# THE DEVELOPMENT OF CARDIO-RESPIRATORY ENDURANCE: A COMPARISON OF CONTINUOUS AND INTERVAL TRAINING


By

LARRY WAYNE GREGORY

Bachelor of Science in Physical Education
Texas Tech University
Lubbock, Texas
1969

Master of Education
Texas Tech University
Lubbock, Texas
1971



Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF EDUCATION
July, 1976

THE DEVELOPMENT OF CARDIO-RESPIRATORY

ENDURANCE: A COMPARISON OF

CONTINUOUS AND INTERVAL

TRAINING

Thesis Approved:

Aix B. Harrison
Thesis Adviser

James H Rogers

D B Aichele

Thomas A. Karman

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

The author would like to express his sincere gratitude to Dr. Aix B. Harrison, Professor, Health, Physical Education, and Recreation, for his guidance and assistance throughout this study. The writing of this study also benefited from the critical appraisals and encouragements of the other committee members and these contributions were particularly valued. These members were Dr. Thomas Karman, Associate Professor, Educational Administration and Higher Education; Dr. Jim Rogers, Associate Professor, Health, Physical Education, and Recreation; and Dr. Douglas Aichele, Associate Professor, Curriculum and Instruction Education.

Special thanks are extended to Dr. Ross Thomas Sanders, Visiting Assistant Professor, Health, Physical Education, and Recreation, and Ms. Marilyn Linsenmeyer, Graduate Assistant, for their time and efforts in assisting with the assessments of cardio-respiratory endurance. Their expertise and patience were important to the successful collection of the research data. Thanks are also extended to Miss Velda Davis for her assistance in the typing of this study.

Finally, it is my wife, Sally, and two sons, Stephen and Heath, who are most deserving of my gratitude. They have sacrificed the most during this endeavor, and yet they have also contributed the most through their continual support and understanding. They have my deepest appreciation.

TABLE OF CONTENTS

## LIST OF TABLES

# CHAPTER I

# INTRODUCTION

## Overview

Until recently, the primary concern in man's daily existence was survival, which was dependent upon his ability to obtain food, find shelter, and escape from danger. Meeting these necessities required that he rely heavily upon such physical qualities as strength, flexibility, and stamina. In more recent years, modern technology has changed the environment and the prevailing social philosophy (1). Today, the vast majority of man's needs are met through the utilization of mechanical power rather than man-power. These developments are so recent that man has not yet adapted physiologically, for his bodily systems and their functional capacities remain much the same as those of his Stone Age ancestors. As our society has become progressively more mechanized, there has been a corresponding increase in the frequency of degenerative diseases that appear to be related to the absence of physical activity (2). Having been constructed for movement, man still needs regular physical activity if he is to develop and maintain optimal functioning and health (3, p. 599).

Today, the qualities of strength, flexibility, and stamina are recognized as basic components of physical fitness, and each of them shares an important role in man's optimal functioning. But the most critical component is stamina or cardio-respiratory endurance (4, p. 13).

In particular, it is the maximum aerobic capacity which constitutes the dominant role in cardio-respiratory endurance. This capacity is considered to be the best index of overall physical fitness due to its reliance upon a powerful heart, efficient lungs, and a good vascular bed (5, p. 16).

An ever increasing portion of our society is concerned with the proper approach to improving this capacity. Many people realize that maximum aerobic capacity can be achieved through physical activity which requires increased metabolic demands, but few understand the processes responsible for supplying energy to meet these demands. In most cases a thorough knowledge of these processes is unnecessary, however those who understand the basic constructs of energy production have a sound basis for the prudent selection of training programs.

## Physiological Considerations

Basically, man has two chemical processes through which energy can be derived for the performance of physical work. These processes are frequently referred to as energy systems, of which there is the aerobic system and the anaerobic system. Both systems are trainable in that the maximal energy capacity of each system may be enhanced through exercise bouts which are regularly repeated and progressively more intense. The involvement of each system in energy production is relatively specific and, as will be developed, the exercise intensity required to train each of these systems is also rather specific. Once an understanding of energy systems has been reached, it is quite helpful for an individual to categorize his training objectives according to the energy systems which they require. This should prove helpful in determining the approach to exercise which is most appropriate for meeting these objectives.

Aerobic literally means "with oxygen", and the aerobic system liberates energy for work through a chemical process that requires the presence of oxygen (6, p. 9). One can classify physical work as being aerobic to the degree which oxygen intake is meeting the requirement for oxygen. If oxygen intake equals oxygen need, the activity is being performed in "steady state" (3, p. 281). Aerobic processes are largely responsible for meeting the energy needs of a broad range of activities which require light to moderate work and are of an ongoing or repetitive nature.

The availability of oxygen for aerobic processes is dependent upon the functional capacities of the respiratory and circulatory systems and the diffusing capacity of oxygen at the cellular level. An individual's ultimate capability for taking in oxygen is referred to as the "maximum aerobic capacity", which is usually expressed in liters per minute or milliliters per kilogram of body weight per minute. As indicated earlier, the maximum aerobic capacity can be trained through the proper selection of the type and amount of exercise. Thus, an individual is able to increase the quantity of oxygen available for aerobic energy production.

The extent to which the maximum aerobic capacity can be trained is a moot point since estimates range from 5% to 40% (7, 8, 9, 10). In general, the amount of improvement is dependent on the intensity, duration, and/or frequency of training, the initial level of fitness, and age. Those programs requiring the most energy expenditure usually experience the greatest changes (11). Although a person's maximum aerobic capacity is subject to training influence, there is little disagreement that heredity plays a major role in determining the upper limits of this trainability (12).

Maximum aerobic capacity can be determined in a laboratory setting through either direct or indirect methods, with the former being the most accurate. It involves the gas analysis of volumes of expired air which are collected while the subject is performing at or near maximal levels of exertion. Usually the subject is required to perform the work on a motorized treadmill or bicycle ergometer. Rather than actually measuring this capacity, it is often less expensive, less time consuming, and more convenient to predict the maximum aerobic capacity through the indirect method of assessment. A subject's aerobic capacity can be predicted based upon his heart rate response to a standardized treadmill or bicycle ergometer test, for that information can be placed into a regression equation that predicts aerobic capacity. This regression equation is derived from data on other individuals who have had their maximum aerobic capacity measured directly. The accuracy of this method increases as the highest heart rate elicited more nearly approximates the subject's maximal heart rate. As indicated earlier, the direct method will give the most precise evaluation of maximum aerobic capacity, and it is the preferred method whenever accurate assessments are of particular value.

Anaerobic processes are involved at the beginning of work and during heavy work. On these occasions, the availability of oxygen is insufficient to meet the oxygen requirement, and chemical processes operating in the absence of oxygen must compensate for the difference between energy demand and the aerobic energy supply. Thus, physical work is said to be anaerobic to the degree which aerobic energy supply is not meeting the total energy need. The amount of anaerobic involvement can be expected to increase in proportion to the severity of the work and will reach its maximum in all-out performance (13, p. 50). Activities of short duration and requiring maximal efforts such as 100-400 meter sprints are characteristic of anaerobic work.

The result of anaerobic involvement is the accumulation of the by-product lactic acid. Its rate of accumulation is directly related to the intensity of the work (13, p. 50).

However, it is generally agreed that anaerobic involvement becomes increasingly important beginning with "crestload" work and beyond (14). Crestload is that work level at which the limits of maximal oxygen consumption become apparent, and in normal young adults this is at an approximate heart rate of 180 beats per minute (bpm). Eventually, the concentration of lactic acid in the blood stream will be so great that it will cause exhaustion and bring about the cessation of work.

Oxygen will be consumed during recovery, which, in large part, will convert this by-product into potential energy sources that may be used by the individual for future energy production. The quantity of oxygen consumed during the recovery period, which exceeds the normal resting consumption, is referred to as the "oxygen debt" (15). This debt represents the difference between the oxygen requirement and the oxygen intake of the work just completed. This capacity for anaerobic involvement or "oxygen debt" is trainable and can be increased through the appropriate selection of amount and type of exercise.

Major variables in training the aerobic and anaerobic energy systems are the amount, duration, and intensity of exercise. Duration and intensity of exercise are inversely related so that every increase in work intensity brings a corresponding decrease in the time over which that work level can be maintained. The amount of work which can be accomplished is a product of the interaction of the method of work selected, the duration of the work, and the intensity with which it is performed.

In a discussion of training these systems, it is important to be aware of the time lapse necessary for an aerobic adjustment to the demands of exercise. If exercise is at or very near maximal levels, it will require approximately one minute for the respiratory and circulatory mechanisms to make the adaptations necessary for peak aerobic involvement (3, p. 286). Prior to that point, the anaerobic system is responsible for meeting the majority of energy demands due to the deficit in available oxygen. Again, it should be emphasized that the time during which maximal work can be maintained is rather brief due to fatigue resulting from the rapid accumulation of lactic acid.

The primary objective of anaerobic training is to accustom the individual to tolerating higher levels of lactic acid accumulation, which results in an increased capability for maintaining work at or near maximal levels for longer periods of time. Both continuous and intermittent exercise can be utilized to train this capability; however, intermittent work is the preferred method for such purposes. During intermittent training, the individual is usually exposed to near maximal exercise for time periods of one-half to one and one-half minutes (6, p. 18). These exercise bouts are repeated several times in order to provide a sufficient overload. All-out performances are generally avoided as they would result in exhaustion and would reduce the amount of work which could be accomplished during the training session. The exercise bouts are separated by periods of rest which are approximately 3-5 minutes in length (3, p. 389; 6, p. 40). Thus, the use of intermittent work in anaerobic training provides an individual with the opportunity to recuperate between work bouts.

The primary objective of aerobic training is to increase an individual's capacity to consume and transport oxygen for metabolism at the cellular level. This adaptation results in a capability for handling a greater portion of the energy demands through aerobic processes. It is then possible for an individual to perform with increased efficiency at some predesignated workload, and it also allows him to accommodate higher workloads for longer periods of time. The accomplishment of this training adjustment requires exercise bouts of sufficient length to involve the aerobic energy system at a relatively high level. This would generally be in excess of three minutes. Usually the exercise employed will incorporate large muscle groups in continuous and rhythmical movement, of which walking, jogging, and swimming are excellent examples. The intensity of the exercise is moderate, as this allows the work to be performed in a steady state for the majority of the training session.

Continuous work has been traditionally accepted as the proper method of training the aerobic energy system; however, in more recent years, intermittent or interval work has been advocated as also being useful for this purpose. Principal among those recommending this approach are Fox and Mathews (6) and Åstrand and Rodahl (3). Their programs are extensions of the interval work which is suggested for training the anaerobic energy system. Adjustments in the program include longer work periods and a reduced work intensity, each of which meets the criteria for training the aerobic system. They suggest that an individual should exercise for 3-5 minutes at an intensity that is near maximal levels or slightly less, with the number of work intervals being dependent on the training objectives. How this approach compares with continuous methods that have been more thoroughly researched is an unanswered question which provided the stimulus for this research study. Of particular interest is whether the interval work required to bring optimal changes in the aerobic energy system is too vigorous for the general population.

Certainly the value of increasing ones maximal aerobic capacity goes beyond the fact of merely increasing ones capacity. It is done with a purpose in mind. Purposes for inducing a training effect generally coincide with three broad classifications of the population, these being athletes, the general public, and those who have suffered some form of coronary insufficiency. This study was concerned only with programs for the general public.

The general public is usually concerned with developing and/or maintaining a functional fitness which provides them with the physical integrity to meet the requirements of their daily work, to pursue recreation freely, and to meet emergencies as they might arise. Crucial to this state of being are circulatory and respiratory systems that are accustomed to handling active states with relative ease. A reflection of this capability is the maximum aerobic capacity, which is determined under circumstances requiring the efficient adaptation of the heart, lungs, and vascular bed to increased metabolic demands.

## Nature of the Problem

A major research objective of exercise physiologists during the past three decades has been the optimal development of cardio-respiratory endurance as measured by maximum aerobic capacity. The results of this undertaking could eventually be what Sharkey (16) and Cooper (4) have referred to as a pharmocopoeia of exercise. Presumably this pharmocopoeia would be composed of a variety of exercise guidelines. The training responses to these guidelines could be predicted and would be expected to occur within a certain tolerance. The prescription of exercise to an individual based upon sex, age, fitness level, and training objectives could then be dispensed with an appropriate degree of confidence and certainty. A typical exercise prescription would identify such factors as intensity, duration, frequency, method, and modality of training.

To date, most of the research on conditioning has examined the effects of intensity, duration, frequency, and modality of training upon cardio-respiratory endurance, and these factors have been examined within the confines of one or the other of two general methods of endurance training. These two methods of training are frequently labelled as continuous, which is slow-paced running over long distances without rest, and interval, which is intermittent, fast-paced running over short distances with intervening rest periods.

In only a few instances (17, 18, 19, 20) has there been a controlled comparison of these two training methods, despite the fact that the results of such comparisons could have far-reaching effects. Both methods have been successfully employed in the training of athletes for endurance events, especially in track. Perhaps Sharkey (16) indirectly explained this research deficit when he noted the shift in research emphasis away from maximal performance in athletics to optimal performance in the adult years.

This shift in emphasis harbors within it an assumption as to the appropriateness of interval training for the general population, especially the adult segment. Interval work is generally considered to be too strenuous for the average person, while continuous training, with its lower work intensity, has been viewed as the preferred type of training. Assuming these observations to be correct, comparative studies would be of little practical value to the general populace, and studies examining variations of continuous training would be of primary benefit. This has essentially been the case as the continuous method of training has been the object of the vast majority of the research and resultant publicity. The book Aerobics authored by Dr. Kenneth Cooper (4) serves as perhaps the best example. This book represents the first major quantification of exercise, and its point systems and recommendations for exercise are based on continuous type work. Because of the wide distribution and popularity of this book, much of what the general public knows about exercise has been centered around the contributions of Dr. Kenneth Cooper.

A preponderance of research on continuous training, in addition to a historical preference for this type of work, has inadvertently restricted the choice of training methods for those individuals who have concerned themselves with acquiring and/or maintaining optimal levels of physical fitness. These influences have also severely limited what is known about alternative methods of training, of which interval training is the most conspicuous.

The suitability of interval training programs for the general populace is a matter deserving further clarification. Research efforts should be initiated to determine if programs of interval work can optimally develop cardio-respiratory endurance and, if so, what particular programs are most suitable for this purpose. Surely this research is necessary if a reasonably complete pharmocopoeia of exercise is to be realized. Exercise prescription would be remiss if it did not include a variety of training methods from which an individual could select according to his or her personal preferences and/or training objectives.

In order for interval training to be appropriate for the development of cardio-respiratory endurance in the general population, it will be necessary to modify these programs which have been used successfully with endurance athletes. The work intensity will need to be less than maximal and closer to moderate levels, and the duration of the work interval will need to be longer. Perhaps the initial research emphasis should be on the comparison of selected interval programs with selected continuous programs to determine whether the results of such training are similar. As indicated earlier, the interval programs selected for such investigation need to have work times and intensities that have been modified before the results of such comparisons will be applicable to the general public.

Since the relative status of these two training methods was inconclusive, it was reasonable to assume that investigations in this area could provide added dimensions to the training possibilities available to sportsmen and the general populace. The comparisons of different training methods might demonstrate the existence of a variety of alternative methods for the optimal improvement of endurance. It was the intent of this study to provide some insight into this area of research through an examination of the effects of interval and continuous training methods upon the development of cardio-respiratory endurance.

## Statement of the Problem

This study compared the effects of interval and continuous training methods upon the development of cardio-respiratory endurance in untrained, college-age males. Changes in cardio-respiratory endurance, resulting from a six-week training period, were compared according to the results of a standardized treadmill test and the direct measurement of maximal oxygen consumption.

## Sub-Problems of the Study

Sub-problems of this study were:

1. The determination of the reliability for oxygen uptake measures based upon the test-retest of ten subjects.
2. The determination of the reliability for performances on the Balke treadmill test based upon the test-retest of ten subjects.
3. The determination of the validity for the use of a ten-second heart rate count as an index of the work intensity during a previous work segment of four minutes duration.
4. The determination of the validity for the Balke treadmill test as a predictor of maximal aerobic capacity.

## Justification for the Study

The concept of moderate intensity, continuous exercise has been so firmly entrenched in our society that few people realize that they may have a choice when selecting methods of training. Almost without exception, the general public resorts to continuous exercise for the acquisition and/or maintenance of optimal levels of physical fitness. This can be explained in large part because of tradition and because of the acceptance of the contributions of Dr. Kenneth Cooper (4, 5) and a majority of other researchers who have focused upon continuous type work in an effort to specify optimal programs of conditioning. Although the ideal frequency, intensity, and duration necessary for optimal conditioning have yet to be firmly established, their research findings have provided a sound basis for the prescription of exercise.

However, the feasibility of intermittent work as a viable method of training for the general population has not been satisfactorily explored, despite the fact it has considerable potential. Åstrand and Rodahl (3) and Fox and Mathews (6) have recommended interval approaches for improving endurance that are quite similar to each other, and the status of these approaches relative to continuous training should be investigated. The results of such comparisons could well stimulate further research into optimal programs of interval training which might eventually provide needed training alternatives for the improvement of cardiorespiratory endurance. This study contributed to this endeavor since it compared the effects of interval and continuous training methods upon the attainment of cardiorespiratory endurance.

## Hypotheses

1. There will be no significant difference between the initial and final measures of maximal oxygen consumption (ml/kg/min) in the control group.
2. There will be no significant difference between the initial and final measures of maximal oxygen consumption (ml/kg/min) in the continuous training group.
3. There will be no significant difference between the initial and final measures of maximal oxygen consumption (ml/kg/min) in the interval training group.
4. There will be no significant difference between the initial and final performances of the control group on the Balke treadmill test.
5. There will be no significant difference between the initial and final performances of the continuous training group on the Balke treadmill test.
6. There will be no significant difference between the initial and final performances of the interval

training group on the Balke treadmill test.

7. There will be no significant difference between the final adjusted mean scores of all groups on the Balke treadmill test.

8. There will be no significant difference between the final adjusted mean measures of maximal oxygen consumption (ml/kg/min) for all groups.

## Limitations

The following conditions are viewed as limitations of this study:

1. The subjects were not randomly selected, but were volunteers from among those male students majoring in physical education at Oklahoma State University.
2. The sample sizes were small.
3. The study did not control the nutrition, rest, or activity patterns of the subjects.

## Delimitations

This study was delimited in the following ways:

1. The concern of this study was the effect of selected training methods upon cardio-respiratory endurance as reflected in the direct measurement of maximal oxygen capacity and performances on the Balke treadmill test.
2. The subject population was restricted to untrained,

college-age males who were majoring in physical education at Oklahoma State University.

3. The modes of training were running and jogging.
4. The training period was confined to a maximum of 30 training sessions during a six-week period.

## Assumptions

1. It was assumed that all subjects were at the same level of cardio-respiratory development relative to their individual and maximal capacity for such development.
2. It was assumed that maximum aerobic capacity was reached at a heart rate of 180 beats per minute.
3. It was assumed that skill proficiency was not a source of appreciable error as both training and testing procedures involved walking and running, both of which require relatively low levels of motor skill.
4. It was assumed that the amount of physical activity other than the prescribed training regimens was minimal.
5. It was assumed that the subjects, with the aid of verbal encouragement and individual attention, maintained equal levels of motivation throughout the training period.

6. It was assumed that the effects of extra-curricular activities were uniform upon all subjects.

## Definition of Terms

Aerobic: The process by which energy is expended in the presence of oxygen.

Anaerobic: The process by which energy is expended in the absence of oxygen.

Steady State: An active state during which the oxygen supply is meeting the oxygen need.

Crestload: The largest workload at which the oxygen supply is meeting the oxygen need.

Oxygen Debt: The quantity of oxygen consumed during recovery which exceeds the normal resting consumption.

Aerobic Energy System: The chemical processes which are responsible for energy production in the presence of oxygen and which transform carbohydrates into carbon dioxide and lactic acid plus energy.

Anaerobic Energy System: The chemical processes which are responsible for energy production in the absence of oxygen and which cause the incomplete transformation of carbohydrates into carbon dioxide and lactic acid plus energy.

Cardio-Respiratory Endurance: The capability to perform work over extended periods of time.

Cool-Down: An attempt to facilitate recovery through a gradual transition from exercise to resting states.

Continuous Work: A manner of performing physical exercise in a single, uninterrupted work bout.

Intermittent Work: A manner of performing physical exercise in work bouts which are interspersed with periods of rest.

Work Interval, Work Period, or Work Segment: A segment of time during which increased metabolic demands are made upon body systems through the performance of some form of physical exercise.

Rest Interval: A segment of time during which body systems are allowed to recuperate in part or full from a prior work interval.

Interval Training: A method of conditioning which incorporates intermittent work and utilizes fast-paced running for work intervals of short to moderate duration.

Training Session: A workout or an occasion when subjects performed a specified training regimen.

Maximum Aerobic Capacity or Maximal Oxygen Consumption: The largest quantity of oxygen—expressed in liters per minute or milliliters per kilogram of body weight per minute (ml/kg/min)—which can be taken in by an individual.

Minute Ventilation Volume: The total volume of air expired by a subject in one minute.

True Oxygen: The quantity of oxygen which is consumed by the body for every 100 milliliters of expired air.

## Description of Instruments

Physiograph: An apparatus used to monitor and record heart rate during rest, work and recovery. (Type PMP-4A; E. and M. Instrument Co., Inc., Houston, Texas.)

Quinton Motorized Treadmill: An apparatus with a continuously moving conveyor belt that is excellent for the standardization of workloads as it may be adjusted to varying speeds and elevations. (Model 642; Speed Range 1.5-25 miles per hour; Elevation (per cent grade) 0-40; Seattle, Washington.)

"J" Breathing Valve (One-Way): A device which allows a subject to inhale atmospheric air and to channel ventilated air into an adjacent tissot tank. (Model - Double "J" Valve; Warren E. Collins, Inc., 220 Wood Road, Braintree, Mass.)

Tissot Tank: A large stainless steel tank which was used for the collection of expired air during work at 180 bpm. (Warren E. Collins, Inc., 555 Huntington Avenue, Boston 15, Mass.; Capacity--120 liters (0mm-720mm); Serial No. 1440.)

Kymograph: A scale connected to the tissot tank which indicates the volume of expired air contained within the tank.

Sample Bags: An expandable, rubber bag used to hold samples of a subject's expired air.

Pulmo-Analyzer: An instrument which was used to determine the percentage of oxygen and carbon dioxide contained in the samples of expired air. (Godart Instrumentation Association, New York, N. Y.)

Nose Clip: A device used to close off the nostrils and prevent nasal ventilation.

Biotelemetry Transmitter: A small battery-powered device used to convey a subject's heart rate via radio waves to a biotelemetry receiver. (Model F. M. 1100-E-2, Part No. 98-100-71; Narco Bio-Systems, Inc., 7651 Airport Blvd., Houston, Texas.)

Biotelemetry Receiver: An aparatus which received heart rate signals conveyed via radio waves from a small, wireless transmitter attached to the subject. (Model F. M. 1100-7; E. and M. Instrument Co., Inc., Houston, Texas.)

Wireless ECG Transmitter: A battery-powered device used to convey a subject's heart rate via radio waves to a Wireless Pre-amp Receiver. (Model 16085; Medtronic, 3055 Highway 8, Minneapolis, Minnesota.)

Wireless Preamp Receiver: An apparatus which received heart rate signals from a Wireless ECG Transmitter. (Model 2055; Medtronic, 3055 Highway 8, Minneapolis, Minnesota.)

Surface Electrodes: Small discs which are attached to the surface of the skin adjacent to the heart and which transduce the electrical impulses of the heart into electrical signals. (Part No. 710-0012; Narco Bio-Systems, Inc., 7651 Airport Blvd., Houston, Texas.)

## CHAPTER II

## REVIEW OF THE LITERATURE

### Introduction

Perhaps the most significant single contribution to the quantification of exercise to date has been the book *Aerobics* published by Dr. Kenneth H. Cooper (4). Based on the extensive research of armed forces personnel, this publication allowed individuals of different ages and levels of conditioning to assign point values for exercise according to its type, intensity, and duration. The primary emphasis of *Aerobics* was on the development and assessment of cardio-respiratory endurance via continuous and rhythmical exercises that incorporate large muscle groups. Cooper (4, p. 23) postulated that "If the exercise is vigorous enough to produce a sustained heart rate of 150 beats per minute or more, the training effect benefits begin about five minutes after the exercise starts and continues as long as the exercise is performed." A conditioning program utilizing such a format is well within the physical capacities of most of the general population, and - if instituted progressively - it represents a sound approach to the development of cardio-respiratory endurance.

Other researchers (16, 20, 21, 22, 23, 24) have also confirmed the concept of moderate intensity, continuous exercise as being effective in improving the maximum aerobic capacity. However, it should be emphasized that the ideal frequency, intensity, and duration necessary for the optimal development of endurance have yet to be established.

Considerably less research attention has been given to interval training. This issue has been addressed in only a few studies (25, 26, 27) which have attempted to isolate optimal programs of interval training. Despite this paucity of research, several prominent exercise physiologists have recommended the general use of interval training for the development of cardio-respiratory endurance.

Åstrand and Rodahl (3, p. 389) indicated "that physical activity ranging from repeated work periods of a few seconds duration up to hours of continuous work may involve a major load on the transporting organs and thereby induce a training effect." For the training of aerobic power, they recommended that

> . . . one should work with large muscle groups for 3 to 5 minutes, rest or engage in light physical activity for an equal length of time, then proceed with a further work period, etc., as required depending on ambitions and the objective of training. The tempo does not have to be maximal during the work periods in question. It is not necessary to be exhausted when the work is discontinued.

Fox and Mathews (6) recommended essentially the same type of interval approach for the training of cardio-respiratory endurance. They suggested three to four intervals per workout lasting from three to five minutes and interspersed with rest periods of equal duration. The intensity of each work interval was to be near maximal.

It seemed appropriate that selected continuous and interval training programs should be compared in an effort to establish their relative effectiveness. These comparisons should be of practical value to those concerned with improving cardio-respiratory endurance even if neither method proved to be superior.

## Research in Continuous Training

Much of the recent emphasis in training research has been devoted to the identification of those factors which will bring about the optimal improvement of maximum aerobic capacity. Many of these studies have focused on continuous work in an effort to specify the intensity, duration, frequency and/or modality of training which is the most beneficial for increasing maximal aerobic capacity. The following is a selected review of this literature.

### Intensity of Training

In a multifactor study, Sharkey (16) examined the effects of three levels of training intensity and two levels of duration by employing a 3 x 2 factorial design (six treatments). Thirty-six young college males were randomly divided into the six treatments and were then trained three days/week for six weeks. Subjects exercised on a bicycle ergometer at heart rate intensities of 130, 150, and 170 beats per minute at each of two levels of total work (7,500 and 15,000 kpm.). The Åstrand-Rhyming step test, Balke treadmill test ($T_{170}$) and Sjostrand's physical working capacity test ($PWC_{170}$) were the three submaximal tests used to assess changes in fitness. Analysis of the testing results did not reveal any significant intensity, duration or interaction effects for any of the test conditions. It was concluded that training intensity did not significantly influence training changes when total work load was held constant.

Faria (21) randomly divided forty college men into one control and three training groups. The experimental groups trained via bench stepping up to heart rate intensities of 120-130, 140-150, and 160-170 beats per minute on five days of each week for a period of four weeks. A 180 beats per minute work capacity test ($PWC_{180}$) was used to detect the development of training adaptations. An analysis of the testing results indicated that the training intensities of 140-150 and 160-170 beats per minute were significantly better than the control and 120-130 groups in improving work capacity on the bicycle ergometer. However, there was no significant difference in work capacity between the 140-150 and 160-170 groups. Faria suggested there is a threshold intensity, in terms of heart rate, below which no training of the oxygen transport system occurs, and this threshold was estimated to be in the vicinity of 140 beats per minute.

Sixteen young college males were divided into three experimental groups and one control group by Sharkey and Holleman (22). These subjects were then trained on a motor driven treadmill at heart rates of 120, 150, and 180 beats per minute. The training program lasted for six weeks with the subjects walking ten minutes three days of each week. Pre- and post-testing procedures included the Åstrand-Rhyming step test and the Balke treadmill test. The 180-training group had improvement which was significantly different from the other groups on both tests. On the Balke test, the 150-training group was found to be significantly different from the control and the 120-training group. It was concluded that exercise at a heart rate intensity of 150 beats per minute was necessary to elicit improvement in cardio-respiratory endurance.

Burke and Franks (23) conducted a study whereby training intensities were specified as given percentages of the maximal heart rate. Sixteen young male subjects were randomly assigned to one of three training groups or to a control group. The experimental groups trained on a bicycle ergometer at 65%, 75%, and 85% of the subjects' maximal heart rate for a period of ten weeks with three training sessions per week. All groups performed the same total work of 12,000 kpm. per training session. Analysis of covariance identified a significant difference in maximal oxygen uptake among these groups. These significant differences existed between the control group and both the 85% and 75% groups. No significant differences existed between the 65% group and the control or between the 75% and the 85% group. It was concluded that a minimum work intensity of 75% of the maximal heart rate is necessary to elicit significant changes in maximal oxygen uptake when mechanical work is held constant.

Karvonen (24) conducted a frequently-quoted study that identified the threshold training stimulus in a somewhat different manner. Untrained medical students were required to run on a treadmill five days a week for four weeks. During each training session, the subjects ran for half an hour at a predetermined heart rate intensity. Since training was conducted at the designated intensities, the treadmill speed was progressively increased as changes in endurance became evident during the training period. If the exercise intensity were insufficient to induce the training effect, no changes in treadmill speed became necessary. The results of the study indicated that to improve maximum aerobic capacity, the intensity of the training has to be above a rather high threshold value. Karvonen expressed this threshold as a percentage of the total range from resting to maximum attainable heart rate. It was observed that 60% of the range appeared to be the threshold above which training is effective and below which it is ineffective.

Frequency of Training

Jackson, Sharkey, and Johnston (28) randomly assigned twenty young male volunteers to one control and four training groups. These groups trained for one, two, three, or five days each week for five weeks. Subjects were trained by running on a treadmill at seven miles per hour for a ten-minute period, and with each completed ten-minute run, the grade was increased one per cent for the next training session. The pre- and post-testing procedure included the Åstrand-Rhyming step test, the Balke treadmill test, the Taylor, Buskirk and Henschel test of maximal oxygen intake, and a record of the number of training sessions completed. Significantly greater improvement was experienced by the five-day group on the Balke test, but the two- and three-day groups were favored on the other methods of measurement. It was concluded that training two or three times a week may be as beneficial as a five-day program when the initial fitness level of the subject is taken into consideration.

Pollock, Cureton, and Greninger (29) studied the effects of exercise frequency on nineteen volunteer men between the ages of twenty-eight and thirty-nine years. These men were randomly assigned to one of two experimental groups. Group I exercised two days a week and Group II four days a week for twenty weeks. Subjects exercised for thirty minutes each session by continuously walking, jogging, or running. The experimental groups were tested at the beginning, middle, and end of the program. Testing procedures included maximum oxygen intake capacity, heart rate response to a standard treadmill run (5 min., 6 mph, 5% grade) and the time required for a two-mile run. Both experimental groups improved significantly on all working capacity and cardio-respiratory variables. It was concluded that endurance training induces changes that are in proportion to the frequency of participation, as the four days/week group had more significant improvement in working capacity and cardiovascular fitness than did the two days/week group.

Duration of Training

Durnin, Brockway and Whitcher (30) divided forty-four untrained young men into one control and three experimental groups. The experimental groups walked 10km, 20km or 30km daily for ten days with one day's rest midway through the training period. The intensity of the walk was sufficient to elicit a heart rate between 120 and 130 beats per minute. Changes in physical fitness were assessed by measurements of pulmonary ventilation, oxygen extraction, oxygen consumption and heart rate during a standardized treadmill test. These tests were applied before, during, and after the training period. The results of the above measures indicated that the 20km group experienced the most improvement. It was hypothesized that the 30km walk was too difficult for the subjects' level of fitness. The authors concluded that, within certain limits, the duration of work is an important exercise consideration as well as the rate of work.

Wilmore et al. (31) trained fifty-five men ranging in age from seventeen to fifty-nine years for a ten-week period. These subjects were divided into two subgroups, one jogged twelve minutes/day, three days/week; and the other jogged twenty-four minutes/day, three days/week. Among the respiratory and cardiovascular measures administered during the pre- and post-testing were vital capacity, oxygen consumption, blood pressure, and work capacity. The results generally found the twenty-four-minute group demonstrating changes of a greater magnitude, however there were no statistically significant differences between the two groups. The authors indicated that perhaps a longer training period may have exhibited differences that were significant. It was also suggested that intensity could be as important as duration in determining changes in endurance.

Tooshi (32) formed three experimental groups and one control group with subjects ranging in age from twenty-seven to forty-five years. The experimental groups trained five days/week for twenty weeks in a program consisting of running, jogging, and walking. All three groups had the same exercise regimen except that each trained for a different length of time each day. The three training times were fifteen minutes, thirty minutes, and forty-five minutes. Time motion analysis was used to quantify the training sessions into calories. The cardiovascular and running tests applied as pre- and post-tests were resting pulse rate, systolic and diastolic blood pressures, amplitude of brachial pulse wave, two-mile and all-out treadmill runs. These measures were improved more significantly by endurance training of thirty and forty-five minutes a day, rather than for fifteen minutes. Improvements were in proportion to the duration of training with the fifteen-minute program showing changes only in the two-mile and all-out treadmill runs. It was concluded that expenditures of less than 600 kilocalories were insufficient to produce significant changes in cardiovascular measures.

## Research in Interval Training

### Physiological Effects of Continuous and Interval Work

Åstrand et al. (33) and Christensen et al. (34) have provided some excellent investigations comparing the physiological effects of continuous and intermittent work. Although neither study incorporated a training period, the influence of each type of work on the aerobic and anaerobic energy systems was well demonstrated.

Christensen (34) compared the total work output, total oxygen consumption, total pulmonary ventilation, and blood lactic acid concentration of two subjects while each ran on a treadmill under continuous and intermittent work conditions. Treadmill speed during both forms of work was 12.4 mph. Continuous work was performed until exhaustion prevented any further work. Intermittent work was performed at work and rest intervals varying from five to fifteen seconds. Under each experimental condition, the work and rest intervals were constant and of equal length. The total exercise time was thirty minutes in each session, and the effective work time and rest time was fifteen minutes each. One subject was exercised at work to rest ratios of ten to five seconds and fifteen to ten seconds, which provided effective work and rest time of twenty to ten minutes and eighteen to twelve minutes, respectively. During continuous work, one subject ran for three minutes and the other for four minutes in covering 1.0 km and 1.35 km, respectively, before reaching exhaustion. All combinations of intermittent work allowed the subjects to generate greater work outputs, and the ten-to five-second format allowed one subject to cover 6.67km in the total exercise time of thirty minutes. Cardiorespiratory measures affirmed the assumption that stored oxygen plays an important role in the oxygen supply during short periods of heavy work. Calculations during the intermittent work at the ten- to fifteen-second ratio indicated that approximately two-thirds of the necessary oxygen was supplied by blood transport during the work while one-third of the oxygen was supplied by available oxygen stores in the muscle. These stores are quickly replenished during each rest period and are then available during the succeeding work period.

Åstrand et al. (33) incorporated longer work and rest periods in a similar experiment with one subject. This subject exercised both continuously and intermittently on a bicycle ergometer at a 2,160 kpm/min. work load. Continuous work was performed until exhaustion while intermittent work was accomplished at work and rest intervals varying between one-half to three minutes. During each experiment, the work intervals were of equal length. The total exercise time was one hour, and the effective work and rest time was thirty minutes each. Measurements of total oxygen consumption, total pulmonary ventilation, total number of heart beats, and blood lactic acid were taken during each experimental condition. A work load of 2,160 kpm/min. could be tolerated for one hour when done intermittently but could only be performed nine minutes when done continuously. The amount of continuous work performed was 19,400 kilogram-meters, and intermittently 64,800 kilogram-meters of work were performed. Results indicated that greater volumes of total work could be accomplished via intermittent rather than continuous work when heavy work loads are involved. It was obvious that at short work and rest intervals (one-half to one minute), a great amount of work could be done at heavy loads with a submaximal loading of circulatory and respiratory systems. By selecting longer work intervals (two to three minutes), an individual could effect maximal loading of the respiratory and circulatory systems for aerobic training purposes. Åstrand et al. (33) reaffirmed the conclusion of Christensen et al. (34) which identified stored oxygen as an important source of oxygen supply during short periods of heavy work.

A study by Karlsson, Åstrand, and Ekblom (35) demonstrated that it is not necessary to perform at maximal speed in order to elicit maximal oxygen uptake. After having established the maximal speed which would bring subjects to exhaustion in four minutes, they found a reduction in this speed to as low as 80% would still require maximal loading of the oxygen transport system. Making the assumption that optimal training requires maximal loading of the oxygen transport system, they observed that submaximal speeds are sufficient to engage maximal oxygen uptake, and these speeds are perhaps optimal as a training stimulus.

Further comparisons of the physiological effects of continuous and intermittent work were carried out by Fox, Robinson and Weigman (36). In this study, six trained subjects ran continuously at a non-steady state pace - i.e., the energy demands of exercise could not be met entirely through aerobic processes - on a motor-driven treadmill until exhausted. The following day the same total work would be performed by running in intervals of ten, twelve, twenty, or sixty seconds with rest periods of twenty or sixty seconds. Measures of blood lactic acid concentration, oxygen consumption, and oxygen debt were performed on the subjects during the experiments. Results indicated that blood lactic acid accumulation and lactacid oxygen debt were always much lower for interval work than when the same total amount of work was performed continuously. Several of the subjects continued interval work until they reached lactate levels comparable to those of the continuous run. The results indicated that two to two and one-half times as much total work was performed before reaching these levels. Thus, more work could be performed before lactic acid caused exhaustion. It was observed that the decrease in energy from the lactacid mechanism during interval running was compensated for by a proportional increase in energy supplied via the alactacid mechanism which provides a reusable energy source due to the introduction of the rest interval.

## Interval Training Programs for the Development of Endurance

Harper, Billings and Mathews (37) matched twenty-five college men on the basis of maximum oxygen consumption and divided them into three groups. Each of the groups utilized one of the following programs: an army conditioning program of calisthenics and marching; interval training through running; and recreational activities. These programs were conducted five days a week for seven weeks. Maximum oxygen consumption and the Harvard Step Test were used as the pre- and post-measures for monitoring changes in conditioning levels. The results indicated that the interval-trained group improved on both fitness measures, while the army trained group improved only on the Harvard Step Test. It was concluded that interval training can elicit greater fitness improvements and can accomplish it with less training time than programs of calisthenics or marching.

Fox et al. (38) investigated the effects of frequency of interval training and its influence on the development of cardio-respiratory endurance. Two groups consisting of twenty-three and twenty-seven young male subjects trained either twice or four times weekly for a period of seven weeks. The four-day/week interval program had two days of short distance running (55 to 220 yds) for sixteen to twenty repetitions, one day of long distance running (660 to 1320 yds) for five or six repetitions, and one day of mixed long and short distance running. Both groups exercised at the same intensity. Pre- and post-testing included both oxygen consumption and pulmonary ventilation at maximal and sub-maximal levels. Both programs significantly improved these variables, and it was concluded that a seven-week interval training program with two workouts per week is as effective as four workouts per week.

Fox et al. (25) examined the influence of intensity and distance of interval training on maximum aerobic capacity. Twenty-three untrained students were divided into three different groups and trained five days per week for seven and one-half weeks. The programs consisted of (1) high-intensity, short-distance sprints (Groups S); (2) low-intensity, long-distance runs (Group L); and (3) a combination of both (Group M). While significant increases in maximum oxygen consumption (liters/min.) were found within each group, only Group S and M experienced significant increases in maximum oxygen consumption (ml/kg/min). No significant differences were found between the groups before or after training. The authors found a relationship between change in maximum oxygen consumption (ml/kg/min) and intensity and concluded that intensity rather than distance was the most important factor in improving maximum oxygen consumption.

Siegel, Blomqvist and Mitchell (26) examined the effects of a fifteen-week interval training program upon nine blind men ranging in age from thirty-two to fifty-nine years. The subjects were trained on a bicycle ergometer three times a week using four three-minute work intervals. Each work interval was followed by a rest interval of equal length. Heart rates at the end of the fourth work interval averaged twenty-seven beats per minute below individual maximal heart rates. Maximal oxygen uptake increased from 24.0 to 28.5 ml/kg/min or by 19%. Also, total heart volume and mean serum cholesterol decreased significantly. Thus, a total of slightly more than one-half hour of exercise each week at a moderately strenuous level produced a 19% increase in maximal oxygen uptake in fifteen weeks.

Knuttgen et al. (27) utilized three different interval training programs for the development of cardio-respiratory endurance in thirty-seven Swedish soldiers. Training was held five days/week for a period of two months. Group I alternated every fifteen seconds of exercise with fifteen seconds of rest while Group II alternated three minutes of exercise with three minutes of rest. Group III had no formal program during the first month and then alternated three minutes exercise with three minutes rest, five days/ week for one month. For each group, the total time of high intensity exercise was fifteen minutes per session. Maximal oxygen uptake was measured on a bicycle ergometer at the beginning, middle, and end of the two-month period. Significant increases in maximal oxygen consumption were experienced within all groups. Groups II and III exhibited significantly greater improvements in maximal oxygen consumption than did Group I, and it was concluded that a training regimen based on three-minute work intervals was more effective than fifteen-second work intervals.

## Research Comparing Continuous and Interval Training Programs

Once it became obvious that more total work could be generated through intermittent rather than continuous exercise, a small number of studies sought to determine the value of interval training for purposes of aerobic conditioning. This was accomplished by comparing the effects of cotninuous and interval training programs upon the development of cardio-respiratory endurance.

Moncrieff (17) divided thirty-four male college students into two matched groups and trained them three days/ week for six weeks. Both groups exercised on a bicycle ergometer with one group performing "steady pace" work and the other performing interval work. Each group performed the same amount of total work during each workout. Changes in work output were measured by a two-minute "all out" performance test on a bicycle ergometer at two, four, and six weeks of the training period. Comparisons with the pre-test results indicated that significant increases in work output were achieved on the four and six weeks tests even though such changes were not evident at the end of two weeks of training. However, there were no statistically significant differences between groups at the end of two, four, or six weeks of training. It was concluded that the same changes in work output could be produced by either method of training as long as the total work done by each group was the same.

Patton (18) divided twenty male college students into a control group and two experimental groups based on the results of an "all out" treadmill run. The experimental groups trained on a motor-driven treadmill five days/week for eight weeks. The same total work was performed daily by each group, however the working intensities differed as the continuous group ran "all out" at seven miles per hour and 8.6% incline while the interval group ran at nine miles per hour and 8.6% incline. The interval group employed work intervals of one minute duration with thirty second rest pauses. Pre- and post-test assessments included a seven miles per hour "all out" treadmill run, Balke treadmill walk, maximal oxygen consumption during the Balke treadmill test and an 880-yard run for time. The results showed a significant increase in cardio-respiratory endurance on all measures for both training groups. There was a significant difference between the experimental groups and the control on all but one test, and there were no significant differences between the experimental groups on any of the test items. It was concluded that both training techniques were considered equal with respect to improving endurance.

A study by Mellerowicz, Meller and Muller (19) examined the effects of continuous and intermittent running at the same work intensity. Twenty-four male students were divided into two matched groups based on the results of a maximum, three-minute test on a bicycle ergometer. The groups trained three days/week for four weeks by performing the same workload at the same intensity, but using the two different methods of work. Training for the continuous group consisted of a run until exhaustion each training day while the intermittent group alternated work with rest until an equivalent workload had been produced. At the conclusion of the study, there was an average increase in performance of 23% and there were no differences in the performances produced by the two training methods. It was concluded that there was no significant difference in the effectiveness of either method.

In a recent study, McKibben (20) compared two continuous training programs with one interval program. Fifteen male subjects were matched according to initial maximal oxygen consumption and then assigned to the three experimental groups. Training was conducted five days/week for seven weeks. Group I ran on a treadmill for fifteen minutes at a heart rate of 150 beats per minute, while Group II utilized interval work for fifteen minutes with heart rates between 120 and 180 beats per minute. Group III covered the same distance as Group II but did so with a continuous run at 150 beats per minute. Pre- and post-tests of maximal oxygen consumption (ml/kg/min) and the mile run were used to assess the improvement of cardiovascular function. All three groups experienced significant improvements in endurance and there were no differences in the degree of improvement experienced by these groups. It was concluded that, when expending equal amounts of energy, there is no difference in continuous and interval training for eliciting cardiovascular benefits.

## Summary

Exercise to improve stamina can generally be classified as continuous or interval. Both of these methods have been successful in significantly improving endurance as is evidenced by the reported literature. Research on continuous exercise has been more comprehensive, and as a result it is the method most commonly selected by the exercising population. Surprisingly little research has been devoted to identifying optimal programs of interval exercise or to the comparison of these two methods.

### Research in Continuous Training

The investigation of continuous exercise can be characterized as a quest to identify the exercise intensity, frequency, and duration which is necessary to stimulate improved cardio-respiratory function. The results of these investigations are as follows:

1. Research findings (21; 4, p. 23; 22; 23; 24) consistently indicate that training benefits begin to accrue at a threshold intensity that lies somewhere between a heart rate of 140 and 150 beats per minute. Intensities beyond this threshold do not appear to produce significantly greater improvements if the total workload is held constant (16, 21, 23).
2. Research findings (28, 29) suggest that an optimal exercise frequency exists between three and five days a week, although improvement is possible with as few as two training sessions a week. It has been suggested that training benefits may well be proportional to the frequency of training (29).
3. Significant improvements in endurance have been accomplished by programs utilizing as few as ten minutes (22, 28) of exercise a day on up to forty-five minutes (32). A reasonable estimate of exercise duration would lie between ten and thirty minutes, and - as with frequency of exercise - one might expect improvements to be proportional to the length of the exercise session (32).

## Research in Interval Training

Investigations into interval training parallel those of continuous training in that frequency, intensity, and duration are the factors most often examined. Results of these investigations support the following conclusions:

1. It appears that both high-intensity, short-distance sprints (25) and low-intensity, long-distance runs (26, 27) are successful in developing endurance. However, prominent authories (3, 6, 26, 27) consistently recommend several work intervals of three to five minutes duration at less than maximal intensity as being optimal for aerobic conditioning.
2. As with continuous training, three to five workouts a week are satisfactory for the development of endurance (25, 26, 27, 37), although as few as two workouts per week may be sufficient to induce a training effect (38).

## Research Comparing Continuous and Interval Training Programs

While the studies (17, 18, 19, 20) comparing interval and continuous training indicate that both are equally capable of increasing endurance, any definite conclusions about the two training methods may be premature. It should be pointed out that with the exception of one investigation

(20), none of the studies reported included training programs which today would be commonly recommended for the specific purpose of improving cardio-respiratory endurance in the general population. Regardless of whether the training method be continuous or interval, the exercise periods during each workout were too intense and did not last for a sufficient length of time to be of optimal benefit for aerobic conditioning. The interval groups utilized work periods of one-half to one minute duration and utilized ratios of work to rest that varied considerably. Also, the continuous groups performed high intensity work in non-steady states for periods of time lasting not longer than five minutes. While it is true the above programs did induce significant improvements in endurance, there is considerable question as to whether the programs employed were optimal for such purposes. From all appearances, these programs were requiring a considerable involvement of both the aerobic and anaerobic energy systems. In addition, most of the pre- and post-test measures required total involvement of both energy systems rather than primarily the aerobic system. These factors make it difficult to interpret the findings, especially as they might apply to the general population. The relative effectiveness of these two training methods for the purpose of improving cardio-respiratory endurance continues to be a moot question.

Bearing in mind the previously mentioned recommendations of Fox and Mathews (6), Åstrand and Rodahl (3), and Cooper

(4) in regard to interval and continuous training, it was apparent that further study would be both useful and productive provided the training programs were constructed according to current research findings. Thus, the required exercise for both methods would be less intense and performed over longer work periods than was the case with the studies reviewed above. The results of such a comparison, regardless of the outcome, should be valuable for the exercise programming of those who are concerned with acquiring and/or maintaining optimal levels of endurance.

# CHAPTER III

# METHODS AND PROCEDURES

## Selection of Subjects

The subjects were volunteers who were solicited from the population of male physical education majors and minors at Oklahoma State University, in the Fall Semester of 1975. These volunteers were screened to include only those who had not participated in any form of regular or systematic training for at least one year prior to the study. While twenty-eight subjects began the training program, only twenty-one fulfilled the training requirements. The subjects, ranging in age from 18.8 to 23.9 years, were randomly assigned to one control and two experimental groups. The mean age and other physical characteristics of each group are presented in Table I (on the following page).

## Determining the Training Programs

The exercise programs of the two experimental groups were designed to be representative of those regimens of continuous and interval work which are being recommended to develop the maximum aerobic power in the general population. Specific training guidelines were determined from the research findings as they related to this type of

TABLE I

PHYSICAL CHARACTERISTICS OF THE SUBJECTS

| Group (N) | Age, yr. | | Height, cm. | | Weight, kg. | |
|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range |
| Control (5) | 20.1 | 18.8-22.0 | 181.6 | 172.1-191.8 | 83.2 | 69.5-105.6 |
| Continuous (9) | 21.6 | 19.1-23.3 | 179.1 | 164.5-193.0 | 74.2 | 61.7-96.7 |
| Interval (7) | 21.7 | 19.5-23.9 | 183.6 | 177.8-190.5 | 81.3 | 65.8-92.2 |
| Total (21) | 21.3 | 18.8-23.9 | 181.2 | 164.5-193.0 | 78.9 | 61.7-105.6 |

conditioning. In addition, the training regimens were constructed to require less than twenty minutes of actual work time for the completion of a total distance requirement of two miles.

One experimental group trained by continuously jogging at a moderate intensity of 162 beats per minute. Subjects of this group determined their work intensity every four minutes with a ten-second carotid pulse count until they had completed the distance requirement. This particular work intensity was selected as being representative of optimal continuous work after reviewing the research findings and recommendations of Cooper (4) and others (16, 21, 22, 23, 24). The other experimental group trained by intermittent running at a work intensity of 174 beats per minute. This group completed the distance requirement by utilizing four-minute work and rest intervals. Work intensity was determined at the end of each work interval by a ten-second carotid pulse count. This particular training approach coincides with the recommendations of Åstrand and Rodahl (3) and Fox and Mathews (6) for interval work which will improve the maximum aerobic capacity.

## Pre-Experimental Testing

Pre-experimental testing was conducted to assess the level of cardio-respiratory endurance for all subjects prior to the beginning of the experimental phase of the study. Cardio-respiratory endurance was evaluated from performances on the Balke treadmill test and the simultaneous and direct measurement of maximal oxygen consumption. This combination of measures was considered to be excellent for monitoring those changes in cardio-respiratory endurance that might result from the experimental treatments.

Reliabilities for the Balke test scores and measurements of maximal oxygen consumption were established by the test-retest method. Retest measurements were obtained within one week of the initial testing and were performed on ten subjects selected at random. These procedures resulted in correlation coefficients of .99 and .94, respectively, for the Balke treadmill test and maximal oxygen consumption (ml/kg/min).

All subjects reported for testing at the Physiology of Exercise Laboratory located in the Colvin Physical Education Center during the week of September 11-18, 1975. They were instructed not to participate in any vigorous physical activity on the day of their testing and were requested to avoid even moderate activity for a period of four hours prior to the test administration. Subjects were also instructed to keep food consumption at moderate levels during the meal preceding testing. In addition, they were requested not to ingest any food one hour prior to testing.

Balke Treadmill Test

The Balke treadmill test is a continuous walking test performed on a motor driven treadmill at $3.4 \pm .1$ miles per hour. Although the treadmill speed remains constant, workloads are continually increased during the test by elevating the treadmill incline one per cent grade each minute. Balke (39) has demonstrated by several criteria that a limitation in optimal cardio-vascular and respiratory function exists when a subject's heart rate reaches approximately 180 beats per minute. This intensity was therefore selected as the point at which the test was terminated. A subject's test score consisted of the number of minutes or elevations required to elicit the designated heart rate.

Generally accepted procedures in administering the Balke treadmill test are as follows:

1. Perform the test on a motor-driven treadmill with the subject walking at a rate of 3.4± .1 mph on the level.
2. At the end of one minute, increase the grade two per cent and at the end of each succeeding minute increase the grade by one per cent increments.
3. Terminate the test when the subject has achieved a pulse rate of 180 beats per minute.
4. Record pulse rate and blood pressure immediately prior to the test, during the last thirty seconds of each minute of the exercise, and at five minutes after the exercise (13, p. 371-72).

The format used in testing all subjects was the same as the preceding format with two exceptions. Blood pressure measures were not taken at any time during the test protocol and heart rate was monitored during the last fifteen seconds of each minute of exercise.

When the subject arrived, he was requested to remove all excess clothing beyond usual gymnasium apparel, i.e., socks, shoes, gym shorts and a t-shirt. The subject's birthdate was ascertained and then he was weighed and measured for height. The t-shirt was then removed, and the subject assumed a supine resting position for ten minutes.

During the first five minutes of this period, areas of the subject's chest were prepared for the attachment of a biotelemetry transmitter and surface electrodes. Gauze pads soaked in alcohol were used to rub away the excess oil and epithelial cells from those areas of the skin where the electrodes were attached. One of the two electrodes was attached to the manubrium of the sternum and the other electrode was placed in a $V_5$ position. This position is approximately four centimeters below the left nipple and six centimeters to the left of the midclavicular line. The biotelemetry transmitter was attached above the left nipple and equidistant between the two electrodes.

Once the electrodes had been attached and connected with the transmitter, the subject was allowed to rest for five uninterrupted minutes. During this time, the biotelemetry receiver and physiograph were adjusted to insure the best possible reception. The physiograph was then set to a paper speed of .5 centimeters per second. At the end of the five minutes of rest, the resting heart rate was recorded on the physiograph via the biotelemetry apparatus.

After obtaining the resting heart rate, the subject was given an orientation to the use of the breathing valve and rubber-tipped nose clip. He was instructed as to when the breathing valve would be used during the test and how the nose clip and mouthpiece should be properly fitted. The treadmill was then started and the subject assumed a standing position on the platform at the side of the treadmill. The subject became familiar with the speed of the treadmill belt, by repeatedly passing his right foot lightly along the moving belt. When he felt confident of the belt speed, he was asked to start walking on the treadmill while supporting himself by the handrails located waist high on either side of the moving belt. After approximately ten to fifteen seconds of walking he was asked to step off the moving belt while partially supporting his body weight on the handrails. This procedure was rehearsed several times until the subject was no longer apprehensive of the moving belt or his ability to get off and on the treadmill. He then resumed walking on the treadmill, but without support. At this time, a stop watch was started to record the duration of the test.

## Maximal Oxygen Consumption

On three occasions during the Balke treadmill test, a thirty-second volume of the subject's expired air was collected in a tissot tank. Each time the subject was handed rubber-tipped nose clip and a Collins one-way "J" breathing valve fitted with a rubber mouthpiece. This breathing valve was connected to the adjacent tissot tank by way of plastic tubing. After the subject had correctly and comfortably fitted the mouthpiece and nose clip, a volume of expired air was collected for thirty seconds in the tissot tank. The first two volumes were collected at heart rates of 120 and 150 beats per minute. These volumes were collected to acquaint the subject with the procedure and to mix adequately the gases contained within the tissot tank. The tissot tank was emptied after each collection. The final collection was taken when the subject reached the target heart rate of 180 beats per minute.

Once the final 30-second volume of expired air was collected, the subject was asked to hand the breathing valve to a lab assistant and then to step off the treadmill and over to the side platform. The subject then walked for thirty seconds, after which he returned to the supine resting position for the remainder of the recovery period. A lab assistant monitored the subject's heart rate each minute for five minutes of the recovery.

Gas samples of the expired air were extracted from the tissot tank within one minute of collection. These samples were collected in rubber sample bags which were immediately attached to the Godart pulmo-analyzer. The sample air was directed through the pulmo-analyzer, which had been previously calibrated with a Lloyd gas analyzer, and the percentage content of oxygen and carbon dioxide was determined. The techniques and procedures used in determining oxygen consumption follow closely the recommendations of Consolazio, Johnson and Pecora (13, p. 9).

For the purposes of computing oxygen consumption, it was necessary to obtain certain ventilation measures as well as the per cent content of oxygen and carbon dioxide in the expired air. Essential to the computation of oxygen consumption is the minute ventilation volume of expired air and the true oxygen value. The minute ventilation volume is the amount of air that is expired in one minute. True oxygen is that quantity of oxygen which is consumed by the body in every 100 milliliters of expired air.

Minute ventilation volume was determined from the kymograph attached to the tissot gasometer. During the collection of expired air, the cylinder of the gasometer rose due to the increasing volume of air which was being ventilated into the tank. A stylus, attached to the tank, recorded the 30-second volume of expired air on the kymograph. This value was then multiplied by a factor of two in order to obtain the minute ventilation volume.

Once the oxygen and carbon dioxide content of the expired air was known, a true oxygen value was obtained from a line chart constructed by Dill and Folling (40).

Barometric pressures and expired air temperatures were taken during each test so that gas volumes could be reduced to standard conditions, for temperature, barometric pressure, dry (STPD). This was accomplished with the aid of a line chart prepared by R. C. Darling as part of the publication by Consolazio, Johnson, and Pecora (13, p. 7).

The necessary computations in determining a subject's maximal oxygen consumption are as follow:

| A | B | | C | | D | | E | | F | | G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 588 | 588/10 | x | 1.332 | x | .989 | = | 70.33 | x | .0472 | = | 3.320 |

where:

A - uncorrected ventilation volume after having been taken from the kymograph and multiplied by a factor of two so as to be a one minute volume

B - uncorrected minute volume expressed in cm

C - tissot factor which converts the uncorrected volumes from cm to liters of expired air. This factor represents the liters of gas equivalent to a rise of one cm in the Tissot bell.

D - correction factor which reduces the liters per minute of expired air into standard condition, for temperature, barometric pressure, dry (STPD), and which is derived from room temperature and the barometric pressure

E - corrected minute volume of expired air

F - percentage of true oxygen which was derived from the Dill and Folling (40) nomogram

G - oxygen consumption in liters per minute

## The Training Period

The experimental groups were required to train for six weeks with five supervised workouts each week. All subjects participated in at least twenty-six of the thirty training sessions with an average attendance of 27.9 sessions. Training began September 18, 1975 for the continuous training group and was completed on October 29, 1975, while the interval training group was in a conditioning program from September 22 to October 31, 1975.

All subjects were required to perform a standardized warm-up prior to each training session. This procedure included static stretching exercises and running in place. These exercises were selected to limber the muscles of the thigh, both anterior and posterior aspects, and the groin area. Running in place for twenty seconds was utilized to increase the heart rate and body temperature in preparation for exercise. As a group, these exercises facilitated both the physiological and psychological preparations necessary for physical exertion.

The continuous training group jogged on a quarter-mile, all-weather track at the moderate intensity of 162 beats per minute until they had completed a two-mile distance requirement. Every four minutes they were signalled to discontinue jogging for a period of fifteen seconds. During this time, a ten-second pulse count was obtained at the carotid artery. At the conclusion of the fifteen seconds and on signal, the subjects would resume jogging at the designated intensity. These pulse counts provided the subjects with immediate feedback as to their work intensity. If the heart rate was higher than the designated level, the subjects slowed their pace and if it was too low they increased their jogging pace. A record of these exercise heart rates and the time needed to complete the distance requirement was kept for each work session during the training period.

The slow interval group trained by intermittent running at a work intensity of 174 beats per minute until they had completed the two-mile distance requirement. Their program consisted of four work intervals of which the first three were of four minutes duration. The fourth interval lasted for that length of time needed to complete the remainder of the total distance requirement. Only one subject did not need part of a fourth work interval as this subject was capable of covering the distance requirement in the first three intervals.

At the conclusion of each work interval, the subjects obtained a ten-second pulse count at the carotid artery. The subjects would then walk slowly for four minutes to allow for recovery. This procedure provided a work/rest ratio of 1:1. By the end of the rest interval, the group assembled at a designated area of the running track and was ready to begin the next work period. A record was kept of the exercise heart rates and the distance covered in each work interval for each subject of the interval group. At the conclusion of each training session, all subjects were required to "cool down" by walking at least one quarter mile.

As indicated earlier, these training programs were designed not to exceed twenty minutes in actual work time. Although the two programs differed in work format, level of intensity, and duration of work, both experimental groups performed the same amount of total work.

## Verification of Work Intensity

### Self-Monitoring the Work Intensity

The exercise programs of both groups were structured around a series of three whistles which were sounded every four minutes throughout each training session. These signals provided the means by which the subjects could self-monitor and regulate their work intensities regardless of their location on the oval track. This series of signals had a slightly different meaning for each group although both groups were exercising simultaneously.

Four minutes after both groups began exercising the first series of whistles was sounded. For the continuous group, the first whistle signalled for them to stop and locate their pulse at the carotid artery. This procedure had been practiced prior to beginning the training program so that accurate counts would be obtained from the beginning. A second whistle came five seconds after the first, and indicated the start of a ten-second period during which each subject counted his carotid pulse. The third whistle, coming fifteen seconds after the initial whistle, ended the ten-second pulse count and also provided the signal for the continuous group to resume jogging. If the pulse count was too high the pace was reduced; if it was too low the pace was increased. As indicated earlier, this procedure was followed every four minutes until all subjects had completed the distance requirement. Each pulse count of the continuous subjects was called out to the investigator as they passed him on the track. These pulse counts and the elapsed time for each exercise session were recorded for each subject.

The interval group having begun their exercise at the same time as the continuous group also obtained a pulse count during the first series of whistles. However, the third whistle of the series was not a signal to resume running, as it was time for this group's first four-minute rest interval. With the next series of whistles, this group was only attentive to the first whistle since it signalled the resumption of the second work interval. During the third series of whistles, the interval group was again monitoring pulse counts as these signals coincided with the conclusion of the second four-minute work interval. The interval subjects did not resume running with the third whistle as it was time for their second rest interval which consisted of slow walking. Thus, it was only on each alternate series of whistles, which also coincided with the end of four-minute work interval, that the interval group would obtain pulse counts. Subjects in the interval group recorded their own pulse counts during the rest intervals.

This procedure of monitoring work intensity provided all subjects with a minimum of three checks on work intensity during each training session.

The control group did not participate in any systematic training program during the experimental period.

Determination of Validity

The validity of using a ten-second pulse count as an index of the work intensity for a previous four-minute work segment was determined by selecting subjects at random and monitoring their heart rates both during and after exercise. This task was accomplished with the aid of a Sony tape recorder and a wireless ECG trasmitter and receiver by Medtronic.

On twelve occasions during the training program, a subject was selected at random and his heart rate was monitored during the training session. On seven of these occasions the subjects were from the interval group and on five occasions they were from the continuous group. During each of these sessions, three work segments were monitored resulting in a total of twenty-one observations on the interval group and fifteen observations on the continuous group. The data obtained from these observations is presented in Appendix A.

At the beginning of the training session, surface electrodes were applied to the subject's chest and a wireless transmitter, to which the electrodes were attached, was strapped to his mid-section with Ace elastic bandages. As the subject exercised, heart beats were being transmitted to a receiver, which in turn, was connected to a tape recorder. Heart rates were telemetered both during and at the end of each work segment. During the work segment, heart beats were telemetered for ten-second intervals at one, two, and three minutes of each segment. While the subject was obtaining a ten-second pulse count at the conclusion of the work segment, the heart rate was also being telemetered. Recordings of the telemetered heart signals were played back after the training session was over, and these signals were checked with a stop watch to determine the heart rate. The average of the three heart rates during each work segment was then compared with the subject's post-exercise pulse count. Also, both of these values were compared against the telemetered heart rate during post exercise. The comparison of these three values determined the accuracy of the subject's post-exercise pulse count and also determined the validity of these counts as an index of the work intensity during the previous work segment.

The correlations between the subject's pulse count and (1) the telemetered pulse count and (2) the average exercise heart rate were .96 and .89, respectively.

## Post-Experimental Testing

At the conclusion of the training period, the initial testing procedures - i.e., body weight, Balke treadmill test, and maximal oxygen consumption - were administered again. Careful attention was given to replicating the conditions under which the original tests were applied. Subjects were tested at the same time of day as the initial test, and the same type of clothing was worn. Since the termination of the training period was different for each group, it was possible to test all subjects within three days of the end of the training period. This reduced any appreciable loss in endurance that could have resulted from detraining.

## Grouping and the Analysis of Data

A statistical analysis of the research data required the determination of validity and reliability, as well as testing within and between groups for significant differences between means. These procedures required the use of Pearson Product-Moment correlations, t-tests, and the analysis of covariance. The significance of testing results was determined by applying the .05 level of confidence.

Pearson Product-Moment correlations were used to determine the reliability of the maximal oxygen consumption measures and performances on the Balke treadmill test. Both of these measures were repeated on ten subjects selected at random and the results of the test-retest measurements were then correlated.

The validity of using a ten-second, post-exercise pulse count as an index of the work intensity for a previous four-minute work segment was also determined by a Pearson Product-Moment correlation. It was determined from thirty-six observations on twelve experimental subjects selected at random. These observations were also used to determine the validity of the subject's pulse counts. This determination of pulse-count validity also required the use of a Pearson Product-Moment correlation.

A Pearson Product-Moment correlation was used to determine the validity of the Balke treadmill test as a predictor of maximal aerobic capacity. This sub-problem was resolved by correlating the direct measurement of maximal oxygen consumption with the predicted maximal oxygen consumption. Predicted oxygen consumption was obtained from a regression line constructed by Balke, which required knowledge of the number of minutes walked on the treadmill test. It was the final measurements of maximal oxygen consumption (ml/kg/min) and the predicted maximal oxygen consumption which were used in this correlation.

The pre- and post-means of body weight, performances on the Balke treadmill test, and oxygen consumption (ml/kg/min) were compared within each group. These comparisons constituted the testing of Hypotheses 1, 2, 3, 4, 5, and 6. This type of analysis required the use of t-tests to determine if there were any significant differences between the within group means as a result of the training period.

Between group comparisons of maximal oxygen consumption (ml/kg/min) and performances on the Balke treadmill test were accomplished with the analysis of covariance. Because the initial group means were unequal, this procedure was utilized to provide a statistical adjustment of the final test means based upon the initial test scores. The final adjusted mean scores for each group were then compared with the New Duncan-Multiple Range Test (41). This test accomplished the task of identifying those group means which were significantly different from one another. These operations formed the basis for testing Hypotheses 7 and 8.

All statistical analyses were performed by computer at the Oklahoma State University Computer Center. The programs for the Pearson Product-Moment correlation and the analysis of covariance were designed by North Carolina State University as part of the Statistical Analysis System (SAS). An in-house program designed for Oklahoma State University by Richard Nearing was used for the t-tests.

# CHAPTER IV

# RESULTS

Sixteen untrained college males were experimental subjects in a six-week training program designed to compare the effects of interval and continuous exercise upon the development of cardio-respiratory endurance. Five subjects were members of the control group. Changes in endurance were determined by the pre- and post-administration of the Balke treadmill test and by the direct measurement of maximal oxygen consumption. Body weight, since its variability influences the calculation of maximal oxygen consumption, was also measured before and after training. This chapter contains the results of these measures as well as the sub-problems of this study.

## Reliability

Realiabilities for the Balke treadmill test and the measurement of maximal oxygen consumption were established by the test-retest method. Ten subjects were selected at random, tested, and then retested within one week of the initial testing. The results of these procedures are presented in Table II, and the data are provided in Appendix B.

TABLE II

RELIABILITY MEASURES ON TEN SUBJECTS SELECTED AT RANDOM

| Variable | Mean | Standard Deviation | Range | Correlation |
|---|---|---|---|---|
| Maximal oxygen consumption (ml/kg/min) | | | | |
| Initial (10) | 45.61 | 6.88 | 38.19-60.58 | .94 |
| Retest (10) | 43.55 | 7.11 | 34.93-59.07 | |
| Balke Treadmill test (elapsed time in min.) | | | | |
| Initial (10) | 17.5 | 2.99 | 13-22 | .99 |
| Retest (10) | 17.3 | 3.02 | 13-22 | |

Maximal oxygen consumption (ml/kg/min) averaged 45.61 in the ten subjects selected for the reliability check. The retest values for these subjects averaged 43.55 (ml/kg/min). A Pearson Product-Moment correlation between the initial and retest values provided a coefficient of .94, which according to Mathews (42) is an excellent reliability coefficient.

For this same group, performances on the Balke treadmill test averaged 17.5 minutes on the initial test and 17.3 minutes on the restest. A Pearson Product-Moment correlation between the initial and retest scores resulted in the excellent coefficient of .99.

Measurements of maximal oxygen consumption (ml/kg/min) and Balke treadmill performance were considered to be reliable based on the above results.

## Validity

### Verification of Work Intensity

During the training period, twelve subjects were selected at random from the two experimental groups and their heart rates were monitored via telemetry. Heart rates were obtained during the work segment and during the rest intervals or exercise pauses while the subjects were obtaining ten-second carotid pulse counts. This provided three separate measures for each work segment, i.e., the average heart rate during exercise (telemetry), the heart rate during the ten seconds immediately following four minutes of exercise (telemetry), and the carotid pulse count obtained by the subject during the same ten seconds following exercise. Each subject was monitored for three work segments so there was a total of three observations per measure per subject. Since there were twelve subjects, there was a total of thirty-six observations for each of the three measures. Of the twelve subjects monitored, seven were in the interval group and five were in the continuous group, resulting in a total of twenty-one observations per measure for the interval group and fifteen observations per measure for the continuous group. The results of these observations are presented in Table III, and the data are provided in Appendix A.

The average exercise heart rates obtained during these observations were slightly higher than the designated work intensities for both groups. The interval group exercised at an average heart rate of 176.34 beats per minute, which was quite close to the designated intensity of 174 beats per minute. An average heart rate of 164.76 beats per minute was obtained for the continuous group which was also close to the designated intensity of 162 beats per minute. These results provide reasonable assurance that both groups were exercising very near the work intensities which had been specified.

The subjects were also obtaining highly accurate pulse counts during post exercise as was evidenced through the comparison of the subject's pulse count and the telemetered

TABLE III

A COMPARISON OF HEART RATES OBTAINED FROM TELEMETRY AND CAROTID PULSE COUNTS

| Group (Number of observations) | Mean Heart Rates During Exercise | Post-Exerise Mean Heart Rates |
|---|---|---|
| Interval (21) | | |
| Telemetry | 176.34* | 175.74* |
| Carotid Count | | 175.44* |
| Continuous (15) | | |
| Telemetry | 164.76* | 164.40* |
| Carotid Count | | 163.98* |
| Total (36) | | |
| Telemetry | 171.48* | 171.00* |
| Carotid Count | | 170.64* |

*These heart rates can be expressed in mean pulse counts for ten seconds by dividing by six.

pulse count. Subjects in the interval group obtained counts that averaged 175.44 beats per minute, which was exceptionally close to the telemetered count which averaged 175.74 beats per minute. The continuous group obtained an average pulse count of 163.98 beats per minute which corresponded well with the average telemetered count of 164.40 beats per minute.

In order to determine the validity of the subject's pulse count, a correlation was calculated between this value and the telemetered pulse count. Observations from both groups were combined for this procedure, and the result was a correlation of .96. According to Mathews (42), this correlation constituted an excellent coefficient especially for the purposes of validity.

Once the validity of the subject's pulse count was established, it was necessary to consider how well this pulse count served as an index of the average intensity during the work segment. A comparison of the average subject pulse count and the average exercise heart rate revealed that these values were in close agreement. While the interval group had an exercise heart rate that averaged 176.34 beats per minute, they were obtaining post-exercise pulse counts that averaged 175.44 beats per minute. The continuous group had an average exercise heart rate of 164.76 beats per minute and a post-exercise pulse count of 163.98 beats per minute. These results indicated that the post-exercise pulse count was a dependable and accurate index of work intensity.

The validity of using the subject's ten-second, post-exercise pulse count as an index of the work intensity for a previous four-minute work segment was determined with a correlation. The exercise heart rates and pulse counts from both groups were used in this procedure, and the result was a correlation of .89 which, according to Mathews (42), constitutes an excellent validity coefficient.

These results indicated that the subjects were obtaining highly accurate pulse counts during post-exercise and that these pulse counts were valid and accurate indices of the average work intensity during the previous four minutes of exercise.

### Prediction of Maximal Oxygen Consumption From Balke Treadmill Performance

Another sub-problem of this study was to determine the validity of predicting maximal oxygen consumption from performances on the Balke treadmill test. By obtaining the elapsed time on the Balke treadmill test and by utilizing a regression line from a chart constructed by Balke (39), it was possible to ascertain the predicted oxygen consumption for each subject. This predicted oxygen uptake was then correlated with the actual oxygen consumption as measured during the treadmill test and expressed in ml/kg/min. The treadmill test performance and oxygen consumption measures obtained during the post-experimental testing were utilized in this procedure. Table IV presents the results of these calculations, and the data are provided in Appendix C.

TABLE IV

A COMPARISON OF PREDICTED AND ACTUAL MAXIMAL OXYGEN CONSUMPTIONS (ml/kg/mim)

| Variable | Mean | S.E.M. | Standard Deviation |
|---|---|---|---|
| Predicted maximal oxygen consumption (ml/kg/min) | 45.55 | 1.49 | 6.82 |
| Actual maximal oxygen consumption (ml/kg/min) | 49.05 | 1.66 | 7.60 |

The maximal oxygen consumptions measured by the open circuit method averaged 49.05 (ml/kg/min) while the predicted oxygen consumptions averaged 45.55 (ml/kg/min). Based on these results, it was apparent that the regression line constructed by Balke (39) tended to predict a lower-than-actual maximal oxygen consumption.

The correlation of actual and predicted oxygen consumptions resulted in an excellent coefficient of .92. A coefficient of this size indicated that the Balke treadmill test is a valid measure of maximal aerobic capacity and would be a satisfactory method for determining this capacity, especially in those situations where the direct measurement of oxygen consumption is not feasible.

## Within Group Comparisons

Testing the significance of differences between pre- and post-means within each group was accomplished with a t-test. This test was administered to the measures of body weight in kilograms, maximal oxygen consumption as expressed in liters per minute (L/min) and in milliliters per kilogram of body weight per minute (ml/kg/min), and elapsed time on the Balke treadmill test. The essential data for determining changes in cardio-respiratory endurance and body weight are presented in Tables V and VI, and the data are provided in Appendix C.

An examination of the data presented in Table V reveals that none of the groups experienced any significant changes in body weight as a result of the six-week training program. Although all groups did have increases in mean weight ranging from .22 to 1.55 kilograms, these changes were not sufficiently large to be of any practical or statistical significance.

During the post-experimental testing, all groups experienced improved maximal oxygen consumption as measured in liters per minute (L/min). The increases ranged from .33 to .80 (L/min), and the continuous and interval groups had statistically significant improvements, while the control group exhibited no such improvement. An improvement of

TABLE V

WITHIN GROUP COMPARISONS OF BODY WEIGHT (kg) AND MAXIMAL OXYGEN CONSUMPTION (L/min)

| Variable | | Pre-Mean ± S.E.M. S.D. | Post-Mean ± S.E.M. S.D. | Difference (Post − Pre) | t-Value | P (Within Groups) |
|---|---|---|---|---|---|---|
| Body weight | Continuous (9) | 74.17 ± 3.65<br>10.95 | 74.39 ± 3.53<br>10.60 | .22 | .50 | NS |
| | Interval (7) | 81.28 ± 3.66<br>9.67 | 81.70 ± 3.63<br>9.60 | .42 | .70 | NS |
| | Control (5) | 83.17 ± 6.50<br>14.52 | 84.72 ± 7.66<br>17.13 | 1.55 | 1.21 | NS |
| Maximal oxygen consumption liters/min. | Continuous (9) | 3.23 ± .18<br>.54 | 3.90 ± .22<br>.66 | .67 | 5.70 | <.001 |
| | Interval (7) | 3.22 ± .28<br>.75 | 4.02 ± .19<br>.51 | .80 | 5.91 | <.01 |
| | Control (5) | 3.18 ± .19<br>.43 | 3.51 ± .25<br>.56 | .33 | 1.19 | NS |

.67 (L/min) or 21% by the continuous group produced a t-value of 5.70, which was significant beyond the .001 level. The interval group improved by .80 (L/min) or 25% from pre- to post-testing, providing a t-value of 5.91, which was significant beyond the .01 level of confidence. Although maximal oxygen consumption increased by .33 (L/min) or 10% in the control group, the resultant t-value of 1.19 was not of any statistical significance.

Maximal oxygen consumption, as measured in milliliters per kilogram of body weight per minute (ml/kg/min), also improved in all groups from pre- to post-testing. Table VI provides a summary of these results. Statistically significant changes were experienced by the continuous and interval groups while the change in the control group was not statistically significant. The continuous group increased 8.9 (ml/kg/min) or 20% as a result of the training program. This increase provided a t-value of 5.7, which was significant beyond the .001 level. Interval training increased oxygen consumption by 9.73 (ml/kg/min) or 25% and this improvement was significant beyond the .01 level of confidence. Although the control group experienced a 2.91 (ml/kg/min) or 7% improvement in maximal oxygen consumption, the resulting t-value of .88 was not sufficient to be of any statistical significance.

Findings similar to those of maximal oxygen consumption resulted from the within group testing of performances on the Balke treadmill test. Those groups which were submitted

TABLE VI

WITHIN GROUP COMPARISONS OF MAXIMAL OXYGEN CONSUMPTION (ml/kg/min) AND BALKE TREADMILL

| Variable | Group (N) | Training Pre-Mean ± S.E.M. S.D. | Training Post-Mean ± S.E.M. S.D. | Difference (Post − Pre) | t-value | P (Within Groups) |
|---|---|---|---|---|---|---|
| Maximal oxygen consumption ml/kg/min | Continuous (9) | 43.71 ± 1.96<br>5.88 | 52.61 ± 2.34<br>7.03 | 8.90 | 5.76 | <.001 |
| | Interval (7) | 39.63 ± 2.90<br>7.68 | 49.36 ± 2.13<br>5.64 | 9.73 | 5.41 | <.01 |
| | Control (5) | 39.32 ± 4.16<br>9.29 | 42.23 ± 3.32<br>7.43 | 2.91 | .88 | NS |
| Balke Treadmill Test (elapsed time in minutes) | Continuous (9) | 17.67 ± 1.04<br>3.12 | 22.22 ± .89<br>2.68 | 4.55 | 9.60 | <.001 |
| | Interval (7) | 17.00 ± .98<br>2.58 | 20.57 ± 1.07<br>2.82 | 3.57 | 9.68 | <.001 |
| | Control (5) | 15.80 ± 2.25<br>5.02 | 16.20 ± 2.33<br>5.22 | .40 | .59 | NS |

to continuous and interval training programs demonstrated improved performance while the control group did not. Continuous training resulted in a 4.55 minute or 26% increase in the time required to elicit a heart rate of 180 beats per minute. This difference produced a corresponding t-value of 9.6 which was significant beyond the .001 level. An improvement of 3.57 minutes or 21% by the interval group provided a t-value of 9.68 which was also significant beyond the .001 level. The control group improved .4 minutes or 2.5% in its performance, but the t-value of .59 was not of any significance.

These results are consistent with those reported in other training studies. Those studies (16, 21, 22, 23, 24) utilizing continuous exercise programs with training formats similar to the one employed in this study have also found significant improvements in measures of cardio-respiratory endurance. This observation applies equally to those studies (26, 27) which have utilized an interval exercise program with a format similar to the one used in this study.

## Between Group Comparisons

An analysis of covariance was utilized to test the significance of differences between the adjusted group means. This statistical procedure was used because it takes into consideration those differences which existed among the initial means. Analysis of covariance was applied to maximal oxygen consumption (ml/kg/min) and the performances on the Balke treadmill test. If a significant F-ratio were obtained, Duncan's New-Multiple Range Test was then used to identify those groups between which there was a significant difference. The results of these tests are presented in Tables VII and VIII. In Table VII, the application of ANOCV to the group means for maximal oxygen consumption (ml/kg/min) resulted in an F-ratio of 4.17, which was significant beyond the .05 level of confidence. This indicated that significant differences existed between some or all of the groups tested. Duncan's New-Multiple Range Test was then applied to locate those differences.

Both the continuous and interval groups - with adjusted means of 51.06 and 50.43 (ml/kg/min), respectively - had significantly higher maximal oxygen consumptions than the control group, which had an adjusted mean of 43.5 (ml/kg/min). The differences between the control and experimental groups were significant beyond the .05 level of confidence. However, there was no significant difference between the continuous and interval groups in maximal oxygen consumption (ml/kg/min) at the end of the training program.

When the analysis of covariance was applied to the group means for the Balke treadmill test - Table VIII - the findings were quite similar to those of maximal oxygen consumption. An F-ratio of 16.60 resulted from the covariance procedure, and this was significant beyond the .001 level. Duncan's New-Multiple Range Test was administered to identify the source of this significance. Both the continuous and

TABLE VII

BETWEEN GROUP COMPARISON OF MAXIMAL OXYGEN CONSUMPTION (ml/kg/min)

| Variable | Group (N) | Pre-mean ± S.E.M. S.D. | Post-mean ± S.E.M. S.D. | Final Adjusted Means | F-Ratio | P |
|---|---|---|---|---|---|---|
| Maximal oxygen consumption ml/kg/min | Continuous (9) | 43.71 ± 1.96<br>5.88 | 52.61 ± 2.34<br>7.03 | 51.06[a] | | |
| | Interval (7) | 39.63 ± 2.90<br>7.68 | 49.36 ± 2.13<br>5.64 | 50.43[a] | 4.17 | <.05(2,17) |
| | Control (5) | 39.32 ± 4.16<br>9.29 | 42.23 ± 3.32<br>7.43 | 43.50[b,c] | | |

[a]Significantly different from the control group at .05 level, Duncan's New-Multiple Range Test.

[b]Significantly different from the continuous group at .05 level, Duncan's New-Multiple Range Test.

[c]Significantly different from the interval group at .05 level, Duncan's New-Multiple Range Test.

TABLE VIII

BETWEEN GROUP COMPARISON OF PERFORMANCES ON THE BALKE TREADMILL TEST

| Variable | Group (N) | Pre-mean ± S.E.M. S.D. | Post-mean ± S.E.M. S.D. | Final Adjusted Means | F-Ratio | P |
|---|---|---|---|---|---|---|
| Balke Tread-mill Test (elapsed time in min. | Continuous (9) | 17.67 ± 1.04<br>3.12 | 22.22 ± .89<br>2.68 | 21.61[a] | | |
| | Interval (7) | 17.00 ± .98<br>2.58 | 20.57 ± 1.07<br>2.82 | 20.57[a] | 16.60 | <.001(2,17) |
| | Control (5) | 15.80 ± 2.25<br>5.02 | 16.20 ± 2.33<br>5.22 | 17.30[b,c] | | |

[a]Significantly different from the control group at .01 level, Duncan's New-Multiple Range Test.

[b]Significantly different from the continuous group at .01 level, Duncan's New-Multiple Range Test.

[c]Significantly different from the interval group at .01 level, Duncan's New Multiple Range Test.

interval groups - with adjusted means of 21.61 and 20.57, respectively - were significantly different from the control group, which had an adjusted mean of 17.30. This difference was significant beyond the .01 level. However, the difference between the means of the continuous and interval groups was not significant.

These findings are in agreement with those of other comparison studies (17, 18, 19) which indicated that both continuous and interval training methods are equally capable of significantly improving cardio-respiratory endurance. However, it should be pointed out that, unlike earlier research efforts, the results of this study were obtained by using exercise programs which would be suitable for the general public. The work periods used in this study, regardless of the method, lasted longer and were less intense than those utilized in the other studies.

The results of both the within and between group comparisons were consistent with those recently reported by McKibben (20). In McKibben's study and this study, both, the continuous and interval training groups experienced significant improvements in measures of endurance, while the control groups did not. Also, there was no significant difference in the improvement obtained by continuous and interval training methods when equal amounts of work were performed.

## Summary

Continuous and interval training methods were compared to determine their relative effectiveness in the development of cardio-respiratory endurance. The results of the pre- and post-administration of the Balke treadmill test and the direct measurement of maximal oxygen consumption (ml/kg/min) were used to assess changes in endurance resulting from a six-week training period.

In order to establish the integrity of the training program and the results obtained, it was necessary to determine the reliability and validity of certain measures. These determinations were identified as sub-problems of this study. The results of these procedures indicated that Balke treadmill test and maximal oxygen consumption (ml/kg/min) were both reliable measures of cardio-respiratory endurance. Also, the Balke treadmill test was established as a valid predictor of maximal oxygen consumption (ml/kg/min). Since both experimental groups were required to exercise at specified intensities, it was necessary for the subjects to self-monitor this intensity every four minutes with a ten-second carotid pulse count. With the aid of telemetry, these pulse counts were determined to be accurate and valid indices of the average work intensity during the prior four minutes of exercise.

A statistical analysis of the pre- and post-test results provided the following findings:

1. No significant changes in body weight were

experienced by any of the groups. Thus, variations in this factor did not influence the calculation of maximal oxygen consumption (ml/kg/min).

2. Both the continuous and interval groups had significant improvements in maximal oxygen consumption (L/min), maximal oxygen consumption (ml/kg/min), and the Balke treadmill test as a result of the training programs. There was no significant improvement by the control group on any of these measures.

3. Significant differences in the post-test measures of maximal oxygen consumption (ml/kg/min) and the Balke treadmill test existed between the control group and both the continuous and interval groups. However, there was no significant difference between the continuous and interval groups on either of these measures.

## CHAPTER V

## SUMMARY AND CONCLUSIONS

### Summary

A review of the reported literature indicated that both continuous and interval training methods have been used successfully to improve maximum aerobic capacity, however few studies have actually compared the two methods. Also, the results of these comparative studies have little applicability to the general population as the exercise programs employed were usually quite severe. Despite these research deficiencies, enough evidence was available to suggest that interval exercise could be a viable training alternative for the general population. To substantiate this, it was necessary to determine the relative effectiveness of both training methods - i.e., continuous and interval - through the comparison of exercise programs suitable for the general public.

The purpose of this study was to compare the effects of continuous and interval training methods upon the development of cardio-respiratory endurance in untrained, college-age males. Changes in cardio-respiratory endurance, resulting from a six-week training period, were assessed through the pre- and post-administration of the Balke treadmill test and the open circuit measurement of maximal oxygen consumption (ml/kg/min).

The primary hypotheses of this study were that no significant differences existed among the three groups - i.e., control, interval training, and continuous training - on measures of cardio-respiratory endurance - i.e., Balke treadmill test and maximal oxygen consumption (ml/kg/min). Secondary hypotheses were designed to test for significant differences in the within-group means on measures of cardio-respiratory endurance and body weight.

Originally twenty-eight volunteers were randomly assigned to one of two experimental groups or a control group. Ten subjects were assigned to each experimental group with eight subjects being assigned to the control group. However, the attrition rate normally associated with training studies reduced the subjects in each group to a final number of 5, 7, and 9 for the control, interval, and continuous groups, respectively. These subjects averaged 21.3 years of age.

All subjects were pre-tested in order to establish their initial levels of cardio-respiratory endurance. Each subject walked the Balke treadmill test until he reached the target heart rate of 180 beats per minute, at which point a thirty-second volume of expired air was collected and used to determine maximal oxygen consumption (ml/kg/min). Both measures of endurance were determined to be reliable based on the test-retest results of ten subjects selected at random. Other measures obtained during the pre-testing included body weight (kg) and maximal oxygen consumption (L/min).

A total of thirty supervised training sessions were held with an average attendance of 27.9 sessions and the minimum number of sessions attended was twenty-six. Training consisted of running or jogging - in accordance with the designated guidelines of each exercise program - on an all-weather, quarter-mile track for a distance of two miles, five days a week for six weeks. While the training programs differed in work format, level of intensity, and duration of work, both experimental groups performed the same amount of total work - i.e., two miles. The control group did not participate in any systematic training during the experimental period.

All subjects began each training session with a standardized warm-up, which was followed with a signal for both groups to begin exercise. Members of the continuous group jogged at or near the moderate intensity of 162 beats per minute until they had completed a distance of two miles. The interval group ran at or near an intensity of 174 beats per minute for the same distance. This group utilized a work/rest ratio of 1:1 with a minimum of three, four-minute work intervals which were alternated with equal periods of rest. Almost all of the interval subjects required a portion of a fourth work interval in order to finish the distance requirement. Each training session was concluded with a "cool down" period which consisted of walking for at least one-quarter mile.

The continuous group estimated work intensity by palpating the carotid artery (beats/10 sec.) every four minutes until the distance requirement was completed. This palpation technique was utilized by the interval group only at the end of each work interval. These pulse counts provided the subjects with immediate feedback as to their work intensity and allowed them to adjust their pace accordingly. With the aid of telemetry, it was determined that these pulse counts were accurate and valid measures of the average work intensity during the prior four minutes of work. The pulse counts obtained by the subjects were recorded and from these records it was determined that the average work intensity for the entire training period - i.e., six weeks - was 162.10 beats per minute for the continuous group and 174.64 beats per minute for the interval group.

Post-experimental measures of body weight, maximal oxygen consumption (L/min), maximal oxygen consumption (ml/kg/min), and the Balke treadmill test were obtained during the three days following the conclusion of the training period. Original testing conditions - i.e., clothing worn and time of day tested - were replicated as closely as possible during this post-experimental testing.

## Findings

The results of this study were tested at the .05 level of confidence and the findings were as follows:

1. None of the groups experienced any significant

change in body weight from the initial to final measures.

2. Hypotheses 1 and 4 - page 16 - stated that the control group would not experience any significant improvement in maximal oxygen consumption (ml/kg/min) or in performance on the Balke treadmill test.

Both of these hypotheses were accepted as the control group experienced no significant change in maximal oxygen consumption (ml/kg/min) or in performance on the Balke treadmill test.

3. Hypotheses 2, 3, 5, and 6 - page 16 - stated that neither the continuous nor interval training groups would experience any significant improvement in maximal oxygen consumption (ml/kg/min) or in performance on the Balke treadmill test.

These hypotheses were rejected as both the continuous and interval training groups experienced significant improvements in maximal oxygen consumption (ml/kg/min) and in performances on the Balke treadmill test.

4. Hypotheses 7 and 8 - page 17 - stated that there would be no significant difference between groups in the adjusted mean scores of the Balke treadmill test and maximal oxygen consumption (ml/kg/min).

These hypotheses were rejected as both the continuous and interval training groups were significantly different from the control group on the final measures of maximal oxygen consumption (ml/kg/min) and the Balke treadmill test. However, no significant difference existed between the continuous and interval training groups on either of these measures.

## Conclusions

1. Continuous jogging for two miles at a heart rate of approximately 162 beats per minute five days/week for six weeks produced significant improvement in cardio-respiratory endurance.
2. Interval running for two miles at a heart rate of approximately 174 beats per minute and performed in alternate work and rest intervals of four minutes, five days/week for six weeks produced significant improvement in cardio-respiratory endurance.
3. When the amount of work performed was held constant, there was no difference in continuous and interval training methods in the development of cardio-respiratory endurance.

No longer should an individual feel restricted to only continuous-type exercise as it is apparent that the general population has at its disposal at least two training methods - i.e., continuous and interval - which are equally effective in improving cardio-respiratory endurance. Contrary to popular belief, interval exercise can improve endurance effectively at exercise intensities that are not highly stressful and which are not beyond the physical capacities of most of the general public. The addition of an alternative training method for general use adds yet another dimension to an ever-expanding pharmocopoeia of exercise.

Now an individual can choose the manner in which he wishes to do his exercise as well as making the usual selections of exercise mode, intensity, duration, and frequency. This choice is available to him when considering either a long-term program or a daily regimen. Should the individual find continuous exercise too tedious or monotonous, he can switch to an interval approach. This allows him to segment the desired amount of work into relatively short work periods which are alternated with periods of rest. This type of approach may well provide the psychological and physiological incentive to stay with an exercise program and to perhaps accomplish more work than just the required minimum.

## Recommendations for Future Study

Recommendations for further research which stem from the results of this study are as follows:

1. Similar studies should be conducted utilizing more subjects for longer training periods.
2. Similar studies should be conducted to determine the influence of age and the initial level

of fitness upon the improvements in cardio-respiratory endurance achieved by each training method.

3. Future studies should incorporate subjective rating scales so that the perceived exertion levels associated with each method of training can be determined.

4. Interval training studies equating workload and the duration of work and rest intervals should be conducted to determine the threshold intensity and to determine the effects of varying work intensities upon the development of cardio-respiratory endurance.

5. Additional interval training studies equating workload and intensity should be conducted to establish the influence of work interval duration upon the development of cardio-respiratory endurance.

6. Interval training studies equating intensity and the duration of work and rest intervals should be conducted to determine the minimum workload - i.e., amount of work accomplished - required to elicit improvements in cardio-respiratory endurance.

7. Additional training studies equating workload, intensity, and the duration of work and rest intervals should be conducted to establish the

effects of training frequency upon the development of cardio-respiratory endurance.

8. Comparison studies equating workload and intensity - at heart rate levels below 168 bpm - should be conducted to determine if both continuous and interval methods could be used to develop endurance at the same intensity.

9. The above studies should be conducted on both male and female populations.

BIBLIOGRAPHY


(1) Life and Health. Del Mar, California: CRM Books, 1972.

(2) Kraus, Hans, and Wilhelm Raab. Hypokinetic Disease. Springfield: Charles C. Thomas Co., 1961.

(3) Åstrand, Per-Olof, and Kaare Rodahl. Textbook of Work Physiology. New York: McGraw-Hill Book Co., 1970.

(4) Cooper, Kenneth H. Aerobics. New York: Bantam Books, 1968.

(5) Cooper, Kenneth H. New Aerobics. New York: Bantam Books, 1970.

(6) Fox, Edward L., and Donald K. Mathews. Interval Training: Conditioning for Sports and General Fitness. Philadelphia: W. B. Saunders Co., 1974.

(7) Cureton, Thomas K. "What Does Maximum Oxygen Intake ($VO_2$Max) Measure? How Is It Interpreted? What Are Its Principal Limitations?". Proceedings of National College Physical Education Association for Men (January 9-12, 1975), p. 203.

(8) Cureton, Thomas K. "Improvements in Oxygen Intake Capacity Resulting From Sports and Exercise Training Programs: A Review." American Corrective Therapy Journal, Vol. 23 (September-October, 1969), pp. 144-147.

(9) Pollock, Michael L., Thomas K. Cureton and Leonard Greninger. "Effects of Frequency of Training on Working Capacity, Cardiovascular Function, and Body Composition of Adult Men." Medicine and Science in Sports, Vol. 1, No. 2 (June, 1969), pp. 70-74.

(10) Shephard, Roy J. Alive Man! Springfield, Illinois: Charles C. Thomas Co., 1972.

(11) Pollock, Michael L. "The Quantification of Endurance Training Programs." Exercise and Sports Sciences Reviews, Jack H. Wilmore, Ed. New York: Academic Press, 1973, pp. 156-162.

(12) deVries, Herbert. Physiology of Exercise for Physical Education and Athletics. Dubuque, Iowa: Wm. C. Brown Publishing Co., 1974.

(13) Consolazio, Frank C., Robert E. Johnson, and Louis J. Pecora. Physiological Measurements of Metabolic Junctions in Man. New York: McGraw-Hill Book Co., 1963.

(14) Karpovich, Peter V. Physiology of Muscular Activity. Philadelphia: W. B. Saunders Co., 1965.

(15) Ricci, Benjamin. Physiological Basis of Performance. Philadelphia: Lea and Febiger, 1967.

(16) Sharkey, Brian J. "Intensity and Duration of Training and the Development of Cardio-respiratory Endurance." Medicine and Science in Sports, Vol. 2, No. 4 (1970), pp. 197-202.

(17) Moncrieff, John. "Variations in the Effect of Two Training Methods on Work Output." (Unpublished Master's Thesis, University of British Columbia, 1963.)

(18) Patton, Robert W. "A Comparison of Two Endurance Training Techniques." (Unpublished Master's Thesis, University of Florida, 1964.)

(19) Mellerowicz, H., W. Meller, and E. Muller. "Vergleichende Untersuchungen uber Leistungssteingerung Durch Intervalltraining und Dauertraining." Trans. C. Buck. Arbeitsphysiologie, Vol. 18 (1960), pp. 376-385.

(20) McKibben, Stephen A. "A Comparison of Three Work Loads of Varying Intensity and Distance on Cardiovascular Endurance." (Unpublished Doctoral Dissertation, Brigham Young University, 1975.)

(21) Faria, Irvin E. "Cardiovascular Response to Exercise as Influenced by Training of Various Intensities." Research Quarterly, Vol. 41, No. 1 (March, 1970), pp. 44-50.

(22) Sharkey, Brian J., and John P. Holleman. "Cardio-respiratory Adaptations to Training at Specified Intensities." Research Quarterly, Vol. 38, No. 4 (December, 1967), pp. 698-704.

(23) Burke, Edmund, and Don Franks. "Changes in $VO_2$Max Resulting From Bicycle Training at Different Intensities Holding Total Mechanical Work Constant." Research Quarterly, Vol. 46, No. 1 (March, 1975), pp. 31-37.

(24) Karvonen, Martti J. "Effects of Vigorous Exercise on the Heart," in Work and the Heart. F. F. Rosenbaum and E. L. Belknap (Eds.). New York: Paul B. Hoeber, 1959, p. 207.

(25) Fox, Edward L., Robert L. Bartels, Charles E. Billings, Donald K. Mathews, Robert Bason, and Wyatt M. Webb. "Intensity and Distance of Interval Training Programs and Changes in Aerobic Power." Medicine and Science in Sports, Vol. 5, No. 1 (1973), pp. 18-22.

(26) Siegel, Wayne, Gunnar Blomqvist, and Jere H. Mitchell. "Effects of a Quantified Physical Training Program on Middle-Aged Sedentary Men." Circulation, Vol. 16 (1970), pp. 19-29.

(27) Knuttgen, H. G. "Physical Conditioning Through Interval Training With Young Male Adults." Medicine and Science in Sports, Vol. 5, No. 4 (1973), pp. 220-226.

(28) Jackson, Jay H., Brian J. Sharkey, and L. Pat Johnston. "Cardio-respiratory Adaptations to Training at Specified Frequencies." Research Quarterly, Vol. 39, No. 2 (May, 1968), pp. 295-300.

(29) Pollock, Michael L., Thomas K. Cureton, and Leonard Greninger. "Effects of Frequency of Training on Working Capacity, Cardiovascular Function, and Body Composition." Medicine and Science in Sports, Vol. 1, No. 2 (1969), pp. 70-74.

(30) Durnin, J. V. G. A., J. M. Brockway, and H. W. Whitcher. "Effects of a Short Period of Training of Varying Severity on Some Measurements of Physical Fitness." Journal of Applied Physiology, Vol. 15 (January, 1960), pp. 161-165.

(31) Wilmore, Jack H., J. Royce, Robert N. Girandola, Frank I. Katch, and Victor L. Katch. "Physiological Alterations Resulting From a 10-Week Program of Jogging." Medicine and Science in Sports, Vol. 2, No. 1 (Spring, 1970), pp. 7-14.

(32) Tooshi, Ali. "Effect of Three Different Durations of Endurance Training on Serum Cholesterol, Body Composition and Other Fitness Measures." (Unpublished Doctoral Dissertation, University of Illinois, 1970.)

(33) Åstrand, Irma, Per-Olof Åstrand, Erik Hohwü Christensen, and Rune Hedman. "Intermittent Muscular Work." <u>Acta Physiologica Scandinavica</u>, Vol. 50 (1960), pp. 448-453.

(34) Christensen, Erik H., Rune Hedman, and Bengt Saltin. "Intermittent and Continuous Running." <u>Acta Physiologica Scandinavica</u>, Vol. 50 (1960), pp. 269-286.

(35) Karlsson, Jan, Per-Olof Åstrand, and Bjorn Ekblom. "Training of the Oxygen Transport System in Man." <u>Journal of Applied Physiology</u>, Vol. 22 (1967), pp. 1061-1065.

(36) Fox, Edward L., Sid Robinson, and David L. Wiegman. "Metabolic Energy Sources During Continuous and Interval Running." <u>Journal of Applied Physiology</u>, Vol. 27, No. 2 (August, 1969), pp. 174-178.

(37) Harper, Donald D., Charles E. Billings, and Donald K. Mathews. "Comparative Effects of Two Physical Conditioning Programs on Cardiovascular Fitness in Man." <u>Research Quarterly</u>, Vol. 40, No. 2 (May, 1969), pp. 293-298.

(38) Fox, Edward L., Charles E. Billings, Robert Bason, and Donald K. Mathews. "Improvement of Physical Fitness by Interval Training II Required Training Frequency." Report RF 2002-3. Columbus, Ohio: Ohio State University Research Foundation, April, 1967.

(39) Balke, Bruno. <u>Correlation of Static and Physical Endurance. I. A. Test of Performance Based on the Cardio-Vascular and Respiratory Responses to Gradually Increased Work.</u> USAF School of Aviation Medicine Project #21-32-004, Report I. Randolph AFB, Texas, April, 1952.

(40) Dill, D. B., and A. Folling. "Studies in Musuclar Activity. II. A Nomographic Description of Expired Air." <u>Journal of Physiology</u>, Vol. 66 (1928), pp. 133-135.

(41) Steel, Robert, and James H. Torrie. _Principles and Procedures of Statistics_. New York: McGraw-Hill Book Co., 1960, p. 107.

(42) Mathews, Donald K. _Measurement in Physical Education_. Philadelphia: W. B. Saunders Co., 1968.

# APPENDIX A

## RAW DATA FOR THE VERIFICATION OF WORK INTENSITY

| Subject ID Number<br>Interval | Average heart beats during exercise (beats/10 sec.) | Telemetered post-exercise pulse count (beats/10 sec.) | Subject's post-exercise pulse count (beats/10 sec.) |
|---|---|---|---|
| 1 | 29.50 | 30 | 30 |
| | 29.33 | 29 | 29 |
| | 29.50 | 29 | 30 |
| | 29.00 | 29 | 29 |
| 2 | 29.50 | 30 | 29 |
| | 30.00 | 30 | 30 |
| | 30.00 | 29 | 29 |
| 3 | 29.00 | 29 | 29 |
| | 30.00 | 29 | 29 |
| | 29.33 | 30 | 30 |
| 4 | 30.00 | 30 | 30 |
| | 29.33 | 29 | 29 |
| | 29.50 | 29 | 29 |
| 5 | 29.67 | 30 | 30 |
| | 30.00 | 30 | 30 |
| | 29.33 | 29 | 29 |
| 6 | 29.50 | 29 | 29 |
| | 29.67 | 30 | 30 |
| | 27.33 | 28 | 27 |
| | 29.33 | 29 | 29 |
| | 28.33 | 28 | 28 |
| | 27.00 | 27 | 27 |
| 1 | 28.50 | 28 | 29 |
| | 27.50 | 28 | 28 |
| | 27.50 | 29 | 29 |
| 2 | 27.00 | 27 | 27 |
| | 27.67 | 28 | 28 |
| | 28.00 | 28 | 28 |

| Subject ID Number<br><u>Interval</u> | Average heart beats during exercise (beats/10 sec.) | Telemetered post-exercise pulse count (beats/10 sec.) | Subject's post-exercise pulse count (beats/10 sec.) |
|---|---|---|---|
| 3 | 27.00 | 27 | 27 |
| | 27.67 | 27 | 27 |
| | 27.00 | 27 | 27 |
| 4 | 27.00 | 27 | 26 |
| | 28.00 | 27 | 27 |
| | 28.00 | 27 | 27 |
| 5 | 27.00 | 27 | 27 |
| | 27.00 | 27 | 29 |

APPENDIX B

RAW DATA ON MEASURES OF RELIABILITY

| Subject's ID Number | Maximal Oxygen Consumption (ml/kg/min) Pre-test | Maximal Oxygen Consumption (ml/kg/min) Re-test | Balke Treadmill Test (elapsed time in min.) Pre-test | Balke Treadmill Test (elapsed time in min.) Re-test |
|---|---|---|---|---|
| 01 | 42.94 | 41.51 | 20 | 20 |
| 02 | 40.74 | 42.67 | 18 | 17 |
| 03 | 44.07 | 39.10 | 17 | 16 |
| 04 | 39.81 | 34.93 | 14 | 14 |
| 05 | 53.99 | 50.76 | 18 | 18 |
| 06 | 43.38 | 44.48 | 20 | 20 |
| 07 | 38.19 | 36.84 | 13 | 13 |
| 08 | 60.58 | 59.07 | 19 | 19 |
| 09 | 47.68 | 45.93 | 22 | 22 |
| 10 | 44.67 | 40.24 | 14 | 14 |

## APPENDIX C

## DATA ON BODY WEIGHT AND MEASURES OF CARDIO-RESPIRATORY ENDURANCE

| | Body Weight (kg) pre | Body Weight (kg) post | Balke Treadmill Test (elapsed time in min.) pre | Balke Treadmill Test (elapsed time in min.) post | Maximal Oxygen Consumption (L/min.) pre | Maximal Oxygen Consumption (L/min.) post | Maximal Oxygen Consumption (ml/kg/min) pre | Maximal Oxygen Consumption (ml/kg/min) post | Predicted Maximal Oxygen Consumption (ml/kg/min) |
|---|---|---|---|---|---|---|---|---|---|
| <u>Control Group</u> | | | | | | | | | |
| 1 | 105.56 | 111.91 | 8 | 8 | 2.972 | 3.483 | 28.15 | 31.12 | 25.00 |
| 2 | 71.05 | 70.37 | 20 | 19 | 3.694 | 3.042 | 51.99 | 43.23 | 43.50 |
| 3 | 85.81 | 87.62 | 14 | 16 | 2.801 | 3.689 | 32.64 | 42.10 | 38.50 |
| 4 | 83.99 | 83.76 | 20 | 22 | 3.606 | 4.359 | 42.94 | 52.05 | 48.50 |
| 5 | 69.46 | 69.92 | 17 | 16 | 2.840 | 2.982 | 40.88 | 42.64 | 38.50 |
| <u>Continuous Group</u> | | | | | | | | | |
| 1 | 65.38 | 66.51 | 18 | 21 | 2.664 | 3.116 | 40.74 | 46.85 | 47.00 |
| 2 | 61.74 | 60.50 | 19 | 25 | 3.080 | 3.486 | 49.89 | 57.62 | 53.50 |
| 3 | 74.46 | 73.09 | 16 | 22 | 2.704 | 3.530 | 36.25 | 48.30 | 48.50 |
| 4 | 72.64 | 74.23 | 14 | 20 | 2.892 | 3.637 | 39.81 | 49.00 | 45.00 |
| 5 | 85.13 | 85.58 | 16 | 22 | 3.844 | 5.045 | 45.15 | 58.95 | 48.50 |
| 6 | 67.19 | 67.65 | 22 | 25 | 3.686 | 3.993 | 54.86 | 59.02 | 53.50 |
| 7 | 67.65 | 68.55 | 21 | 25 | 3.050 | 4.274 | 45.08 | 62.35 | 53.50 |
| 8 | 96.70 | 94.89 | 20 | 23 | 4.195 | 4.727 | 43.38 | 49.82 | 50.00 |
| 9 | 76.61 | 78.54 | 13 | 17 | 2.926 | 3.267 | 38.19 | 41.59 | 40.00 |
| <u>Interval Group</u> | | | | | | | | | |
| 1 | 71.05 | 72.64 | 16 | 20 | 2.716 | 3.778 | 38.23 | 52.01 | 45.00 |
| 2 | 85.13 | 85.35 | 15 | 18 | 2.517 | 3.768 | 29.57 | 44.15 | 42.00 |
| 3 | 85.35 | 85.47 | 19 | 24 | 4.446 | 4.612 | 52.09 | 53.96 | 52.00 |
| 4 | 92.16 | 90.57 | 16 | 20 | 3.320 | 4.228 | 36.02 | 46.68 | 45.00 |
| 5 | 80.02 | 79.00 | 22 | 25 | 3.815 | 4.606 | 47.68 | 58.30 | 53.50 |
| 6 | 65.83 | 66.28 | 15 | 19 | 2.353 | 3.170 | 35.74 | 47.82 | 43.50 |
| 7 | 89.44 | 92.62 | 16 | 18 | 3.404 | 3.944 | 38.06 | 42.58 | 42.00 |

APPENDIX D

DATA COLLECTED DURING THE SIX WEEKS

OF TRAINING

| | Mean Exercise H.R. | Ave. Distance (yds) Per 4-min. Work Interval | Ave. Distance (yds) of Incomplete Work Interval | Ave. Time (min:sec) of Incomplete Work Interval | Ave. Time (Continuous Group) for 2-miles* |
|---|---|---|---|---|---|
| **Continous Group** | | | | | |
| 1 | 162.96 | | | | 15:31 |
| 2 | 159.17 | | | | 14:49 |
| 3 | 163.89 | | | | 15:02 |
| 4 | 161.88 | | | | 13:42 |
| 5 | 161.98 | | | | 14:53 |
| 6 | 162.38 | | | | 13:40 |
| 7 | 162.96 | | | | 13:16 |
| 8 | 160.02 | | | | 15:16 |
| 9 | 163.69 | | | | 15:32 |
| | $\overline{X}$ = 162.10 | | | | $\overline{X}$ = 14:38 |
| **Interval Group** | | | | | |
| 1 | 177.50 | 928.4 | 734.8 | 3:09 | |
| 2 | 174.63 | 1065.6 | 321.2 | 1:13 | |
| 3 | 173.08 | 1041.3 | 396.0 | 1:20 | |
| 4 | 175.57 | 978.3 | 585.0 | 2:34 | |
| 5 | 172.18 | 1170.3 | 9.2 | 0:00 | |
| 6 | 173.48 | 1037.1 | 408.6 | 1:34 | |
| 7 | 176.04 | 941.9 | 694.4 | 3:05 | |
| | $\overline{X}$ = 174.64 | $\overline{X}$ = 1023.3 | $\overline{X}$ = 449.9 | $\overline{X}$ = 1:51 | |

VITA

Larry Wayne Gregory

Candidate for the Degree of

Doctor of Education

Thesis: THE DEVELOPMENT OF CARDIO-RESPIRATORY ENDURANCE: A COMPARISON OF CONTINUOUS AND INTERVAL TRAINING

Major Field: Higher Education

Minor Field: Health, Physical Education and Recreation

Biographical:

Personal Data: Born in Pampa, Texas, March 5, 1946, the son of Mr. and Mrs. Harold L. Gregory. Married Sally Lou Sanders August 5, 1973; two sons, Stephen and Heath.

Education: Attended elementary, junior high, and high school in Pampa, Texas; graduated from Pampa High School in 1964; received the Bachelor of Science in Physical Education degree from Texas Tech University, May, 1969, with a major in Physical Education; received the Master of Education degree in Physical Education from Texas Tech University, May, 1971; completed requirements for the Doctor of Education degree in July, 1976.

Professional Experience: Served as a teacher of elementary physical education and health in the Amarillo Public Schools, Amarillo, Texas, 1969-70; served as intramural graduate assistant at Texas Tech University, Lubbock, Texas, 1970-71; served as an Instructor and Assistant Director of Recreation at Oklahoma State University, Stillwater, Oklahoma, 1971-73; served as graduate teaching assistant and research assistant at Oklahoma State University, 1973-76. Member of American Alliance of Health, Physical Education and Recreation; American College of Sports Medicine-National and Central States Chapters; Oklahoma Association for Health, Physical Education and Recreation.