>
<td>-0.25</td>
<td>-7.0</td>
<td>-1.93</td>
<td>&gt;.05</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\dot{V}O_2$</td>
<td>0.76</td>
<td>1.16</td>
<td>0.40</td>
<td>0.15</td>
<td>&gt;.1</td>
</tr>
<tr>
<td>$VE_{BTPS}$</td>
<td>0.42</td>
<td>3.23</td>
<td>2.82</td>
<td>0.49</td>
<td>&gt;.4</td>
</tr>
<tr>
<td>$VE/\dot{V}O_2$</td>
<td>6.21</td>
<td>2.46</td>
<td>-3.75</td>
<td>-0.91</td>
<td>&gt;.1</td>
</tr>
<tr>
<td>HR</td>
<td>-0.50</td>
<td>-2.63</td>
<td>-2.13</td>
<td>-0.28</td>
<td>&gt;.1</td>
</tr>
<tr>
<td>RR</td>
<td>1.75</td>
<td>-0.75</td>
<td>-2.50</td>
<td>-1.50</td>
<td>&gt;.05</td>
</tr>
</tbody>
</table>
Discussion

Strength Adaptations to Circuit Weight Training

Previous studies, and the present study, have shown that muscular strength can be significantly increased by circuit weight training programs. The results of the present study showed that there was a significant mean increase in the number of repetitions in the squat, bench press, and sit-up tests with a gain of 26%, 18%, and 39% respectively (p < .01). The female subjects gained 43% in the squat, 14% in bench press, and 26% in sit-up tests. The male subjects gained 24% in squat, 19% in bench press, and 48% in sit-up tests. These gains were consistent with those found in other circuit weight training programs (Wilmore et al, 1980; Gettman and Pollock, 1982; Harris and Holly, 1987; Coyle et al, 1983).

The results of the present study confirmed the studies which report that circuit weight training imposes a sufficient stimulus to the neuromuscular and the physiological systems to elicit improvement in muscular strength (Edington and Edgerton, 1976). Adaptations of the neuromuscular system to the stress of the strength training program involves changes in the recruitment patterns of the motor units. Such a change would reflect an increase in
spatial summation and a corresponding decrease in the nerve activation threshold due in part to greater facilitation of the synapse (O'Shea and Wegner, 1981). Moreover, strength training induces changes in blood metabolites which reflects a mobilization of both carbohydrate and lipid stores for energy (Guezennes et al, 1986).

Both the male and the female subjects showed larger strength gains for the squat test than for the bench press test. The result was expected for the following reasons: 1) squat strength training involves the larger muscle groups in the body and normally demonstrates the greater proportional gains than the smaller muscle groups such as those used for the bench press; 2) from an anatomical viewpoint, the squat movement develops the erector spinae, gluteus maximus, and medius, tensor fasciae latae, quadriceps, abdominals, hamstrings, and ankle flexors (O'Shea, 1983). The bench press develops the triceps, deltoids, pectorals, and latissimus dorsi (Capen, 1956). The large muscle groups used in the squat demonstrate greater strength gains than the the small muscle groups, and used in the bench press; 3) it has been shown that the larger muscle groups demonstrate a greater trainability than the smaller muscle groups (Sung, 1983).
Cardiorespiratory Adaptations to Circuit Weight Training

The results of the present study showed no significant difference in the pre-test versus the post-test measures of peak \( \dot{V}O_2 \), heart rate, or respiratory rate. There was a significant increase in the treadmill post-test peak VE with a mean increase of 7\% (\( p < .05 \)). There were also significant increases in the swim bench and treadmill post-test ventilatory equivalent responses with a mean increase of 16\% and 11\%, respectively (\( p < .05 \)).

The results of the study failed to support the notion that circuit weight training improved peak oxygen uptake (peak \( \dot{V}O_2 \)). The possible explanation for this result may be accounted for by referring to the following equation:

\[
\text{peak oxygen uptake} = \text{maximal cardiac output} \times \text{maximal arterio/venous difference (a-\text{v}O_2 \text{ difference})}
\]

Maximal cardiac output is the maximal blood volume pumped by the heart per minute, while maximal arterial-venous difference is the maximal difference in oxygen content of the arterial versus the venous blood. When the body has an increasing demand for oxygen, the cardiovascular system responds by enhancing stroke volume, heart rate, and maximal a-\text{v}O_2 difference. Peak oxygen uptake would be increased if any of the three elements were increased, provided no change otherwise.

Factors contributing to a-\text{v}O_2 difference have been
well established: 1) an individual's capacity to divert a large portion of the cardiac output to working muscle groups; 2) local aerobic capacity (the level of microcirculation in the skeletal muscle) may also affect a-\(\text{VO}_2\) difference, i.e. an increase in the capillary-to-fiber ratio would provide for a greater interface for the exchange of nutrients and metabolic gases (Coyle et al 1983; Hermansen & Wachtlova, 1981; and Saltin et al, 1977), and; 3) the ability of individual muscle cells to generate energy aerobically (aerobic glycolysis). The mitochondria enlarge and increase in number and the quantity of enzymes for aerobic energy transfer also increase (Hickson, 1981; Holloszy & Coyle, 1984). This results in an enhanced capacity for the aerobic glycolysis of ATP as well as the ability of the cell to generate a steady rate of aerobic metabolism without an increase in blood lactate (Coyle et al, 1983).

The primary explanation for the insignificant difference in the peak \(\text{VO}_2\) may be the utilization of the intermediate level weight training students as subjects. The initial mean peak \(\text{VO}_2\) values for the male and female subjects were 51.78 ml/kg·min\(^{-1}\) and 44.58 ml/kg·min\(^{-1}\) respectively. In contrast, the initial average peak \(\text{VO}_2\) for the subjects in Messier and Dill (1985) and Gettman and Pollack (1982) were 47.43 ± 4.3 ml/kg·min\(^{-1}\) and 47.67 ±1.5 ml/kg·min\(^{-1}\) respectively. The potential for gains in peak
\( \dot{V}O_2 \) for the subjects of the present study may have been a limiting factor due to a ceiling effect from prior circuit weight training experience. A second factor may have been that training only two times a week seems to be insufficient to develop significant increase in peak \( \dot{V}O_2 \).

When comparing the peak \( \dot{V}O_2 \) responses between the swim-bench and the treadmill, the swim-bench peak \( \dot{V}O_2 \) was only 41-43% of the treadmill test (Appendix D). In addition, the swim-bench values are somewhat lower than those reported for standard arm-crank ergometry in which peak \( \dot{V}O_2 \) values are generally between 65-75% of treadmill peak \( \dot{V}O_2 \) values (Magel et al, 1978).

The relatively low peak \( \dot{V}O_2 \) values during the swim bench test may be attributed to two main factors. First, the upper body is used in the swim bench test thus using the relatively small muscle groups. With the activation of the smaller muscle groups, there would be an expected lower demand on the central circulation, and thus a lower total aerobic demand when compared to large muscle groups (Lewis et al, 1983).

Second, it is possible that the exercise posture performed on the swim bench restricted normal chest expansion and thereby decreased minute ventilation and increased ventilatory equivalent. The swim bench peak \( \dot{V}E \), BTPS values were only 63-67% of the treadmill run values, and the swim bench peak \( \dot{V}E/\dot{V}O_2 \) values were as high as
142-148% of the treadmill values. This indicated that the position of the torso on the swim bench limited minute ventilation and produced a larger ventilatory equivalent. It appears that although the position on the swim bench restricted breathing movements of the thorax, oxygen consumption was much smaller than while running on the treadmill and therefore the ventilatory equivalent was greater on the swim bench.

**Minute Ventilation (peak \( \dot{VE} \), BTPS)**

As shown in Appendix D, the swim bench pre-and post-mean peak \( \dot{VE}, \text{BTPS} \) were 58.80 ±22.44 and 59.32 ± 20.09 l·min\(^{-1}\) respectively. The treadmill run pre- and post-test mean peak \( \dot{VE}, \text{BTPS} \) were 87.96 ±16.37 and 94.15 ± 13.94 l·min\(^{-1}\) respectively. There were no significant pre- and post-test differences between the swim bench and the treadmill run tests. A significant difference in the treadmill pre- and post-test was found: the post-test value was 7% greater than the pre-test value (p<.05).

The swim bench peak \( \dot{VE}, \text{BTPS} \) values were 63-67% of the treadmill run values. As previously mentioned, this may be due to the body position on the swim bench which restricts chest expansion and thereby decreases peak \( \dot{VE}, \text{BTPS} \) values. Since peak \( \dot{VE} \), BTPS increases with \( \dot{VO}_2 \) and \( \text{CO}_2 \) production during exercise to maintain the proper capillary gradients and to enhance optimal rates of gas exchange, a greater
ventilatory response would be expected from the treadmill run test because there was no restriction on chest expansion during the test.

**Ventilatory Equivalent (VE/VO₂)**

Ventilatory equivalent refers to the ratio of minute ventilation to oxygen consumption; therefore, the measurement of ventilatory equivalent is related to the efficiency of ventilation per liter of oxygen consumed. The greatest respiratory efficiency is found in exercises that produce the lowest ventilatory equivalent values. A comparison between the swim bench and the treadmill run test peak VE/VO₂ values shows that the swim bench has an excessive 29% and 48% difference in the pre- and post-test measurements respectively (Appendix D). This suggests that the swim bench performance was less efficient per liter of oxygen consumed than the treadmill run performance. These results were expected because ventilatory adaptation appears highly specific to the type of exercise used during training. When an individual performs either arm or leg exercise, the ventilatory equivalent is always greater during arm work than during leg work (Rasmussen et al, 1975). Moreover, the restrictive nature of the swim bench on breathing may pose a problem in providing for adequate gas exchange, thereby, decreasing the efficiency of ventilation per liter of oxygen consumed, which in turn
increases the ventilatory equivalent.

**Heart Rate**

The heart rates obtained at the highest peak $\dot{V}O_2$ during the swim bench test were 81% and 77% of the pre- and the post-treadmill run tests, respectively. These values were relatively high when compared to the same comparison for peak $\dot{V}O_2$. The swim bench peak $\dot{V}O_2$ at pre-test was 43% of that achieved during the treadmill pre-test and 41% of that achieved during the treadmill post-test (Appendix D). Astrand et al (1965) and Stenberg et al (1967) reported that heart rate at a given oxygen uptake is higher when the exercise is performed with the arms than with the legs. This probably explains why at peak $\dot{V}O_2$ during the swim bench test constituted 41-43% of the peak $\dot{V}O_2$ of the treadmill run test whereas the heart rate was as high as 77% and 81% of the maximal heart rate during the treadmill run test.

The analysis of the data indicated that there was no significant pre- and post-test difference in heart rate between swim bench and treadmill run tests. This may be due to the nature of circuit weight training programs with the emphasis on upper body rather than lower body work (Wilmore et al 1978; Messier & Dill, 1985; Gettman et al, 1978 Gettman and Pollack, 1982). Since the musculature of the lower body was not highly involved, the demands placed
on the circulatory system may not have created the demand necessary to elicit a training effect (Benerakis, 1983).

**Respiratory Rate**

The peak respiratory rate values recorded for the swim bench pre- and post-test were 46.79 ± 8.29 and 48.0 ± 4.84 breaths/min, and 46.50 ± 9.24 and 47.92 ± 10.09 breaths/min for the treadmill run test (Appendix D). Astrand and Rodahl (1977) reported that in many types of physical work, the respiratory rate tends to become fixed to the work rhythm.

The results of the present study showed that the respiratory rate obtained during the swim bench test was not significantly different than the treadmill run test even though the ventilation values during the swim bench test were only 63 to 67% of the treadmill run test.

Expired volume may be calculated by multiplying respiratory rate in breaths per minute times mean tidal volume. Since this is true, our data suggests a 33-37% reduction of tidal volume while performing the swim bench test. This again may be due to the prone position used to perform the swim bench test which restricted chest expansion and thereby decreased minute ventilation, thus increasing ventilatory equivalent. The observed incremented respiratory rate during swim bench testing may represent an adaptation to these conditions.
CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The present study was designed to investigate the cardiorespiratory responses to circuit weight training as measured by a biokinetic swim bench test versus a treadmill run test. It was hypothesized that as a result of an eight-week circuit weight training program, there would be no significant difference in cardiorespiratory responses as measured by a biokinetic swim bench test versus a treadmill run test.

The subjects for the study were eight male and four female students with a mean age of 21.63 ± 2.46 years; a mean of height 177.59 ± 7.84 cm; and a mean weight of 70.69 ± 12.19 kg. Strength endurance was measured for three exercises (squat, bench press, and sit-up) both prior to, and following the training program. Peak oxygen uptake (peak VO₂), peak minute ventilation (peak VE,BTPS), peak ventilatory equivalent (peak VE/VO₂), heart rate (HR), and respiratory rates were measured (pre- and post-test) using graded biokinetic swim bench and treadmill run tests.

To determine the reliability of the biokinetic swim
bench testing protocol used in the present study, a test - re-test data collection session was performed. The results from the peak VO₂ measurements were used to find the test reliability by Pearson's correlation coefficient.

Circuit weight training has received considerable attention as a means of increasing physical fitness. The literature on the effect of circuit weight training on cardiorespiratory function is voluminous; however, conflicting evidence exists among the previous studies regarding the cardiorespiratory benefits of circuit weight training. This may be due to the role specificity plays in aerobic testing and training. Training specificity says that adaptations to training are best seen when performing the specific activity that was used to produce the changes. The difficulty with evaluating a circuit weight training program is there is no single test that accurately simulates a training program. Better results could be obtained if there were a device that accurately evaluated the demands of the specific training programs.

The following results from the study were noted:

1. The correlation coefficient of peak VO₂ test - re-test was r = .85, suggesting that strong reliability exists in the biokinetic swim bench testing protocol developed for the present study.

2. There was a significant increase in mean number of
repetitions for all subjects in the squat, bench press, and sit up tests with a mean improvement of 26%, 18%, and 39% respectively (p < .01).

3. No significant changes were found in the pre- and post-test measures of peak $\dot{V}O_2$, heart rate, or respiratory rate.

4. There was a significant peak $V_e$, BTPS difference in the treadmill pre- and post-test, with a mean increase of 7% (p < .05) for the post-test.

5. There was a significant increase in the swim bench and treadmill post-test peak $V_e/\dot{V}O_2$ measurements with a mean increase of 16% and 11% respectively (p<.05).

Conclusions

Within the limitations of the present study, the following conclusions appear to be justified:

1. An eight week circuit weight training will produce significant strength gains in those individuals who follow the program correctly.

2. The present study failed to support the notion that circuit weight training programs improve cardiorespiratory responses when training only two times a week.

3. The biokinetic swim bench testing protocol used in the present study was found to be reliable and can be used as a means for the evaluation of aerobic capacity for upper
Recommendations for Further Research

The lack of standardization in the design of circuit weight training programs may account for the inconsistent findings concerning cardiorespiratory benefits of circuit weight training. The observations from previous studies have shown that the training programs vary in the number of repetitions, in the number of sets, in the amount of rest between exercises, and the amount of resistance used. Apparently, there is a need for the development of a scientific basis for circuit weight training programs. Although the program used in the present study showed no significant improvement in the pre- and post-tests of the cardiorespiratory system, a significant gain in strength indicated that the program imposed a sufficient stimulus to the neuromuscular and physiological systems for the development of improved fitness.

It is suggested that a significant increase in cardiorespiratory function may possibly be seen if the following changes were made in the design of the study:

1. Conduct a similar study using a large sample size.

2. Increase the training period or the number of training sessions within the training period.

3. Compare the changes in responses for both beginner and intermediate individuals. The use of intermediate level
students in the present study may have limited the demonstration of improvements in cardiorespiratory responses to circuit weight training because of a plateau effect due to the prior weight training experience of the subjects.

4. Redesign the biokinetic swim-bench so as to eliminate the pressure on the chest.

5. Redesign the biokinetic swim bench so as to include both arm and leg action.
REFERENCES


Bradshaw, P. *A comparison of three modes of testing for*


Morgan, R.E. and Adamson, G.T. *Circuit weight training*. Bell


APPENDICES
APPENDIX A

INFORMED CONSENT RELEASE

In consideration of the benefits to be derived and the data to be generated, the undersigned, a student of Oregon State University, agrees to participate in the research project Cardiorespiratory Responses to Circuit Weight Training as Measured by a Biokinetic Swim-Bench Test and a Treadmill Run Test under the direction of Dr. J.P. O'Shea, professor of physical education, Oregon State University.

The undersigned states that he or she has read an outline of a proposed study, including the possible risks and benefits, and is participating voluntarily and consents to following testing and training program outlined. The undersigned also agrees to the use of the data generated as the above agencies may desire.

At any time during the study, if circumstances should arise and the undersigned cannot complete the study, he or she is free to discontinue. The student, however, understands that payment as agreed can be provided only if the study is completed in full.

Participant

Date
APPENDIX B

WEIGHT TRAINING CIRCUIT

MONDAY AND WEDNESDAY WORKOUT SCHEDULE

Do the following exercises in the order given:

1. Front dumbbell raise - 3 sets of 20 reps.
2. Bench press - 3-4 sets of 8 - 10 reps.
5. Front lat pull-downs 3 sets or 12-15 reps.
6. Parallel bar dips - 3 sets of 10-12 reps.
7. Dumbbell curls - 3-4 sets of 10-12 reps.
8. Squats - 3 sets of 8-10 reps.
10. Sit-ups - 2-3 sets of 20 reps.

Each exercise should be 45 seconds in duration, followed by a 1 minute recovery period.
### APPENDIX C

**WEIGHT CALCULATION**

<table>
<thead>
<tr>
<th>Exercise</th>
<th>% of body Wt</th>
<th>Weight</th>
<th>reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front dumbbell raise</td>
<td>20-25</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>Bench press.</td>
<td>40-50</td>
<td>8-10</td>
<td>3-4</td>
</tr>
<tr>
<td>Bent-over row</td>
<td>25-30</td>
<td>12-15</td>
<td>3</td>
</tr>
<tr>
<td>Arm/shoulder extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with tubes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front lat pull-downs</td>
<td>55-60</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>Parallel bar dips</td>
<td>25-30</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>Dumbbell curls</td>
<td>20-25</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>Squats</td>
<td>65-75</td>
<td>8-10</td>
<td>3</td>
</tr>
<tr>
<td>Leg extension</td>
<td>40-50</td>
<td>12-15</td>
<td>2</td>
</tr>
<tr>
<td>Sit-ups</td>
<td>10-15</td>
<td>20</td>
<td>2-3</td>
</tr>
</tbody>
</table>
## APPENDIX D

### SUMMARY OF RESULTS

<table>
<thead>
<tr>
<th>Test</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>t</th>
<th>%</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB $\dot{V}O_2$ (ml/kg/min$^{-1}$)</td>
<td>21.15±4.90</td>
<td>19.99±3.59</td>
<td>-.51</td>
<td>-5%</td>
<td></td>
</tr>
<tr>
<td>TM $\dot{V}O_2$ (ml/kg/min$^{-1}$)</td>
<td>49.40±5.75</td>
<td>49.39±5.90</td>
<td>-.50</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>SB VE (l/min$^{-1}$)</td>
<td>58.80±22.44</td>
<td>59.32±20.09</td>
<td>.21</td>
<td>+1%</td>
<td></td>
</tr>
<tr>
<td>TM VE (l/min$^{-1}$)</td>
<td>87.96±16.37</td>
<td>94.15±13.94</td>
<td>1.97*</td>
<td>+7%</td>
<td></td>
</tr>
<tr>
<td>SB VE/$\dot{V}O_2$ (l/min$^{-1}$)</td>
<td>36.46±8.45</td>
<td>42.25±7.32</td>
<td>1.99*</td>
<td>+16%</td>
<td></td>
</tr>
<tr>
<td>TM VE/$\dot{V}O_2$ (l/min$^{-1}$)</td>
<td>25.72±3.48</td>
<td>28.46±4.38</td>
<td>2.15*</td>
<td>+11%</td>
<td></td>
</tr>
<tr>
<td>SB HR (beats/min)</td>
<td>153.33±24.58</td>
<td>152.33±23.27</td>
<td>-.63</td>
<td>-1%</td>
<td></td>
</tr>
<tr>
<td>TM HR (beats/min)</td>
<td>188.75±6.68</td>
<td>192.67±6.11</td>
<td>1.75</td>
<td>+2%</td>
<td></td>
</tr>
<tr>
<td>SB RR (breaths/min)</td>
<td>46.79±8.29</td>
<td>48.00±4.84</td>
<td>.67</td>
<td>+3%</td>
<td></td>
</tr>
<tr>
<td>TM RR (breaths/min)</td>
<td>46.50±9.24</td>
<td>47.92±10.09</td>
<td>1.60</td>
<td>+3%</td>
<td></td>
</tr>
<tr>
<td>Squat (# of reps)</td>
<td>46.38±8.32</td>
<td>58.83±10.24</td>
<td>6.63**</td>
<td>+26%</td>
<td></td>
</tr>
<tr>
<td>Bench (# of reps)</td>
<td>40.17±13.55</td>
<td>47.25±16.85</td>
<td>2.86**</td>
<td>+18%</td>
<td></td>
</tr>
<tr>
<td>Sit-up (# of reps)</td>
<td>41.25±11.66</td>
<td>57.17±12.97</td>
<td>6.76**</td>
<td>+39%</td>
<td></td>
</tr>
</tbody>
</table>

* p <.05  SB = Biokinetic Swim Bench Test  
** P <.01  TM = Treadmill Run Test
### APPENDIX E

**SWIM BENCH TEST RELIABILITY DATA**

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Sex</th>
<th>Age</th>
<th>Wt.</th>
<th>$\dot{V}O_2$ pre</th>
<th>$\dot{V}O_2$ post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>yr.</td>
<td>KG</td>
<td>l·min⁻¹</td>
<td>l·min⁻¹</td>
</tr>
<tr>
<td>1</td>
<td>F</td>
<td>20</td>
<td>62.6</td>
<td>1.62</td>
<td>1.50</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>20</td>
<td>58.2</td>
<td>0.96</td>
<td>1.45</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>21</td>
<td>53.4</td>
<td>0.62</td>
<td>0.92</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>26</td>
<td>65.2</td>
<td>1.93</td>
<td>1.83</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>30</td>
<td>78.4</td>
<td>1.25</td>
<td>1.43</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>23</td>
<td>63.0</td>
<td>1.56</td>
<td>1.56</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>21</td>
<td>90.3</td>
<td>2.05</td>
<td>2.94</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>22</td>
<td>53.3</td>
<td>0.71</td>
<td>0.71</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>22</td>
<td>79.6</td>
<td>1.56</td>
<td>1.68</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>20</td>
<td>81.3</td>
<td>1.87</td>
<td>1.87</td>
</tr>
</tbody>
</table>

Mean ± SD  
$r = .85$

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>22.5</td>
<td>68.53</td>
<td>1.41</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>±3.2</td>
<td>±12.92</td>
<td>±.51</td>
<td>±.60</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX F

PEAK $\dot{V}O_2$ PRE- and POST-TEST
APPENDIX G

HEART RATE PRE- and POST-TEST

Swim Bench Heart Rate
Pre-test

Swim Bench Heart Rate
Post-test

Treadmill Heart Rate
Post-test

Treadmill Heart Rate
Post-test
APPENDIX H

RESPIRATORY RATE PRE- and POST-TEST

![Box plots showing respiratory rates pre- and post-test for different activities.](image-url)

- **Swim Bench Respiratory Rate Pre-test**
- **Swim Bench Respiratory Rate Post-test**
- **Treadmill Respiratory Rate Pre-test**
- **Treadmill Respiratory Rate Post-test**