

A COMPARISON AMONG THREE SUBMAXIMAL STEP TESTS  
FOR PREDICTING MAXIMAL OXYGEN INTAKE

By

CHARLES HOBERT HUNDLEY  
"

Bachelor of Science  
Oklahoma State University  
Stillwater, Oklahoma  
1951

Master of Science  
Oklahoma State University  
Stillwater, Oklahoma  
1958

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  
May, 1975

Thesis  
1975 D  
H 933c  
cop. 2

MAY 12 1976

A COMPARISON AMONG THREE SUBMAXIMAL STEP TESTS  
FOR PREDICTING MAXIMAL OXYGEN INTAKE

Thesis Approved:

*Alvin B. Harrison*

Thesis Adviser

*Betty H. Abernethy*

*John W. Bayless*

*Robert L. Brown*

*N. N. Darden*

Dean of the Graduate College

938945

## PREFACE

Having been involved in physical education for over 20 years and realizing that physical fitness of the population is of concern nationally, as well as locally, my interest in determining the physically fit individual has deepened. There is a great need for determining the best method or methods for classifying individuals in fitness categories in order that physical training programs, wherever the program is undertaken, can be more adequately prescribed.

This study is concerned with determining which of three different step tests is a more valid field test that can be administered to individuals or groups of individuals to predict maximum oxygen intake and through this determine the level of an individual's physical fitness. Maximum oxygen intake has been established as the best criterion for ascertaining endurance as one aspect of physical fitness. This study is an attempt to advance knowledge in my chosen field of Health, Physical Education, and Recreation.

The author wishes to thank the members of his advisory committee, Dr. A. B. Harrison, Dr. Betty Abercrombie, Dr. John Bayless, and Dr. Robert Brown, for their very valuable guidance and assistance in the development of this study. Additional thanks are given to those 36 men who participated in this study.

My special gratitude to my wife, Joella, and son, Chet, for their encouragement, understanding, and sacrifice throughout this study.

TABLE OF CONTENTS

Chapter	Page
I. INTRODUCTION . . . . .	1
Purpose of the Study . . . . .	10
Statement of the Problem . . . . .	11
Limitations . . . . .	12
Delimitations . . . . .	12
Assumptions . . . . .	12
Internal Validity . . . . .	13
II. REVIEW OF RELATED LITERATURE . . . . .	15
III. METHOD AND PROCEDURE . . . . .	29
Selection of Subjects . . . . .	29
Test Selection . . . . .	30
Administration of the Tests . . . . .	31
Grouping and Analysis of Data . . . . .	44
IV. DATA ANALYSIS AND RESULTS . . . . .	46
V. CONCLUSIONS AND RECOMMENDATIONS . . . . .	66
Recommendations . . . . .	70
Recommendations for Further Study . . . . .	70
A SELECTED BIBLIOGRAPHY . . . . .	72
APPENDIX . . . . .	75

LIST OF TABLES

Table	Page
I. Exercise Heart Rate . . . . .	61
II. Summary of Three Step Tests Results . . . . .	65

## LIST OF FIGURES

Figure	Page
1. Subject Performing the Michael and Adams One-Minute Step Test . . . . .	35
2. Subject Performing the Ohio State University Step Test . . . . .	37
3. Subject Performing the Lewis Progressive Step Test . . . . .	40
4. Resting Heart Rates Before Exercise Indicating Range, Mean, and Standard Deviation . . . . .	47
5. Reliability Check on Michael and Adams One-Minute Step Test. . . . .	48
6. Reliability Check on Lewis Progressive Step Test . . . . .	48
7. Reliability Check on Ohio State University Test . . . . .	49
8. Maximum Oxygen Intake Indicating Range, Mean, and Standard Deviation . . . . .	50
9. Relationship of Various Tests With Calculated Maximum Oxygen Intake . . . . .	52
10. Cross-Checked Interrelationship Between Each of the Three Step Tests . . . . .	55
11. Fitness Categories Based Upon Established Percentile Norms for the Lewis Progressive Step Test . . . . .	57
12. Fitness Categories Based Upon Established Percentile Norms for the Ohio State University Step Test . . . . .	58
13. Fitness Categories Based Upon Established Percentile Norms for the Michael and Adams One-Minute Step Test; Three Minute Recovery Heart Rates . . . . .	59
14. Comparison of Calculated Maximum O <sub>2</sub> Intake and Predicted Maximum O <sub>2</sub> Intake . . . . .	60

## CHAPTER I

### INTRODUCTION

Physical fitness is of growing concern to the population of the United States. In a day and age where there is a rapid growth in labor saving devices, there are no longer many occupations that place a demand upon the vital organs of the body which will stress them to the point that they function or develop to their optimum levels.

During the growth and development years of our youth, there is little if any activity that youth can participate in around the home that will develop the vital organs of the body with satisfactory results. Woods writes that:

The cardiovascular diseases, collectively, pose the greatest single threat to the lives, health, and well-being of the American population today. It is estimated by the United States Department of Health, Education and Welfare that nearly 20 percent of our total population is affected with one or another form of heart disease and statistics indicate that the prevalence of cardiovascular disorders is on a steady increase.<sup>1</sup>

Schneider claims that the effects of a sedentary occupation are reduction of muscle tone, decrease in appetite, constipation, shallow breathing, and slow circulation, which are characteristics of the inefficient, and can be offset by physical activity.<sup>2</sup>

---

<sup>1</sup>Francis James Woods, "The Validation of the Ohio State University Cardiovascular Fitness Test," Dissertation Abstracts, 29A, Part 5 (1969), p. 2990A.

<sup>2</sup>Leonard A. Larson, "Cardiovascular-Respiratory Function in Relation to Physical Fitness," Supplement to the Research Quarterly, 12 (1941), p. 459.



For these reasons, to become physically fit is an aim that should appeal to every normal person. It is known that a satisfactory degree of physical fitness cannot be achieved except through an adequate physical exercise program and cannot be maintained if training stops. One of the major problems of physical education is the measurement of physical condition. It becomes very important to have ways of appraising fitness so that fitness programs can be implemented that will help increase physical fitness.

The term "physical fitness" has been found to be rather difficult to define. There are perhaps as many definitions as there are authors. About the simplest definition is: The capacity of an individual to perform a given task. Consolazio defines physical fitness as the ability to perform a specific task requiring muscular effort in which speed and endurance are the main criteria.<sup>3</sup>

Morehouse and Miller write that general fitness implies more than one task and is usually meant to include not only the activities of everyday life but also emergencies in which a person is unexpectedly called upon to perform activities demanding unusual expenditures of strength, energy, and adaptive ability under extremely unfavorable environments.<sup>4</sup>

Cooper defines physical fitness as the difference between minimal and maximal requirements for performing work based upon the energy demands and the ability to utilize oxygen. Fitness is dependent upon

---

<sup>3</sup>C. Frank Consolazio, Robert E. Johnson, and Louis J. Pecora, Physiological Measurements of Metabolic Function in Man (New York, N.Y., 1963), p. 340.

<sup>4</sup>Lawrence E. Morehouse and Augustus T. Miller, Physiology of Exercise (St. Louis, Mo., 1971), p. 277.

an ability to rapidly breathe large amounts of air, forcefully deliver large volumes of blood, and effectively deliver oxygen to all parts of the body.<sup>5</sup>

Cureton defines physical fitness as the ability to handle the body well and the capacity to work hard over a long period of time without diminished efficiency. He writes that:

Circulatory-respiratory function is the heart of it all, as without sufficient intake of oxygen, both in the quiet state and in the exercise state, there cannot be adequate energy to live a vigorous life. The maximal intake capacity for oxygen reflects the capacity of the body to circulate blood. It is the circulation of the blood that acts to pull the oxygen into the body. Its dissemination to various parts of the body in a constant stream of supply is the 'life of the body' and makes possible the combustion of foodstuffs and recovery from exertion.<sup>6</sup>

Some of the components for evaluating physical fitness are endurance (both cardio-respiratory and muscular), power, agility, strength, balance, and flexibility. Of these, endurance is one of the most important, since it is required for performing heavy work over extended periods of time without a decrease in efficiency.<sup>7</sup>

Endurance is an extremely important factor of physical fitness. There are two types, cardio-respiratory and muscular. Muscular endurance is related to the individual muscles ability to continue to contract over a longer period of time. This is related to strength. Cardio-respiratory endurance is related to work or contractions of large muscle groups over a long period of time and depends on the effectiveness of the heart, blood vessels, and lungs, which together take in oxygen and release carbon dioxide and carry them in the blood

---

<sup>5</sup>Kenneth H. Cooper, Aerobics (New York, N.Y., 1968), pp. 7-14.

<sup>6</sup>Thomas K. Cureton, Physical Fitness Workbook for Adults (Champaign, Ill., 1970), p. 22.

<sup>7</sup>Consolazio, p. 341.

stream to and from the muscles. Endurance requires the development of the respiratory and circulatory systems.

Of the many factors concerned in maintaining the normal functioning of a living organism, respiration is probably the most important. Respiration involves the coordinated participation of tissue fluids, blood, the circulation, many muscles, and a considerable part of the central nervous system.<sup>8</sup>

The most immediate function of the respiratory system is to take oxygen from the atmosphere and deliver it to the blood, which in turn delivers it to the cells where oxidation occurs. In exercise, the amount of energy expended by the body is increased. Also, the requirement for oxygen, which is used in the release of this energy, is increased.

The energy provided to the cells is in the form of organic compounds. When organic compounds are oxidized, there are two important by-products, carbon dioxide and water. The carbon dioxide cannot be used by the tissues and is considered a waste product and must be eliminated from the body. Thus, the second major function of the respiratory system is the removal of carbon dioxide from the body.

The efficiency of the circulorespiratory system in vigorous performance of work is related primarily to endurance. Fitness of the circulorespiratory system is very important in determining how long an organism can maintain a particular level of effort.<sup>9</sup>

This study was concerned with cardio-respiratory endurance as a phase of fitness as opposed to muscular endurance. Cardio-respiratory endurance is specifically related to the ability of the muscles of the

---

<sup>8</sup>Charles R. Brassfield, "Some Physiological Aspects of Physical Fitness," Research Quarterly, 14 (1943), pp. 106-107.

<sup>9</sup>Clayne R. Jensen and Gordon W. Schultz, Applied Kinseology (New York, N.Y., 1970), pp. 176-177.

body to function at an optimum level for long periods of time and to the body's cardio-respiratory ability to supply adequate amounts of fuel (oxygen) to feed the muscles and to carry away carbon dioxide.

Since muscles will not be able to function for long without oxygen, it appears that the cardio-respiratory aspect of endurance is of most importance to physical fitness. Brassfield states that "the muscles are more immediately dependent on oxygen than on any other substance. Lactic acid accumulates within them when they do not receive this gas in adequate amounts."<sup>10</sup> The accumulation of excessive amounts of lactic acid in the blood and the muscles accelerate the onset of fatigue and will cause the muscles to cease functioning.

The circulation, however, is usually looked upon as the important factor in the limitation of muscular exertion. The chief determining factor, therefore, in the oxygen intake is the rate of circulation of the blood. . . . In the final analysis, physical fitness then appears to be limited by the cardio-respiratory system.<sup>11</sup>

It has been determined by many individuals working in research in physiology that maximal oxygen consumption is the best measure of fitness for continuous exercise. Maximum oxygen intake is defined as the capacity of the body to transfer oxygen from the atmosphere to the tissues.

A high maximum intake is dependent on the optimal functioning of the cardiovascular and respiratory systems and the transfer of gases between the blood the tissues as well as between the blood and lungs.<sup>12</sup>

By measuring maximal oxygen intake, one may determine a subject's

---

<sup>10</sup>Brassfield, p. 111.

<sup>11</sup>Ibid.

<sup>12</sup>Peter V. Karpovich and Wayne E. Sinning, Physiology of Muscular Activity (Philadelphia, Pa., 1971), p. 111.

capacity for submaximal exercise and categorize him in regard to his physical fitness.

Cooper believes that the ability to do prolonged work without undue fatigue is called endurance fitness or working capacity, and the key is oxygen consumption. Most of us can produce enough energy to perform ordinary daily activities; however, as activities become more vigorous, some of us cannot keep up. This difference between our minimum requirement and our maximum capacity is the best measure of our fitness. Our maximum oxygen consumption is the best measure of our fitness.<sup>13</sup> As a person's physical fitness level increases, the ability to take in and utilize more oxygen improves and a person is able to perform exercise for longer periods of time. Maximum oxygen intake is the best single measure of an individual's cardio-respiratory fitness; therefore, these two terms are used synonymously.

There are basically two types of tests used in the measurement of cardio-respiratory endurance. The most accurate way of measuring maximum oxygen intake is done in elaborate laboratories where exact work load can be controlled and equipment is available to analyze expired air of the subject for oxygen consumption and carbon dioxide content.

The laboratory tests allow continuous monitoring of the circulatory and respiratory responses to exercise which is essential for the recognition of an individual's capacity for coordinating a complexity of organic functions.<sup>14</sup>

The measurement of human physical working capacity as commonly performed through measuring maximal oxygen intake while the subject is stressed on a bicycle

---

<sup>13</sup>Cooper, p. 9.

<sup>14</sup>John G. Bayless, "A Metabolic Functional Capacity Test for Upper Elementary Age Boys" (unpublished Ed.D. Dissertation, Oklahoma State University, 1966), p. 3.

ergometer or treadmill is an extremely rigorous and demanding one for the subject.<sup>15</sup>

It is generally agreed that of all the measurements for testing physical efficiency, the pulse rate during severe exercise seems to be the most reliable. Studies at the Harvard Fatigue Laboratory have shown that in addition to the pulse rate during an exhausting run, the duration of the run, the pulse rate immediately after the run,<sup>16</sup> and the blood lactate are all related to physical fitness.

"Fortunately, however, pulse rate, which is easy to measure, correlates significantly with oxygen consumption during exercise."<sup>17</sup>

As a result of this significant correlation, numerous submaximal tests have been constructed with which one may predict maximal oxygen intake from pulse rates; thus, the second major type of physical fitness test was developed, the field test. The field test is a test that can be administered outside of the laboratory, with little equipment necessary, and may be given to large numbers of subjects in relatively short time.

The field test makes it possible for the physical educator to administer fitness tests in the classroom to large numbers of subjects with relative ease, with little equipment, and at a minimum cost of money and time.

Balke proposed that a submaximal heart rate, 180 beats per minute, be used to measure circulorespiratory capacity. From his work he concluded that the attainment of a heart rate of 180 in exercise represents a physiological point at which circulorespiratory limitations become manifest. He observed that the optimal work capacity was exceeded at about this heart rate, since a sudden rise in anaerobic work occurred. This was indicated by--  
(a) A decreased pulse pressure as the heart rate approached

---

<sup>15</sup>Herbert A. deVries and Carl E. Klafs, "Prediction of Maximal Oxygen Intake from Submaximal Tests," Journal of Sports Medicine and Physical Fitness, 5 (1965), p. 207.

<sup>16</sup>Consolazio, p. 342.

<sup>17</sup>Morehouse, p. 279.

or exceeded a rate of 180 beats per minute . . . . (b) A decreased oxygen pulse (ratio of oxygen consumed to the heart rate) and a disproportionate rise in ventilation compared to the heart rate and oxygen consumption.

Repeated observations of this kind led Balke to conclude that the 180 heart rate serves as a valid cut-off point in a performance to measure circulorespiratory capacity. He points out that the 180 heart rate does not have the limitations of the all-out run test.<sup>18</sup>

Balke, Dill, Mathews, Morehouse, and others have established that there is a straight line relationship between heart rate and oxygen intake up to a heart rate of about 160 beats per minute.

Continuous muscular work depends upon an adequate supply of oxygen. The relationship between oxygen consumption and the production of work is linear, and this linearity has been widely used as a basis for determining fitness for exertion.<sup>19</sup>

There are three general types of field tests: the bicycle ergometer test, run-walk tests of various kinds, and step tests for measuring maximal oxygen intake. Astrand developed a test on the bicycle ergometer, which was designed to predict one's maximal oxygen intake from a submaximal exercise, and he published a nomogram for calculation of maximum oxygen intake from submaximal pulse rate. The original nomogram has been modified because in some cases the maximum oxygen intake was overestimated or underestimated depending upon the physical fitness of the individual being tested. The test provides an accurate measure of work done by controlling the wheel resistance against pedalling and the pedalling rate. The advantage of this type of test is that it is submaximal, requiring the subject to reach pulse rates of only from

---

<sup>18</sup>Francis J. Nagle and Thomas G. Bedeck, "Use of the 180 Heart Rate Response as a Measure of Circulorespiratory Capacity," Research Quarterly, 34 (1963), p. 362.

<sup>19</sup>Morehouse, p. 279.

120-170 beats per minute after five minutes of work. By being able to monitor the heart rate each minute, it is possible to see that the work load does remain submaximal throughout the test. If the heart rate stabilizes, within five to six beats per minute, between 120 and 170 beats per minute, the test is terminated. By using charts developed by Astrand and Rhyming, the subject can determine his predicted oxygen intake capacity and his fitness classification.<sup>20</sup>

Balke devised a 15-minute field test in which the subject would run or walk as fast as he could for 15 minutes around or along known distances and, at the end of the exercise, his speed, measured in meters per minute, would be calculated. This value appeared to correlate well with his maximum oxygen consumption established on a treadmill run.

Cooper, following the lead of Balke, developed a 12-minute run-walk test in which the subject runs, jogs, or walks as far as possible in a 12-minute period of time. By determining the distance covered in this period of time, one may find his physical fitness classification through using charts developed for this purpose by Cooper for use in his aerobics plan of developing physical fitness. In addition to his 12-minute run-walk test, Cooper developed a 1.5 mile test to evaluate aerobic power and established standards for fitness classifications based upon time taken to complete the 1.5 mile run.<sup>21</sup>

Numerous step tests have been developed since the first attempts at measuring cardiorespiratory fitness with a stepping device.

---

<sup>20</sup>P. O. Astrand and Irma Rhyming, "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) From Pulse Rate During Submaximal Work," Journal of Applied Physiology, 7 (1954), p. 218.

<sup>21</sup>Edward Fox and Donald Mathews, Interval Training (Philadelphia, Pa., 1974), p. 253.



Schneider (1920) recommended the step-up on an ordinary chair at the rate of five steps in 15 seconds in his cardiovascular test. In 1921 Hambly and Hunt experimented with the effect upon pulse rate of running and walking up and down stairs.<sup>22</sup> Many variations in step tests have been experimented with since the advent of perhaps the most widely known the Harvard Step Test developed in 1942 by Brouha in the Harvard Fatigue Laboratory.

Step tests have become very popular over the years because they are field tests not requiring elaborate, sophisticated laboratory equipment. In addition, they can be administered to large groups, the work can be controlled, and they can be administered by the physical educator with relative ease as they require equipment usually found in most schools or at least equipment that can be built easily and at little cost. They are submaximal tests that reduce the danger to the participant in that most of them do not take the heart rate above the 180 heart beats per minute advocated by Balke. Because step tests have become popular as instruments to measure maximum oxygen intake, and because of the proliferation of these instruments, and the confusion as to which test to administer, it was feasible to conduct this study.

#### Purpose of the Study

The purpose of this study was to compare three previously developed step tests--a One-Minute Step Test developed by Michael and Adams of the Environmental Stress Laboratory, University of California; the Ohio

---

<sup>22</sup>Waldo Miller and Edwin Elbel, "The Effect Upon Pulse Rate of Various Cadences in the Step-Up Test," Research Quarterly, 17 (1946), pp. 263-264.

State University Cardiovascular Fitness Test; and the Progressive Step Test to Predict Maximum Oxygen Intake developed at Oklahoma State University by Lewis--as methods of measuring physical fitness, specifically work capacity or cardio-respiratory endurance, and determine if one test was a better indicator of maximum oxygen intake than another and, if so, which step test is the most feasible in terms of a field test that can be given to large numbers of subjects in the classroom. In this study, the criterion against which each of the three step tests was judged was maximum oxygen intake as determined in the laboratory using the gas analysis technique.

#### Statement of the Problem

The problem of this study was to determine if one of three selected step tests was a better measure of physical fitness than another and, if so, which one was most feasible in terms of a field test that could be given to large numbers of subjects in the classroom.

The criteria to determine the better test of physical fitness in the problem were: (1) Compare the relative validity of each step test as a measurement of maximum oxygen intake against the actual measured maximum oxygen intake; (2) Compare the interrelationship of each step test with the other two step tests; (3) Compare the reliability of each step test.

The criteria to determine the feasibility in the problem were: (1) Length of time necessary to administer the test; (2) Number of subjects that can be tested at any one time; (3) Equipment needed to administer the test; (4) Number of test administrators needed; (5) Ease with which test can be administered.

Sub-problems in this study were: (1) Compare the results of the subjects involved in this study with physical fitness norms established for each of the three step tests; (2) Compare the predicted oxygen intake from the Balke Charts based on percent of treadmill grades with the measured oxygen intake.

#### Limitations

Limitations in this study were: (1) The subjects involved were limited to volunteers and could not be considered a random sampling of the general population; (2) The number of subjects involved was thirty-six, which may be considered a small sampling; (3) The tests were administered to subjects at a time convenient to both the subject involved and the test administrator; (4) The subjects may have taken the tests at different times of the day.

#### Delimitations

The subjects were male students within the age range of from 18 to 25 years of age.

#### Assumptions

Assumptions in this study were: (1) Crest-load, the dividing line between aerobic and anaerobic work, occurs at approximately 180 heart beats per minute and is the point where maximum oxygen intake is measured; (2) Changes in maximum oxygen intake and changes in physical conditioning are reflected in the Michael and Adams One-Minute Step Test--the authors did not claim that their test was a valid measure of maximum oxygen intake.

### Internal Validity

The subjects were reasonably healthy male college students, as determined by the subject's doctor when the doctor signed the subject's physical examination form required for entrance to Oklahoma State University. The maximum oxygen intake determined at the end of the Balke Treadmill Procedure was administered after a short familiarization period on the treadmill. Each subject witnessed the giving of each of the three step tests in the familiarization process to reduce any anxiety that he may have had.

Environmental conditions, for the treadmill test, were controlled in the laboratory at a temperature of approximately 22<sup>o</sup> Centigrade with humidity approximately 50 percent. The subjects were dressed in approximately the same manner in gym shorts, shirts, and gym shoes. The subjects were asked to not participate in any unusual physical activity preceding the test and to not eat two hours before the test.

The subjects were randomly assigned to one of three groups for order of testing. The order of administration of the three step tests was rotated among the groups to reduce the conditioning factor and learning.

In summary, because of wide variations of fitness and individual differences, it is suggested that it is more beneficial to develop fitness programs on an individual need basis. This being unrealistic in the classroom, the next best solution would be to place students in as homogeneous a group as possible for fitness training. This can be accomplished with fitness tests that separate subjects into excellent, good, average, or poor groups. Tests would allow the instructor to

follow the progress of a given subject during a training period and to check the adequacy of the assigned training program.

Many instruments have been developed for measuring maximum oxygen intake, determining physical fitness, and other aspects of fitness. The instruments generally consist of run tests, bicycle tests, and step tests. The field tests that have been developed use a variety of methods to control work load, various cadences are used, and heights in stepping devices differ.

## CHAPTER II

### REVIEW OF RELATED LITERATURE

Over the past several years, many attempts have been made to assess physical fitness through some kind of testing procedure. This became necessary as greater interest in fitness and fitness programs developed to promote and maintain fitness as a segment of health.

Because of the fitness programs and a need for determining progress towards fitness, a number of physical fitness tests were developed to assess maximum oxygen intake as it is related to endurance. Perhaps the most popular among these tests are the following: (1) Cooper's Twelve-Minute Run-Walk Test; (2) Astrand's Bicycle Ergometer Test; (3) A variety of step tests, including the Harvard Step Test and modifications of it; (4) Balke's Treadmill Test. One widely accepted measure of cardio-respiratory fitness is the run-walk test.

Balke was the first to develop a field test designed to evaluate aerobic capacity based upon the distance run in a given period of time. This test employs a running period of 15 minutes and permits accurate prediction of aerobic capacity with adult subjects. Cooper has recently proposed a modification of the original 15-minute run which employs a 12-minute running period. The test has been applied to a large population of adults, primarily Air Force personnel.<sup>1</sup>

Results reported by Doolittle and Bigbee, using adolescent boys,

---

<sup>1</sup>Michael G. Maksud and Kenneth D. Coutts, "Application of the Cooper Twelve-Minute Run-Walk Test to Young Males," Research Quarterly, 42 (1971), p. 54.

indicated that the distance covered in a 12-minute run-walk is a highly reliable and valid indicator of maximum oxygen intake.<sup>2</sup>

Balke developed the Treadmill Test as a submaximal test of aerobic capacity. The test consists of walking on a motor driven treadmill at a speed of 3.4 miles per hour with the grade increased one percent each minute. The test is terminated at a heart rate of 180 beats per minute.

Balke proposed that a submaximal heart rate, 180 beats per minute, be used to measure circulorespiratory capacity. From his work he concluded that the attainment of a heart rate of 180 in exercise represents a physiological point at which circulorespiratory limitations become manifest. He observed that the optimal work capacity was exceeded at about this heart rate since a sudden rise in anaerobic work occurred.<sup>3</sup>

Astrand and Rhyming developed a nomogram for calculation of aerobic capacity, physical fitness, from pulse rate during submaximal work.

Astrand and Rhyming believe that:

The individual's capacity or fitness for heavy prolonged muscular work will first of all be dependent on the supply of oxygen to the working muscles. In types of work which engage large groups of muscles, the limiting factor for the maximal oxygen intake (aerobic capacity) will probably be the capacity and regulation of the oxygen-transporting system.<sup>4</sup>

In the Astrand and Rhyming study it was determined:

The best results were obtained when the test work was of such a severity that the heart rate during steady state attained a level somewhere between 125 and 170. Within these limits there is normally an almost linear increase in metabolism with heart rate.

---

<sup>2</sup>T. L. Doolittle and Rollin Bigbee, "The Twelve-Minute Run Walk: A Test of Cardiorespiratory Fitness of Adolescent Boys," Research Quarterly, 39 (1968), p. 493.

<sup>3</sup>Nagle and Bedeck, p. 362.

<sup>4</sup>Astrand and Rhyming, p. 218.

The maximal oxygen intake probably varies with the muscular mass, and the ratio of muscular mass to body weight should in many instances be an important factor in determining the individual's capacity for hard work. Thus, the maximal oxygen per kilogram body weight will give a good conception of physical fitness.

A nomogram is presented where an individual's maximal attainable oxygen intake (aerobic capacity) can be calculated from heart rate and oxygen intake (or work level) reached during a test with a submaximal rate of work . . . . Values for healthy, well-trained men and women 20-30 years of age are presented.<sup>5</sup>

The step test is purported to measure the functional status of the body and its ability to do strenuous work.<sup>6</sup> The step tests described in this survey are shown in chronological order.

Schneider (1920) recommended the step-up on an ordinary chair at the rate of 5 steps in 15 seconds as part of his suggested cardiovascular test.<sup>7</sup> Hambly and Hunt (1921) experimented with the effect upon pulse rate of running and walking up and down stairs. Later this method was given up in favor of the step-up exercise in which a 13-inch step was used at cadences varying from 6 to 36 steps a minute.<sup>8</sup> In an attempt to find two exercises, one which would produce a pulse-ratio below 2.5 and another a ratio slightly above 2.5, Hambly, Pembrey, and Warner (1925) used a 13-inch step with a cadence of 18 and 24 steps per minute. They concluded that, "For many reasons the pulse affords the best test of efficiency."<sup>9</sup> Campbell (1925) used the technique of Hambly

---

<sup>5</sup>Ibid.

<sup>6</sup>Henry J. Montoye, "The 'Harvard Step Test' and Work Capacity," Revue Canadienne de Biologie, 11 (1952), p. 491.

<sup>7</sup>Miller and Elbel, p. 264.

<sup>8</sup>Ibid., p. 263.

<sup>9</sup>Ibid.



and Hunt. He used a 13-inch bench but a cadence of 28 steps per minute. Campbell concluded that his step test showed a greater difference between the unfit and the average men than between the average men and the athletes.<sup>10</sup>

Tuttle (1931) of the State University of Iowa developed a cardiovascular step test which takes very little time and can be administered by a relatively inexperienced leader. This test was called the Pulse-Ratio Test.

The pulse-ratio is defined as the ratio of the pulse rate after exercise (seated) to the normal sitting pulse rate. It is found by dividing the total pulse for two minutes immediately following the standard 30-step exercise in a minute (on a chair, bench, or stool) by the normal sitting pulse for one minute.<sup>11</sup>

The Tuttle Test established two different stepping rates (one stepping cadence was a light work load, the other a heavy work load on a 13-inch high stool) to determine the stepping rates needed to establish a 2.5 pulse-ratio.<sup>12</sup>

The Harvard Step Test, Johnson, Brouha and Darling (1942) was originally developed for appraising the fitness of healthy men; however, modifications have been made which have rendered the test applicable to boys, young women, girls, and older men and patients. The test requires a subject to step onto a 20-inch bench at the rate of 30 steps per minute for as long as he is able, or if still stepping at the end of five minutes, the exercise is terminated. The recovery pulse is then

---

<sup>10</sup>Ibid.

<sup>11</sup>Thomas K. Cureton, Physical Fitness Workbook (St. Louis, Mo., 1947), p. 123.

<sup>12</sup>W. W. Tuttle, "The Use of the Pulse-Ratio Test for Rating Physical Efficiency," Research Quarterly, 2 (1931), p. 5.

counted from 1 - 1½, 2 - 2½, and 3 - 3½ minutes after the cessation of exercise. A physical fitness index is computed from a formula.<sup>13</sup>

The Harvard Step Test has been criticized in that it is too strenuous and requires an all-out effort on the part of the subject and that the height of the stepping device is difficult to negotiate for some subjects. Gallagher and Brouha (1943) modified the Harvard Step Test for boys. Preliminary tests showed that because of the wide range of size in boys between the ages of 12 and 18 years, it is desirable to divide all boys into two groups on the basis of their surface area. Surface area, based on height and weight, was determined by means of a nomographic chart. The exercise involved in the test consists in stepping up and down at the rate of 30 times a minute on a platform, the height of which is 18 inches for the smaller boys and 20 inches for the larger boys. The exercise is carried on for four minutes unless the subject stops from exhaustion before then. The duration of the exercise is recorded. The heart rate is counted three times during the 3½ minutes after the exercise has ceased, and the physical fitness score is calculated by dividing the number of seconds of exercise by the sum of the three heart rates counted during the subsequent rest period. The higher the score, the more fit the boy.<sup>14</sup> Gallagher and Brouha also modified the test for high school girls which entailed a bench 16 inches in height with an exercise time of four minutes.

---

<sup>13</sup>Lucien Brouha, "The Step Test: A Simple Method of Measuring Physical Fitness for Muscular Work in Young Men," Research Quarterly, 14, No. 1 (1943), p. 32.

<sup>14</sup>J. Roswell Gallagher and Lucien Brouha, "A Simple Method of Testing the Physical Fitness of Boys," Research Quarterly, 14 (1943), p. 24.

Modifications of the Harvard Step Test have taken various directions. The height of the step has been adjusted to various levels, and the rate of stepping has been adjusted or progressive stepping cadences have been used.

Karpovich, Starr, and Weiss (1944) used the 20-inch step and a cadence of 24 steps per minute over a period of 30 seconds. They evaluated the condition of patients in Army hospitals for participation in mild forms of physical activity. The patient's physical condition was evaluated by the pulse response and his ability to endure the exercise.<sup>15</sup>

Elbel and Green (1946) used a standardized cadence of 24 steps per minute with steps 12, 14, 16, 18, and 20 inches in height during exercise periods of 30 and 60 seconds. They found that the pulse in the healthy male subjects, taken one minute after exercise, returned to approximately the pre-exercise level whether the exercise was 30 or 60 seconds long in duration and regardless of the height of the bench.<sup>16</sup>

The original Sjostrand Test (1947) was a method of measuring maximum oxygen intake while exercising on a bicycle ergometer; however, since the American population rides bicycles infrequently, it was hypothesized that the test principle might be employed more effectively with less experimental variability in the U.S.A. through the use of bench stepping as the standard exercise. The modified Sjostrand Test uses the bench stepping procedure in accordance with the directions for the Harvard Step Test, onto a 20-inch bench but at cadences of 12 and

---

<sup>15</sup>Miller and Elbel, p. 264.

<sup>16</sup>Ibid.

24 complete steps per minute for the first and second six-minute tests, respectively. The heart rate was taken stethoscopically for 30 second periods at 1:30, 3:30, and 5:30 of each six-minute test. The modified Sjostrand Test, using bench stepping instead of the bicycle ergometer, was disappointing in its lack of significant correlation with maximal oxygen intake.<sup>17</sup>

Montoye, a critic of the Harvard Step Test, conducted a study in 1952 to determine the relationship between the Fitness Index of the Harvard Step Test scores and several criteria of work performance using 50 young college men who had participated in a three-month physical conditioning program. Other studies had used too few subjects, according to Montoye. Montoye concluded that "despite the fact that work performance cannot be predicted from step test scores, there is an appreciable amount of evidence that the Index does reflect the relative state of fitness of the cardiovascular system."<sup>18</sup>

The Rhyming Step Test (1953), a modification of the Harvard Step Test, was designed to predict the maximum oxygen intake within reasonable limits of accuracy. The details of the step test, prescribed for college men, are as follows: bench height, 40 cm; total time, 5 minutes; 22.5 stepping cycles (90 steps) per minute. The subject's pulse is counted during the last 15 seconds of each minute while he performs. A steady value is usually reached after the second minute and this is the score. If no steady value is reached, then the last

---

<sup>17</sup> deVries and Klafs, pp. 207-209, 212.

<sup>18</sup> Montoye, pp. 491-497.

value becomes the score which is used in the prediction of the maximal oxygen consumption.<sup>19</sup>

The Sloan Step Test (1959) is a modification of the Harvard Step Test suitable for use with women. The subject steps up and down on a 17-inch bench at the rate of 30 steps per minute for a total exercise period of five minutes or until she is unable to continue the exercise. Standards have been established for interpreting the score on this test.<sup>20</sup>

The Waxman Modified Progressive Pulse-Ratio Test (1960) consists of stepping up and down on a 17-inch high bench at the rate of 12 steps per minute to the sound of a metronome. The first ten seconds after the one-minute exercise is used to put the stethoscope in place and then the heart beat is counted for two minutes. The subject rests until his pulse stabilizes within eight to twelve beats of his normal standing pulse rate. The same procedure is then repeated at 18, 24, 30, and 36 steps per minute. The Progressive Pulse-Ratio Test has been found to have a correlation of .71 in regard to maximum oxygen intake.<sup>21</sup>

Skubic and Hodgkins (1963) modified the Harvard Step Test in various ways in order to validate a step test for women. They found that a 3-minute test, using an 18-inch bench and a stepping rate of 24 steps per minute, was both reliable and valid and that it clearly

---

<sup>19</sup>James P. Day, "A Statistical Investigation of the Rhyming Step Test," Research Quarterly, 38 (1967), pp. 539-540.

<sup>20</sup>Fox and Mathews, p. 251.

<sup>21</sup>W. W. Waxman, "Physical Fitness Development for Adults in the YMCA," Exercise and Fitness, A Collection of Papers Presented at the Colloquium on Exercise and Fitness, University of Illinois College of Physical Education, Athletic Institute, 1960, pp. 185-186.

differentiates among females who are in a highly trained state, those who are moderately active, and those who are sedentary. After one minute of rest following exercise, the pulse was taken for 30 seconds. In this study, the correlation between the 3-minute and the original Harvard 5-minute test was .790.<sup>22</sup>

Bayless (1966) developed a progressive step test at Oklahoma State University. The Bayless test consisted of stepping at a rate of 30 steps per minute on a motorized stepper.

The stepper can be raised from ground level to a maximum of 20 inches by simply switching on a toggle switch. The device provides a stepping platform which could be varied to any height from ground level to 20 inches while work was being performed. The height of the step at the beginning was 4 inches and each minute the height of the platform was raised one inch to produce corresponding increases in work load. The test was terminated when anaerobic work began in the subject as indicated by pulse rate at 180 beats per minute and systolic blood pressure.<sup>23</sup>

Bayless validated his progressive step test on fourth, fifth, and sixth grade boys. Bayless concluded that this test offers a valid measure of functional metabolic capacity.

Frye (1966), using the Bayless Step Test, validated the step test for elementary school girls. She found that there is not a wide enough difference between the results for elementary school girls and boys to conclude that they reach the crest-load capacity at different physiological levels of cardiovascular and metabolic measures.<sup>24</sup>

---

<sup>22</sup>Vera Skubic and Jean Hodgkins, "Cardiovascular Efficiency Test for Girls and Women," Research Quarterly, 34 (1963), pp. 191-197.

<sup>23</sup>Bayless, pp. 21-22.

<sup>24</sup>Mary L. Frye, "A Progressive Step Test for Elementary School Girls" (unpublished Master's Thesis, Oklahoma State University, 1966), p. 33.

Shephard (1967) developed a progressive step test using a double 9-inch step or a single 18-inch step for those subjects in his study who had difficulty in climbing two 9-inch steps at the requisite rate. The progressively increasing stepping rates were 10 ascents per minute for two minutes, 15 ascents per minute for three minutes, 20 ascents per minute for three minutes, and 25 ascents per minute for three minutes. From the results, the rate of stepping seems a more important determinant of efficiency than the height of the step, and the view that step height should be tailored to leg length is not substantiated at least for adult males. The predicted maximal oxygen consumption did not differ significantly with different step heights.<sup>25</sup>

A modification of the Ohio State University Step Test (1968)--the Ohio State University Step Test will be described on page 26 because it is a part of this study--was developed suitable for mass testing in a classroom by Cotten (1971) at Georgia Southern College. The differences between this modification and the Ohio Test were as follows: (1) A 17-inch step was used; (2) No handbar was used; (3) In order to provide an increased work load in Phase III (without a higher step), the stepping cadence was increased to 36 steps per minute. All other testing procedures were identical to that of the Ohio Test.

Test-retest reliability of the modified step test was .95. The modified test correlation of .84 with the Balke Test compares favorably with the correlation between the Ohio Step Test and the Balke Test (.94). The modified step test appears to be a satisfactory measure of cardiovascular fitness. It also has the advantages of not requiring the student to exert maximal effort or possess a high degree of

---

<sup>25</sup>R. J. Shephard, "The Prediction of 'Maximal' Oxygen Consumption Using a New Progressive Step Test," Ergonomics, 10 (1967), p. 3.

skill. It also requires little special equipment and can be administered in one class period.<sup>26</sup>

Matthews (1972) conducted a study using a progressive step test. The test consisted of stepping onto a 14-inch bench for 1.5 minutes at each cadence. A progressive cadence of 12, 15, 18, 21, 24, 27, 30, 33, 36, and 39 steps per minute was used without a recovery period between stepping cadences. He took expired air samples during the stepping procedure to determine the subject's maximum oxygen intake. He found the test to be a valid measure of maximum oxygen intake for college men at a cadence of 33 steps per minute.<sup>27</sup>

The following step tests are not in the original chronological order because they are the three step tests selected to be used in this study. They are described in greater detail.

Michael and Adams of the Environmental Stress Laboratory, the University of California, developed a one-minute step test for college-age men in 1964. This test consisted of stepping onto a 17-inch bench for one minute at the rate of 36 steps per minute. At the end of the exercise, a 15-second pulse count was taken starting five seconds after the exercise and at one, two, and three minutes following exercise. Scores were calculated by adding the pulse rate per minute taken at one, two, and three minutes following exercise. Percentile and T-scores were determined for the group tests; N = 938.

The average pulse rate at the end of exercise was 143; at one

---

<sup>26</sup>Doyice J. Cotten, "A Modified Step Test for Group Cardiovascular Testing," Research Quarterly, 42 (1971), pp. 92-93.

<sup>27</sup>N. D. Matthews, "A Progressive Step Test for Assessing the Cardio-respiratory Fitness of College Men" (unpublished Ed.D. Dissertation, Oklahoma State University, 1972), pp. 27-28.



minute, 109; at two minutes, 100; and at three minutes after exercise, the recovery pulse rate averaged 92 beats per minute. If the percentile scale is used, classification of fitness can be established. A score below 210 (80th percentile) would be excellent; 210-270, good; 270-330, average; 330-400, fair; and above 400 (20th percentile) poor.

It was felt that this type of submaximal test should not be validated against tests involving all-out exercise or hard maximal work since the purpose of the test is not to predict all-out performance but rather fitness for moderate strenuous activities.<sup>28</sup>

Kurucz, Fox, and Mathews, members of the Ohio State University Exercise Physiology Research Laboratory, developed a submaximal step test known as the Ohio State University Step Test in 1968. The test was developed to be used with men between the ages of 18 and 60 years. Exercise on a bench was first considered because the bench is easily and economically constructed, the work load is constant for the individual, and skill is not an important factor. An adjustable hand bar, level with the subject's head, was included to cause greater body involvement. A second consideration was to develop a testing situation wherein the subject would not exceed a heart rate of 150 beats per minute during exercise.

The bench constructed for the Ohio State University Step Test was a two-level device; one level was 15 inches high and the other was 20 inches, with an adjustable hand bar. The test consisted of 18 innings of 50 seconds duration; each inning was 30 seconds of work with a

---

<sup>28</sup>Ernest D. Michael, Jr. and Adran Adams, "The Use of a One-Minute Step Test to Estimate Exercise Fitness," Ergonomics, 7 (1964), pp. 211-214.

20-second rest period during which 10 seconds were used to take the subject's heart rate and 10 seconds were used in preparing to take the heart rate and for beginning the next inning.

Phase I consists of 6 innings at 24 steps per minute on the 15-inch bench. Phase II consists of 6 innings at 30 steps per minute on the 15-inch bench. Phase III consists of 6 innings at 30 steps per minute on the 20-inch bench.<sup>29</sup>

A test-retest reliability coefficient of .94 was obtained on the Ohio State University Step Test. Test results correlated with the Balke Treadmill Test resulted in a validity coefficient of .94.

In 1970 in the Oklahoma State University Exercise Physiology Research Laboratory, Lewis developed a progressive step test to predict maximum oxygen intake. The test consisted of stepping onto a 14-inch high bench for a period of 1.5 minutes for each cadence. A progressive cadence of 12, 15, 18, 21, 24, 27, 30, 33, 36, and 39 steps per minute was used. Recovery heart rates were recorded for a 15-second period immediately following each exercise cadence. The test was a submaximal test.

To determine if there was a valid cut-off point in the Progressive Cadence Step Test where the test could be stopped submaximally and predict maximum oxygen intake, a correlation study was done between the heart rates of the various cadences and the actual maximum oxygen intake as determined through use of the Balke Treadmill Test. The largest correlation was found when comparing the results of 30 steps per minute with actual maximum oxygen intake. This correlation was -.757. Lewis concluded: (1) This test offers a valid measure of the endurance status of college-age men ( $r = -.757$  with maximum  $O_2$  intake); (2) The test

---

<sup>29</sup>Robert L. Kurucz, Edward L. Fox, and Donald K. Mathews, "Construction of a Submaximal Cardiovascular Step Test," Research Quarterly, 40 (1969), p. 116.

procedure is reliable; (3) The cadence of 30 steps/min is recommended as the cut-off point for college-age men.<sup>30</sup>

In summary, a survey of literature on step tests shows numerous variations in field tests for predicting maximum oxygen intake. From the 1920's to the present, among the variations noted in step tests have been the following: (1) Stepping onto an ordinary bench, stepping onto motorized stepping devices, stepping onto two-level stepping platforms; (2) Bench height from 4 inches to 20 inches; (3) Stepping cadences from 6 to 39 steps per minute; and (4) Progressive stepping tests using differing cadences.

---

<sup>30</sup>Albert L. Lewis, "A Progressive Step Test to Predict Maximum Oxygen Intake" (unpublished Ed.D. Dissertation, Oklahoma State University, 1970), p. 48.

## CHAPTER III

### METHOD AND PROCEDURE

#### Selection of Subjects

The subjects for this study were 36 male volunteer undergraduate and graduate college students between the ages of 18 to 25 years enrolled at Oklahoma State University, Stillwater, Oklahoma. The subjects for this study had a medical physical examination as a requirement for entrance into college. Each subject was asked to complete a form and indicate whether or not he had any medical problem that would contraindicate his participation in physical exercise. (A specimen copy of the form is shown in the Appendix, p. 76.)

Each subject was asked to complete and sign an informed consent form which appraised him of the test procedures. (A specimen consent form is shown in the Appendix, p. 77.)

The subjects for this study were volunteers from Kerr-Drummond Hall, a men's residence hall on the Oklahoma State University Campus; Farm House, a men's fraternity at Oklahoma State; and, three theory physical education classes. These sources were used from which to solicit volunteers because of the large concentrations of male students found in these locations. They were conveniently available to the researcher.

The procedure followed by the researcher in soliciting volunteers was as follows:

A notice was placed in the rooms of the male residents of Kerr Hall explaining the purpose of this study, describing the four tests to be administered, and explaining the possible benefits that one might personally derive from participating in such a study. Each subject was asked to indicate his interest in such a study by signing the invitation and returning it to the mail box of the researcher. At the time of this part of the study, the researcher was a resident of Kerr Hall. (A specimen copy of the invitation is shown in the Appendix, p. 76.)

At the Farm House Fraternity, the researcher requested the opportunity to speak to the residents to explain the purpose of the study, describe the various tests and testing procedures, and to ask for volunteers to participate in the study. The same procedure was followed in three theory physical education classes being conducted during the 1974 summer semester on the Oklahoma State University Campus.

This process of obtaining students for subjects resulted in 36 volunteers, a majority of which were from Kerr Hall and Farm House. Thirty-six subjects completed all of the tests.

Following the invitation, each of the 36 subjects was sent a questionnaire regarding his health status which the subject completed and returned to the researcher. (A copy of the questionnaire is shown in the Appendix, p. 77.) Dates and times for testing sessions were then determined for each of the four tests in which the subjects were to participate.

#### Test Selection

The three step tests selected for this study were Michael and Adams

One-Minute Step Test<sup>1</sup> for college-age men, Lewis Progressive Step Test to Predict Maximum Oxygen Intake,<sup>2</sup> and the Ohio State University Step Test.<sup>3</sup> These step tests were selected because they are submaximal tests that are relatively easy to administer to large groups of subjects in a short period of time. The equipment needed for the tests can be constructed easily and at little cost. Also, the researcher selected these three step tests because, in his opinion, they are representative of the many step tests reviewed: the stepping heights included 14, 15, 17, and 20 inch benches; the benches were both one-level and two-level stepping platforms; the stepping cadences were from 12 through 36 steps per minute; and a progressive cadence step test was involved.

The maximum oxygen intake test was selected as the criterion test against which the test results from the step tests were compared. Maximal oxygen intake is widely accepted by noted people in research in the field of Human Physical Fitness Testing and is considered a valid test of cardiorespiratory fitness.<sup>4</sup>

#### Administration of the Tests

All tests were administered in the Physiology of Exercise Laboratory in the Colvin Physical Education Center at Oklahoma State University, Stillwater, Oklahoma. All instructions for the stepping cadences and the taking of heart rates were taped for use on an electrically operated

---

<sup>1</sup>Michael and Adams, pp. 211-215.

<sup>2</sup>Lewis, pp. 1-61.

<sup>3</sup>Kurucz, Fox, and Matthews, pp. 115-121.

<sup>4</sup>Nagle, pp. 361-369.

tape recorder, and the tapes were used during the testing sessions in order that all subjects received the same instructions.

The subjects drew lots to determine the sequence they would follow in taking the tests. Sequence I was the Michael and Adams One-Minute Step Test, Lewis Progressive Step Test, and the Ohio State University Step Test. Sequence II was Lewis Progressive Step Test, Ohio State University Step Test, and Michael and Adams One-Minute Step Test. Sequence III was the Ohio State University Step Test, Michael and Adams One-Minute Step Test, and Lewis Progressive Step Test. This procedure was used to nullify learning and practice which might cause invalid test results. Five to ten days after each subject had completed the three step tests, the maximum oxygen intake test was given.

Subjects were dressed in gym shirts, gym shorts, and gym shoes. Upon arriving at the laboratory, the subjects were asked to sit down and rest quietly while they listened to the recorded testing procedures and observed a demonstration of the test. A resting heart rate was taken through a stethoscope by the researcher while the subject checked the accuracy of the count by palpation at the carotid artery, the principal artery of the neck.

Following the resting heart rate recording, the testing exercise began. Each subject saw a demonstration by the researcher on the stepping procedure and was told to step up and down to the beat of the metronome as recorded on a tape which was playing from an electrically operated tape recorder. Heart rates were monitored at each work load level on all tests as an important safety precaution.

### Michael and Adams One-Minute Step Test

The stepping device for the Michael and Adams One-Minute Step Test was a bench 17 inches in height with the stepping time being one minute at a rate of 36 steps per minute.

After the preliminary instructions, which included showing the subject how to count his heart beat at the carotid artery, the tape recording started with, "Your researcher will now take a 15-second resting heart rate, prepare to count, count; prepare to stop, stop." "Please prepare to take the test. Stand in front of the bench." At this time, the sound of the metronome became audible. The next command was, "Ready, begin." The subject stepped up, up, down, down, for one full minute to the sound of the metronome, at which time he was directed to, "Prepare to stop, stop. Please be seated and prepare to count." The researcher put the stethoscope in place, and the subject found his own carotid artery in five seconds. The command was given, "Ready to count, count." A 15-second recovery pulse was counted until the command, "Prepare to stop, stop." was given. The recovery pulse rate taken at five seconds after the work load was completed was used for comparison purposes with the maximum oxygen intake test results.

Recovery pulse rates were taken again at one minute after exercise, two minutes after exercise, and again at three minutes after exercise. The subject's score was calculated by adding the pulse rate per minute taken at one, two, and three minutes following exercise, which allowed the subject's fitness to be categorized based upon established percentile norms developed for the Michael and Adams One-Minute Step Test. (The Michael and Adams One-Minute Step Test norms are shown in the



Appendix, p. 80.) Figure 1, page 35, shows a subject taking the Michael and Adams One-Minute Step Test.

#### Ohio State University Step Test

The stepping device for the Ohio State University Step Test was a two-level platform, one level being 15 inches in height and the second level being 20 inches in height. An adjustable hand bar was set at head height, which the subject grasped with both hands while stepping. This permitted the use of the arms as an aid in stepping and increased the number of large muscles being exercised during the work load.

The test consisted of 18 innings of 50-second duration. Each inning was divided into a 30-second work period and a 20-second rest period. The work load consisted of the following:

- A. Phase I, 6 innings at 24 steps per minute on the 15-inch bench.
- B. Phase II, 6 innings at 30 steps per minute on the 15-inch bench.
- C. Phase III, 6 innings at 30 steps per minute on the 20-inch bench.

Phases I, II, and III were given during the same testing period. The test was terminated when the subject's heart rate reached 25 beats per 10-second count (150 beats/minute) or when the subject completed the entire 18 innings, whichever occurred first. The subject's score was the inning in which the heart rate reached 150 beats per minutes. If the subject's heart rate did not reach 150 beats per minute at the end of the 18th inning, he was given an arbitrary score of 19 according to the prescribed testing procedure. The inning during which the subject's

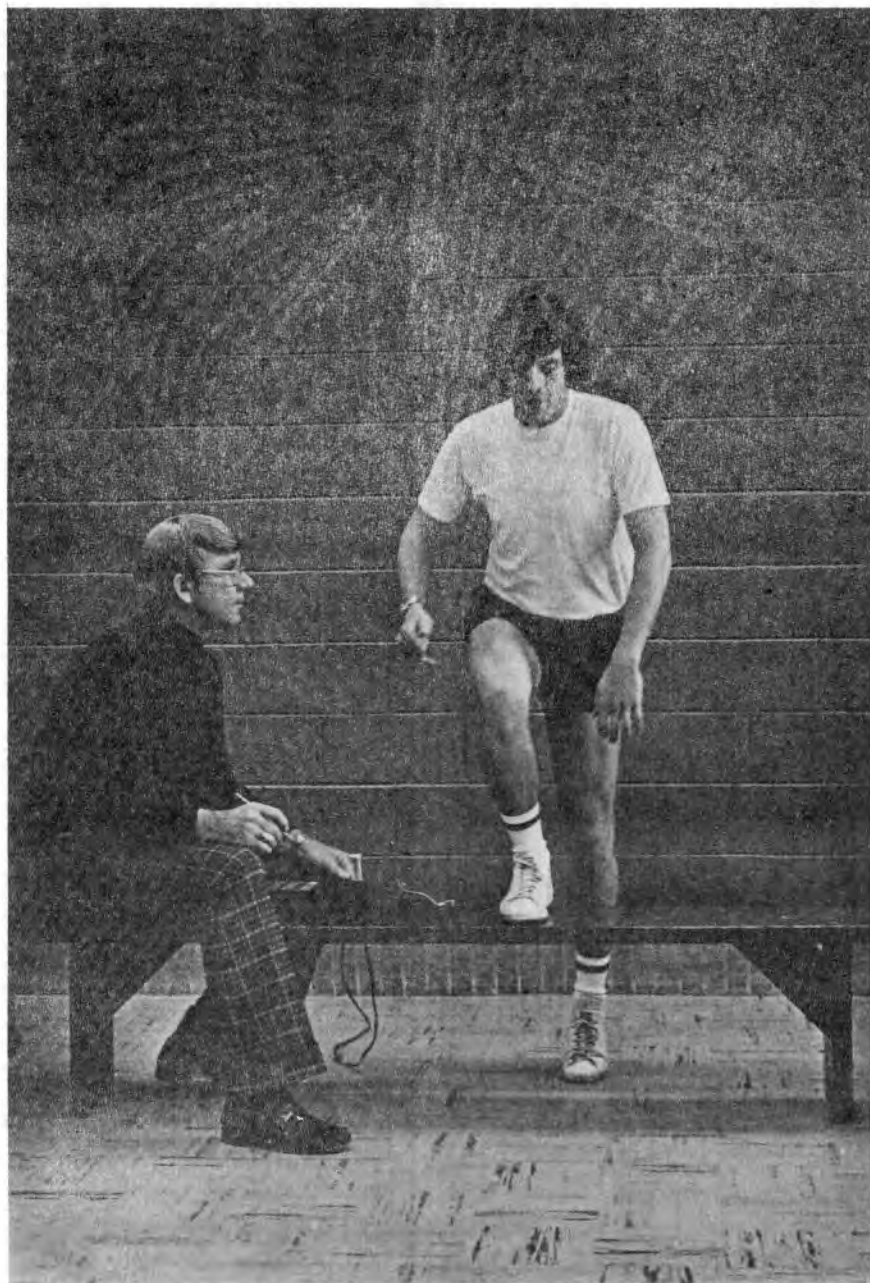


Figure 1. Subject Performing the Michael and Adams One-Minute Step Test

heart rate reached 150 beats per minute was used for comparison purposes with maximum oxygen intake and was used to compare the results of the subject involved in the study with norms developed for the Ohio State University Step Test.

A 10-second resting heart rate was taken preceding the testing session. After the preliminary test instructions were given, including demonstrating how the subject counts heart beat at the carotid artery and a demonstration of the stepping procedure, the taped instructions started with, "Please stand in front of the 15-inch bench and grasp the hand bar with both hands and step in cadence with the metronome. Inning 1, ready up, ready stop; find your pulse." The researcher had five seconds to place the stethoscope, then, "Ready, count; stop; prepare to exercise." The subject was given five seconds to get ready. "Inning 2, ready up. . ." This procedure was followed throughout the 18 innings or until the heart rate reached 25 beats per 10 seconds (150 beats/minute) at which time the test was terminated. (Ohio State University Step Test norms are shown in Appendix, p. 81.) A subject taking the Ohio State University Step Test is shown in Figure 2, page 37.

#### Lewis Progressive Step Test

The stepping device for the Lewis Progressive Step Test was a bench 14 inches in height. The progressive step cadences for this test were 12, 15, 18, 21, 24, 27, and 30 steps. Each cadence was for a period of 1.5 minutes. At the end of each 1.5 minute work period, the subject was asked to be seated, and a sitting heart rate was counted by the researcher through stethoscope for 15 seconds, beginning five seconds after each work cadence, with the subject counting by palpation at the

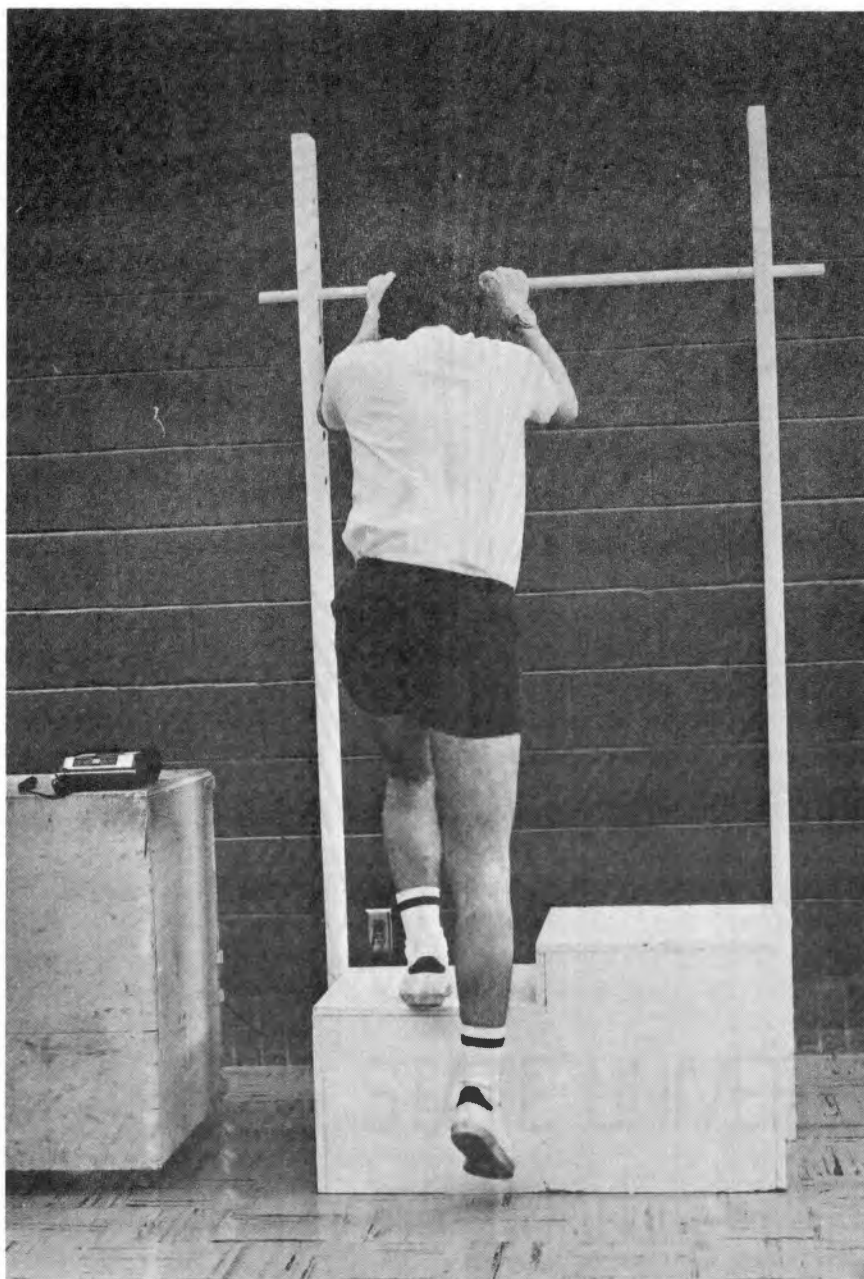


Figure 2. Subject Performing the Ohio State University Step Test

carotid artery for verification purposes with heart rate counted by the researcher through the stethoscope. The next ten seconds in recovery were used by the subject in preparation for the next cadence.

The test was terminated at the end of the 30-step cadence or when the subject's heart rate reached 180 beats per minute, whichever occurred first. The recovery heart rate from the cadence of 30 steps per minute, or the cadence in which the subject's heart rate reached 180 beats per minute, was used in making comparisons with maximum oxygen intake and to compare the results of this study with norms developed in the Lewis Progressive Step Test.

Following the 15-second resting heart rate count, which preceded the test session, the exercise test began. The subject was made aware of the testing procedures through a demonstration by the researcher of the first cadence and told to step up and down to the beat of the metronome, as recorded on tape. The subject was shown how to count a heart beat at the carotid artery. The tape recording started with, "Ready 12, being now." The cadence up, up, down, down was given audibly the first 30 seconds of each exercise period, with the next minute of exercise done only to the sound of the metronome. Upon completion of the 1.5 minutes of exercise, the taped command was, "Ready, stop now. Please sit down." The researcher was given five seconds to put the stethoscope in place, and the subject found his carotid artery at this time. The command to, "Begin count, now," was given. A 15-second recovery pulse was counted until the command to, "Stop count, now," was given. In the next ten seconds, the subject prepared himself for the next cadence exercise period. The same procedure was followed for each of the succeeding cadences which were, as indicated previously,

15, 18, 21, 24, 27, and 30 steps per minute, at which time the test was terminated. (The Lewis Progressive Step Test norms are shown in the Appendix, p. 81.)

The subject's heart rate at the point where the test was terminated was used for comparison purposes with maximum oxygen intake and to compare the results of the subject involved in this study with norms developed for the Progressive Step Test.

At the completion of the Lewis Progressive Step Test, each subject was asked to remain in the laboratory to see and become familiar with the treadmill, physiograph, and the breathing device through which he would be breathing during the maximum oxygen intake test he would be taking at a later date. The Lewis Progressive Step Test is being demonstrated by the subject pictured in Figure 3, p. 40.

To check the reliability of the three step test procedures, five randomly selected subjects for each step test were asked to repeat each test. Different subjects were randomly selected for each test. Each subject received the same instructions as in the original test with the same measurements included.

#### Maximum Oxygen Intake Test

Five to ten days after each subject had completed the three step tests, the maximum oxygen intake test was administered. When the subject reported to the Physiology of Exercise Laboratory on the Oklahoma State University campus, he was weighed and the barometric pressure and room temperature were recorded. Each subject was asked to remove his shirt before taking the maximum oxygen intake test and to be seated while the telemetry system electrodes were attached to his sternum and



Figure 3. Subject Performing the Lewis Progressive Step Test

rib cage with the transmitter taped in place. A seated pre-exercise heart rate was recorded on the physiograph, and the treadmill procedure was explained as a demonstration was performed by the researcher. Following the demonstration, the subject was instructed to get on the treadmill and was given a practice trial at a treadmill speed of 3.4 miles per hour at 0 percent grade for one minute.

Following the introduction, the subject went through the maximum oxygen intake test using the Balke Treadmill Test procedure. The incline of the treadmill was raised to 2 percent at the end of the first minute and 1 percent at the end of each minute thereafter until the heart rate reached 180 beats per minute. The heart rate was recorded on the physiograph during the last 15 seconds of every minute. An electrocardiogram was made during the exercise when the subject's heart rate reached 150 beats per minute in order to monitor S-T segments and heart rhythm.

The subject was instructed to place the Collins one-way breathing valve mouth piece in his mouth and to put the noseclip in place as the heart rate approached 160 beats per minute. Based upon the conclusions of Balke and others, the heart rate of 180 beats per minute serves as a valid cut-off point in a performance to measure circulorespiratory capacity.<sup>5</sup> The researcher obtained a 30-second expired air sample as the subject's heart rate reached 180 beats per minute through a one-way breathing valve into a Collins 120 Liters Tissot tank for the purpose of calculating the actual oxygen consumption. The subject walked an

---

<sup>5</sup>Nagle and Bedeck, p. 362.



additional minute and another 30-second expired air sample was taken as previously described.

It was necessary to have a minimum of two people administer the treadmill test because of the short period of time necessary for taking air samples in the Tissot tank, noting the volume of air, and transferring the gas to rubber sample bags for each sample. One individual operated the physiograph and treadmill. The other individual operated the Tissot tank and took two 30-second expired air samples. The maximal oxygen intake was determined by the procedure described by Consolazio.<sup>6</sup>

#### Analysis of Expired Air

Air expired during the last 30 seconds of each of the last two minutes of the treadmill test was collected in the Collins 120 Liters Tissot tank. The volume of air expired by the subject was determined by noting the Kymograph recording at the beginning and ending of each of the two expired air samples. The ventilation reading from the Tissot tank and the correction factor for barometric pressure and temperatures taken from the Harvard Line Chart were used in calculating oxygen intakes for each subject. (Harvard Line Chart is shown in the Appendix, p. 83.) Two samples were taken in rubber bags from the Tissot tank for each of the two 30-second expired air samples. These samples were analyzed for carbon dioxide percentages by the Godart Pulmo-Analyzer instrument.

The Godart Pulmo-Analyzer is designed for the analysis of several different gases and was used in this study to ascertain the carbon dioxide content of expired air samples collected during the maximum

---

<sup>6</sup>Consolazio, pp. 8-9.

oxygen intake test performed on the treadmill. The expired air sample bag is attached to the inlet nipple. The sample is drawn in two directions. It first passes into a five-way valve after which the gas is dried and pulled into the reference cell through a sodalime-absorber, then through a drying calcium chloride absorber and on into the test cell. The test cell contains a reference gas without carbon dioxide, and the reference cell contains the dried carbon dioxide laden sample to be analyzed. The pen deflections for carbon dioxide were noted and divided by the constant 6.63 to determine the percentage of carbon dioxide in the sample.<sup>7</sup>

Following the determination of carbon dioxide percentages in the expired air sample, oxygen percentage content was determined using the Beckman 715 Process Oxygen Monitor. The Beckman is a battery powered instrument designed to determine the oxygen content of gases. It operates by pulling the expired air sample through a sensor which has previously been calibrated to room air oxygen of 21 percent. As the expired air sample passes through the sensor, the pen needle deflects away from the 21 percent setting indicating the oxygen content of the air sample. This procedure for determining oxygen and carbon dioxide percentages in the expired air samples was performed on each of the two samples taken as the subject's heart rate reached 180 beats per minute and one minute later. Oxygen intake was determined according to the procedure described by Consolazio.<sup>8</sup> (The calculation sheet is shown in the Appendix, p. 82.) The oxygen and carbon dioxide percentages were

---

<sup>7</sup>Godart Pulmo-Analyzer, Instrumentation Associates, Inc., 17 West 60th Street, New York, N.Y. 10023, pp. 7-9.

<sup>8</sup>Consolazio, pp. 8-9.

used to determine true oxygen, read from the Harvard Line Chart (Appendix, p. 82).

Ventilations per minute were noted and recorded from the Tissot tank on both samples, and calculations were performed to determine ventilation in liters per minute. Then with the temperature correction factor, taken from the Harvard Line Chart, the corrected ventilations in liters per minute were determined. Oxygen intake was calculated in liters per minute using the following formula:

$$O_2 \text{ Intake} = \frac{\text{True } O_2 \times \text{Ventilation}}{100} .$$

This sum was converted into milliliters per kilogram of weight per minute to compensate for differences in weight of the subjects in this study. The largest of the two oxygen intake readings was accepted as the maximum oxygen intake for each subject.

#### Grouping and Analysis of Data

When the 36 subjects had completed all of the four tests and the laboratory metabolic calculations had been performed, the data were put into table and figure form for observing comparisons on the tests. Tables and figures were developed to show resting heart rates, exercise heart rates, fitness categories, maximum oxygen intake, validity, and test-retest reliability.

To determine the validity of the three tests used in this study, a product moment correlation<sup>9</sup> was calculated on the Michael and Adams

---

<sup>9</sup>Thomas J. Sheehan, An Introduction to the Evaluation of Measurement Data in Physical Education (Reading, Mass., 1971), p. 129.

One-Minute Step Test and the Lewis Progressive Step Test and a rank order correlation on the Ohio State University Step Test with the maximum oxygen intake test results. The results of each step test were correlated against each of the other step tests in the same manner. Norms established for each of the step tests were used to ascertain physical fitness categories for each subject participating in this study. (These norms are shown in the Appendix, pp. 80, 81.) The results of the correlations were put in table form for ease in observing comparison between the step tests and maximum oxygen intake as determined by the Balke Treadmill Procedure.

## CHAPTER IV

### DATA ANALYSIS AND RESULTS

This study was an attempt to determine which of three widely different step tests was a more valid test for measuring cardiorespiratory fitness, which could be administered with relative ease and little sophisticated equipment.

The resting heart rate of 72 beats per minute is considered as the average heart rate of the general population of the United States. The mean resting heart rates shown in the data in Figure 4 illustrates that the subjects in this study were average subjects with regard to resting heart rates and were neither trained athletes in top condition nor untrained individuals in poor condition. They were a cross section of the population. The mean resting heart rate on each of the three step tests was within one beat of the average of 72 beats per minute.

The end results of the reliability test-retest were very similar, as shown in Figures 5, 6, and 7 with one exception, that being with one subject on the Michael and Adams One-Minute Step Test, Figure 5. The subject's first test score was 132 beats per minute, and his second test score was 108 beats per minute. There may have been an error in counting the heart rate in either the first or second test session. This one discrepancy would lead to a large error in computing a reliability correlation coefficient and is evidenced in the resulting low reliability of the test .77, which may be in error when considering the closeness of

the end results of the other four subjects on this test. The reliability of the other two step tests, the Lewis Progressive Step Test .96, Figure 6, and the Ohio State University Step Test .94, Figure 7, indicate they are highly reliable tests.

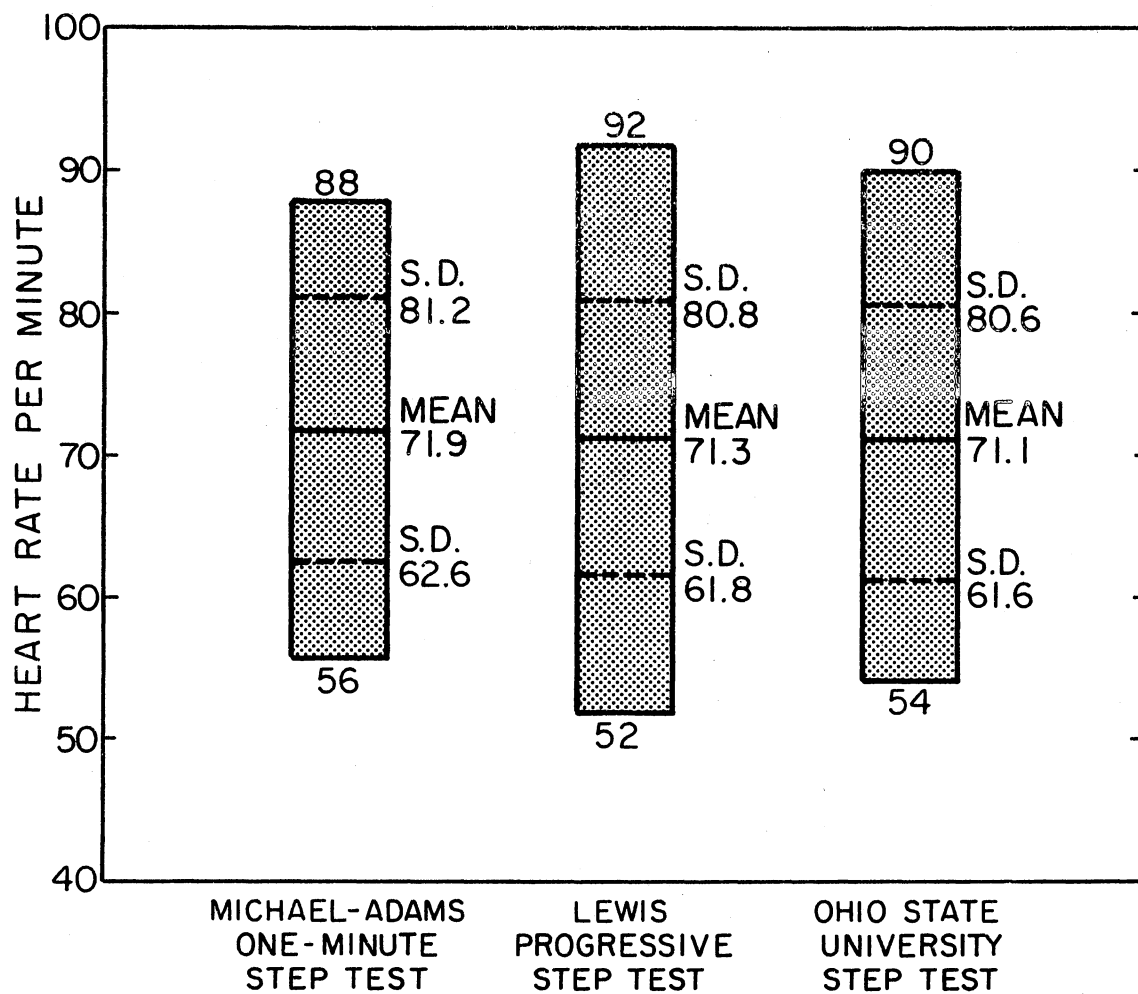


Figure 4. Resting Heart Rates Before Exercise Indicating Range, Mean, and Standard Deviation

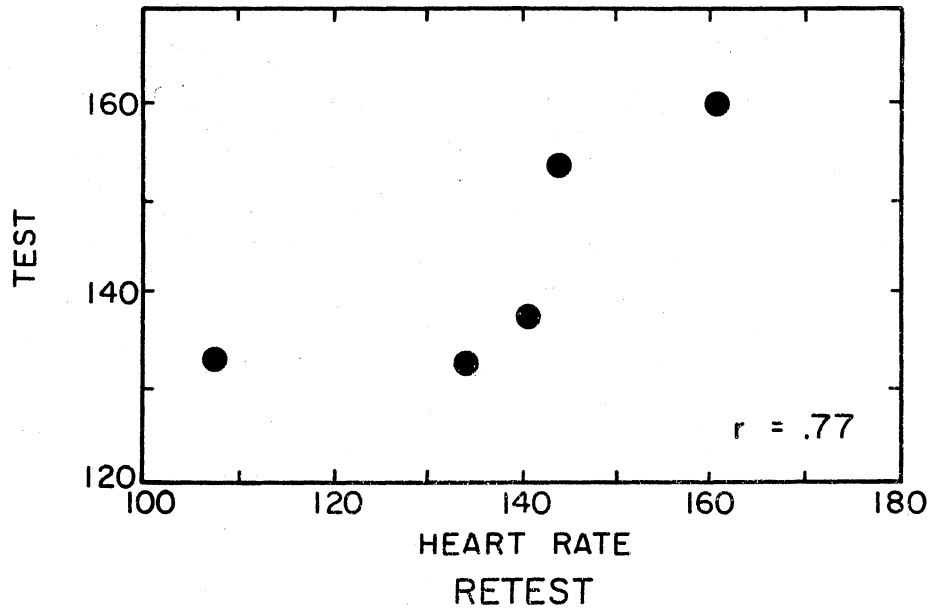


Figure 5. Reliability Check on Michael and Adams One-Minute Step Test

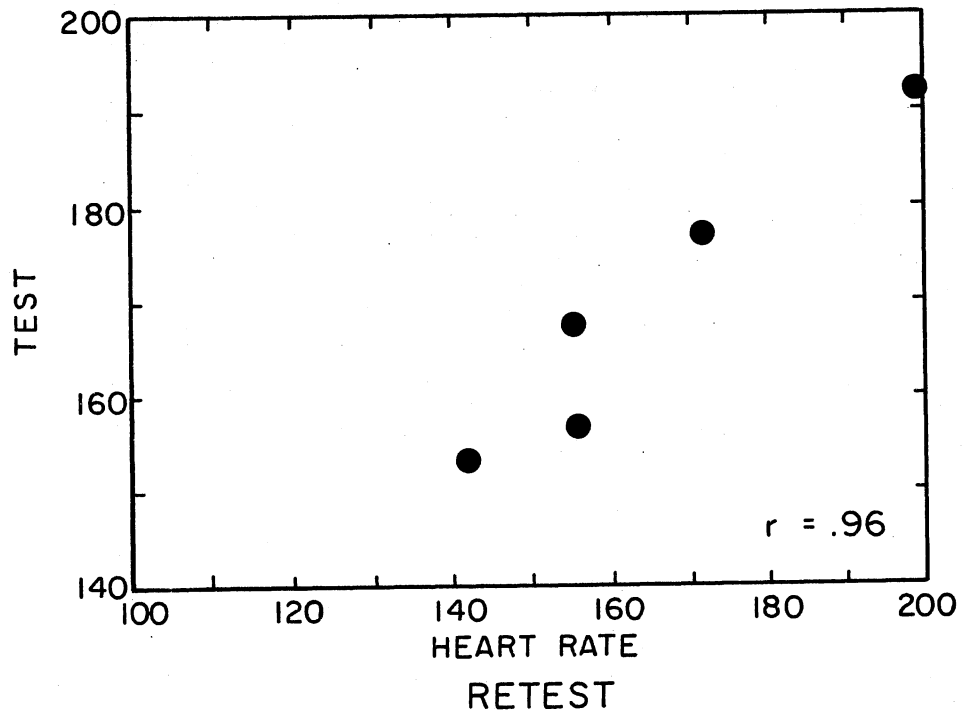


Figure 6. Reliability Check on Lewis Progressive Step Test

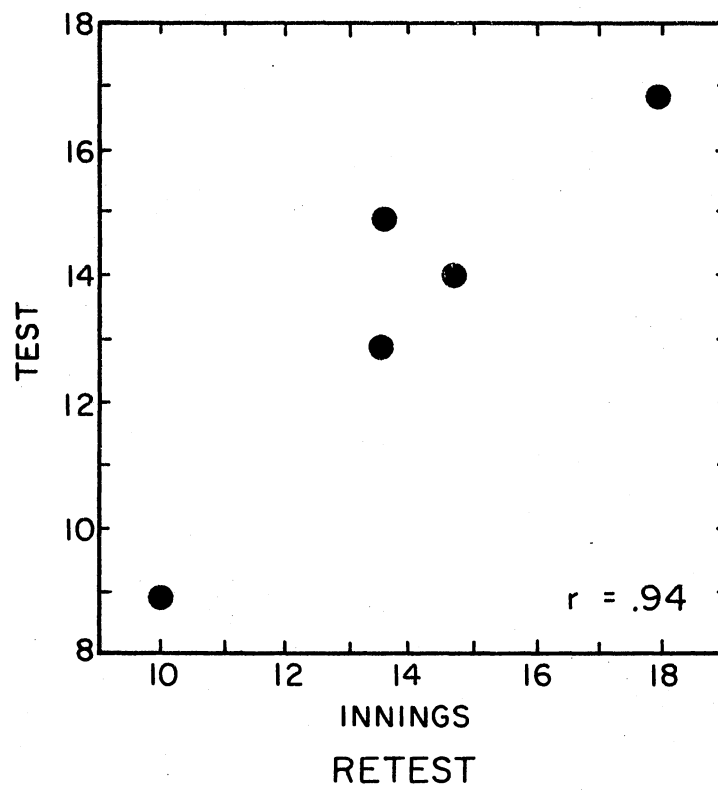


Figure 7. Reliability Check on Ohio State University Test



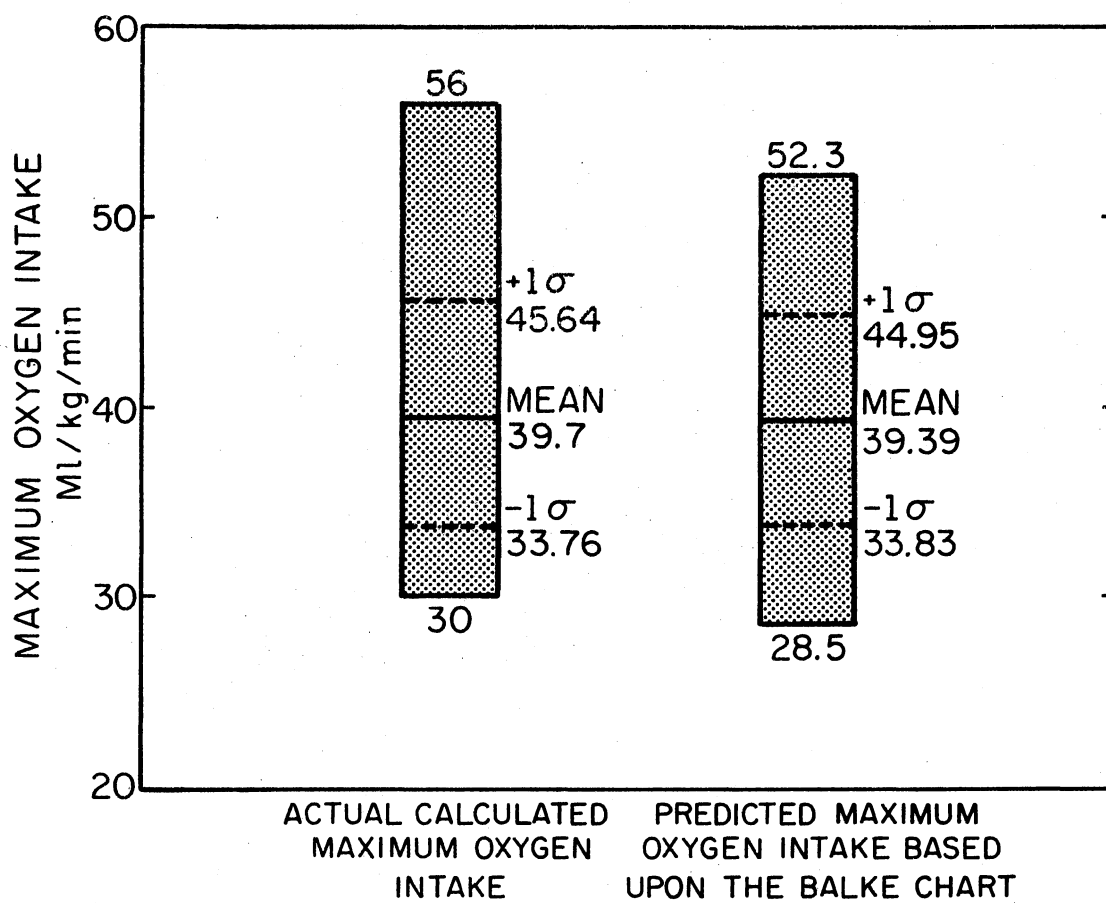


Figure 8. Maximum Oxygen Intake Indicating Range, Mean, and Standard Deviation

Figure 8 indicates a mean calculated maximum oxygen intake of 39.7 Ml/kg/min and a mean predicted maximum oxygen intake of 39.39 Ml/kg/min based on the Balke Chart. The mean calculated maximum oxygen intake data shown in this study compares favorably with the mean maximum oxygen intake in the Lewis Study, 41 Ml/kg/min; Matthews Study, 42 Ml/kg/min; and mean predicted by Cooper for males under 30 years of age, 38.15 Ml/kg/min.

Correlations were computed between actual calculated maximum oxygen intake as determined by the maximum oxygen intake test procedure and the end results of each of the three step tests in this study. The first correlation of interest was between the Michael and Adams One-Minute Step Test and actual calculated maximum oxygen intake. This correlation coefficient was found to be  $-.441$ , which indicates only a moderate relationship between the two items. When correlating heart rates in groups against maximum oxygen intake, negative correlations will result because there is an inverse relationship between these two variables. The quicker a subject reaches the cut-off point of 180 beats a minute, or steady state, the lower the amount of maximum oxygen intake he will have. Figure 9 illustrates the various correlations computed between each of the three tests and maximum oxygen intake. The correlation between the actual calculated maximum oxygen intake and that predicted by the Balke Charts, based upon percent of grade walked on the treadmill, is shown in Figure 9 and is discussed on page 60.

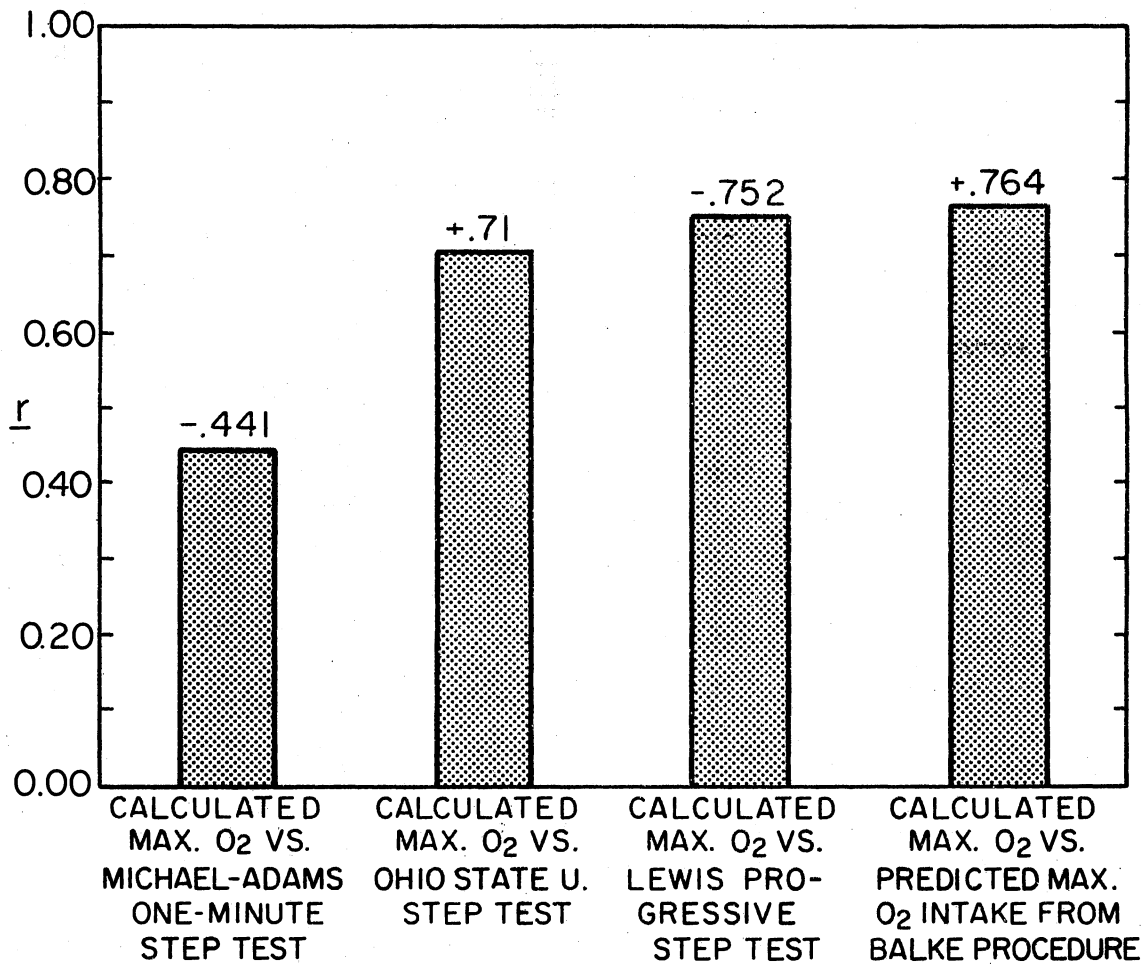


Figure 9. Relationship of Various Tests With Calculated Maximum Oxygen Intake

In addition to the rather moderate correlation between the Michael and Adams One-Minute Step Test and maximum oxygen intake, there are other factors that must be taken into consideration when one selects a fitness test that is to be administered in a general physical education class. The Michael and Adams One-Minute Step Test is a relatively easy test to administer. All that is needed in the way of equipment is a 17-inch bench, which is easily constructed and may be any length desired making it possible to test large numbers of subjects at one time, and a

tape recorder to record and play instructions, which frees the teacher to help individuals who are having difficulty with the stepping procedure. The 17-inch bench is a step that can be negotiated without difficulty; however, the cadence of 36 steps per minute is difficult for subjects who are uncoordinated or overweight. This cadence also takes the heart rate up rapidly with no opportunity for the test administrator to terminate the test in cases where the heart rates exceed the recommended limits for safety. The time needed to administer the Michael and Adams One-Minute Step Test, including a demonstration, all instructions, and testing was ten minutes.

The second correlation of interest was between the actual maximum oxygen intake and the Ohio State University Step Test. This test was based on innings completed when the subject's heart rate attained 150 beats per minute; therefore, a positive correlation coefficient was found. The correlation between this step test and maximum oxygen intake was  $+0.71$ , which denotes a high relationship between the two variables.

The cadence of the Ohio State University Step Test, 20 and 30 steps per minute on the 15-inch bench and 30 steps per minute on the 20-inch bench, appeared to be within the capability of the subjects tested. In some cases, however, the 20-inch bench was too high for those subjects who were short of stature. The result was leg cramps and instability in negotiating the 20-inch bench height. The hand bar did aid the subject in maintaining balance and helped him perform the test but is questionable with regard to increasing the work load by involving a greater number of large muscles. Heart rates were monitored upon completion of each work load, which is an important safety factor. The stepping device is limited to testing only one subject at a time and, therefore,

this test is time consuming. The time needed for administering the Ohio State University Step Test was 20 minutes per individual.

The third correlation was between the actual maximum oxygen intake and the Lewis Progressive Step Test. Again, as with the Michael and Adams One-Minute Step Test, negative correlations were found for the same reasons as given on page 49. This correlation was found to be  $-.752$ , which denotes a higher relationship between these two variables than that found between the Ohio State University Step Test and maximum oxygen intake.

The Lewis Progressive Step Test is performed on a 14-inch bench, which can be found in most schools, or the bench can be built for a nominal amount of money. Large numbers of subjects can be tested at the same time. The Lewis Progressive Step Test cadences of 12, 15, 18, 21, 24, 27, and 30 steps per minute were within the capability of the subjects being tested, and it was possible to monitor heart rates at each work load level so that the test could be terminated within the safety limits of 180 beats per minute. The only cadence with which the subjects had difficulty was the 12 steps per minute which was a stepping cadence not normally encountered. The subjects tended to want to step at a faster rate and had to be constantly reminded to stay with the proper cadence. Testing time, including a demonstration and all instructions, was 22 minutes for the Lewis Progressive Step Test.

Figure 10 illustrates the correlation coefficients between the Michael and Adams One-Minute Step Test, Lewis Progressive Step Test, and the Ohio State University Step Test.

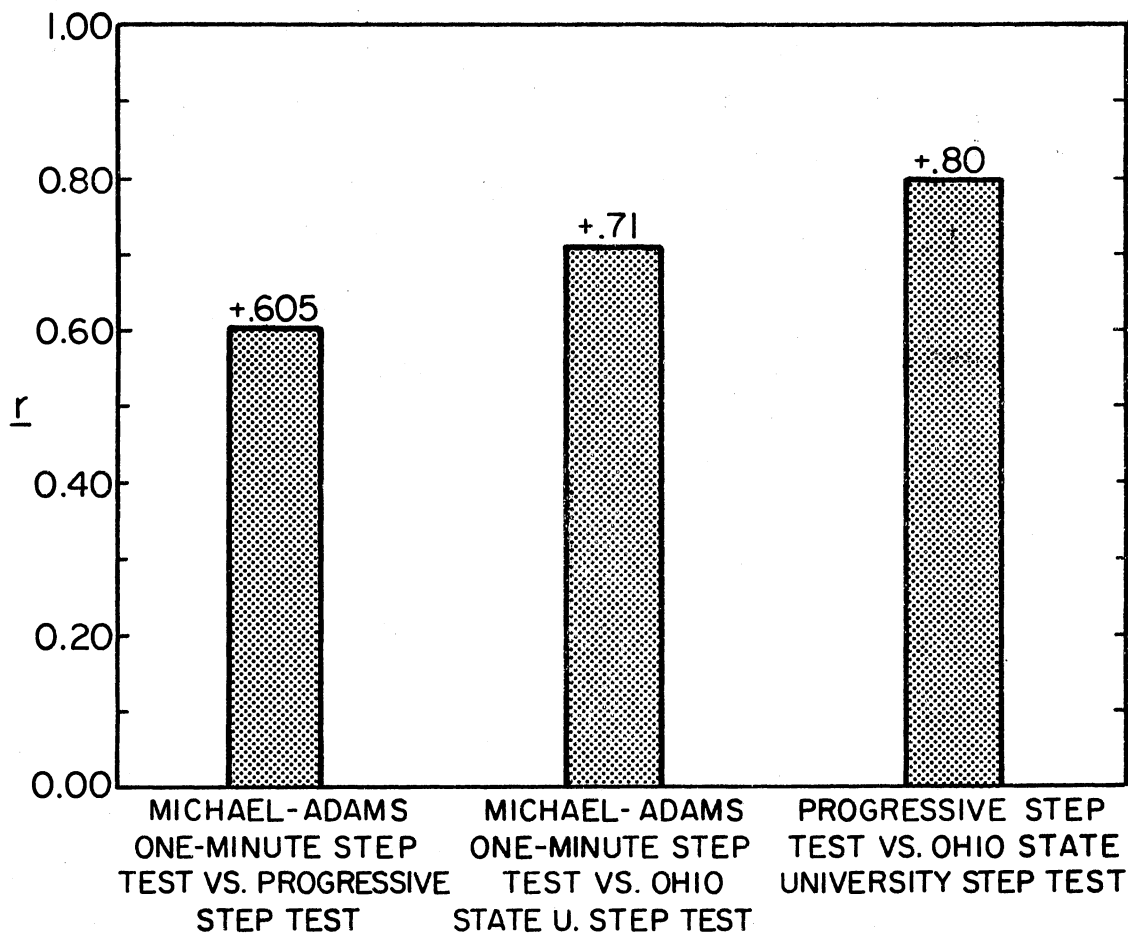


Figure 10. Cross-Checked Interrelationship Between Each of the Three Step Tests

The first correlation was between the Michael and Adams One-Minute Step Test and the Lewis Progressive Step Test. The correlation found was  $+.605$ , which indicates a moderate relationship between these two variables.

The second consideration was the relationship between the Michael and Adams One-Minute Step Test and the Ohio State University Step Test. The correlation found was  $+.71$ , which indicated a slightly higher

relationship between these two variables than occurred between the Michael and Adams One-Minute Step Test and the Lewis Progressive Step Test. However, the greatest relationship existed between the Lewis Progressive Step Test and the Ohio State University Step Test with a correlation coefficient of  $+0.80$ , which denoted a higher relationship between these two step tests.

One of the sub-problems of this study was to compare the results of the subjects in this study with physical fitness norms established for each of the step tests. The data in Figures 11, 12, and 13 illustrates that the subjects' mean physical fitness category ranged close to the 50th percentile and placed them in the average fitness category in all but one of the step tests. Raw heart rate scores were converted to Z-scores, which were used in plotting the scales illustrated in Figures 11, 12, and 13 to smooth out the data shown. The Lewis Progressive Step Test, Figure 11, was positively skewed because no subjects fell into the poor and very poor fitness categories. More subjects fell into the above average category than any other category. The fitness categories for both the Michael and Adams One-Minute Step Test and the Ohio State University Step Test did not have an above average fitness category.

A second sub-problem was to make a comparison between the predicted maximum oxygen intake based upon the Balke Charts as determined from the percent of grade a subject could walk on the Balke Treadmill Test and the actual calculated maximum oxygen intake. Figure 14 indicates the relationship between the calculated maximum oxygen intake and the predicted maximum oxygen intake predicted from the Balke Charts based upon treadmill walking, and the mean maximum oxygen intake for both the

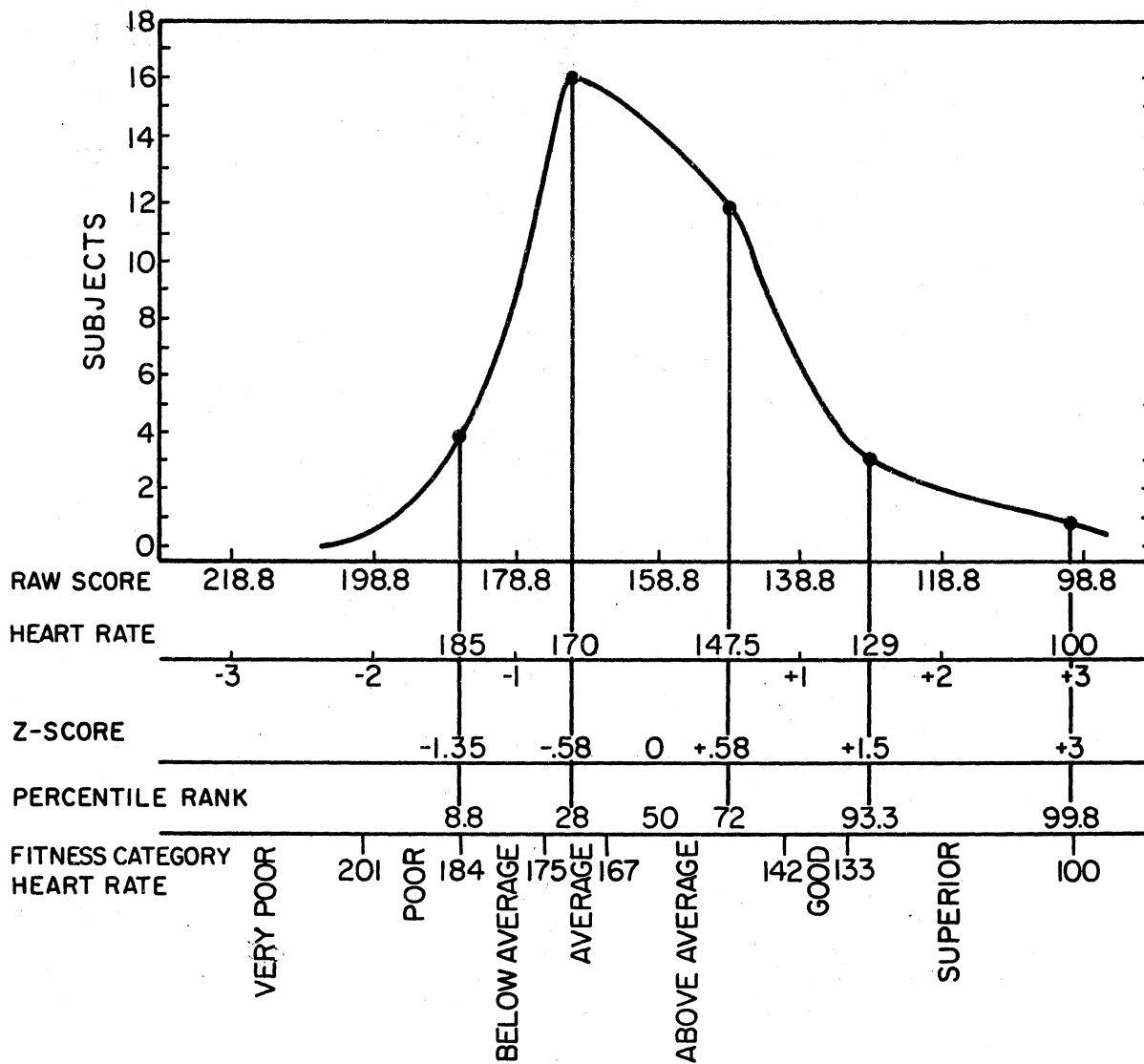


Figure 11. Fitness Categories Based Upon Established Percentile Norms for the Lewis Progressive Step Test



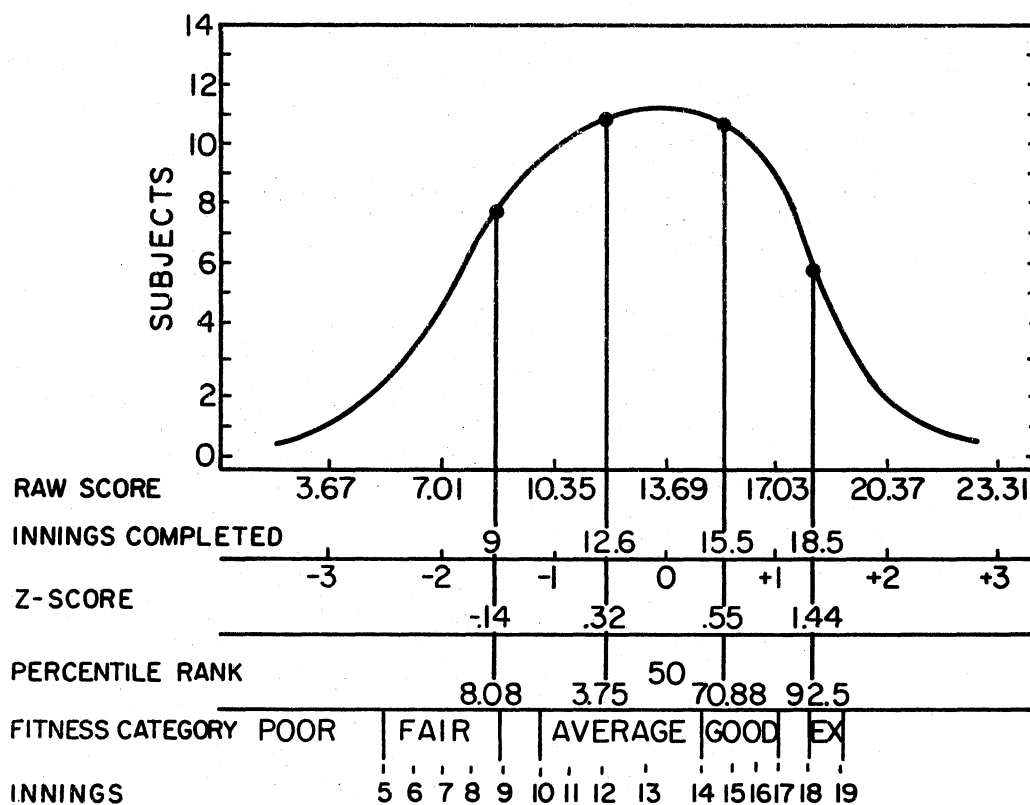


Figure 12. Fitness Categories Based Upon Established Percentile Norms for the Ohio State University Step Test

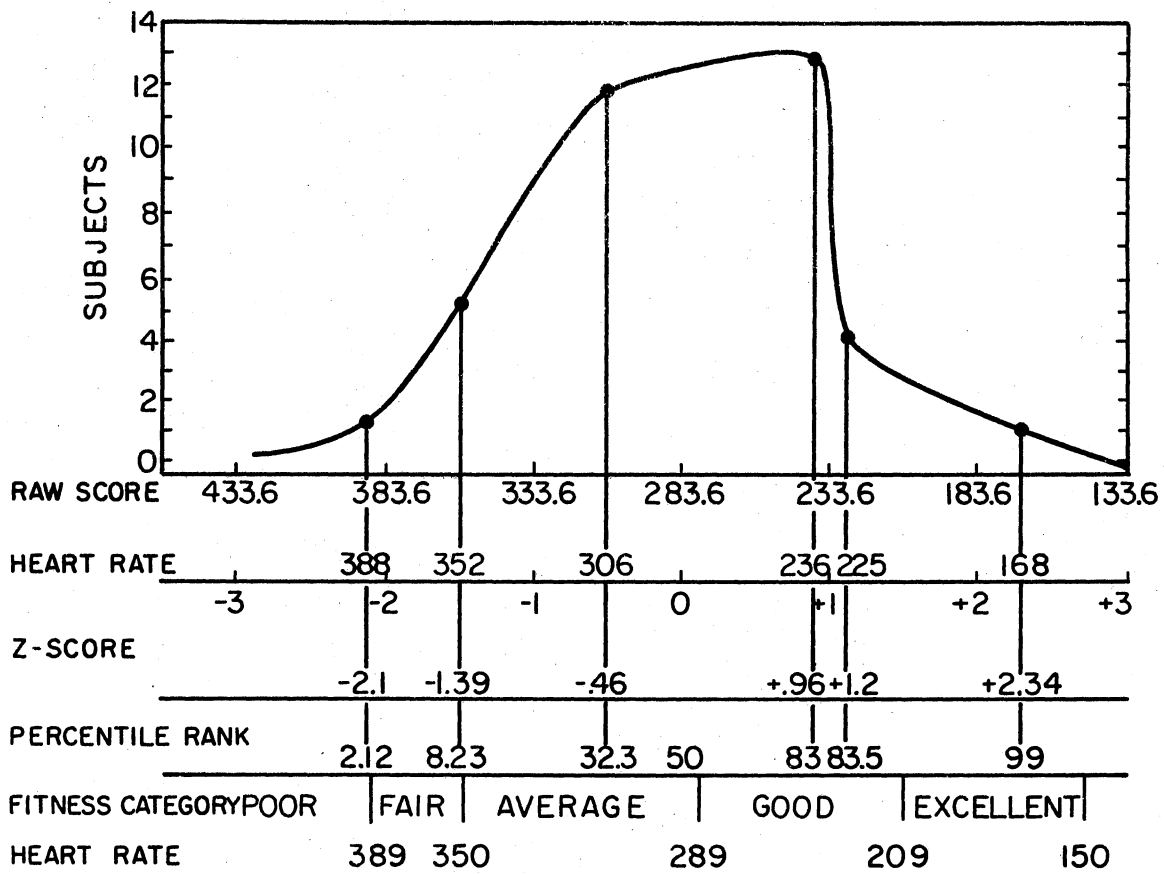


Figure 13. Fitness Categories Based Upon Established Percentile Norms for the Michael and Adams One-Minute Step Test; Three Minute Recovery Heart Rates

calculated, 39.7 Ml/kg/min., and the predicted maximum oxygen intake, 39.4 Ml/kg/min. The means were almost identical.

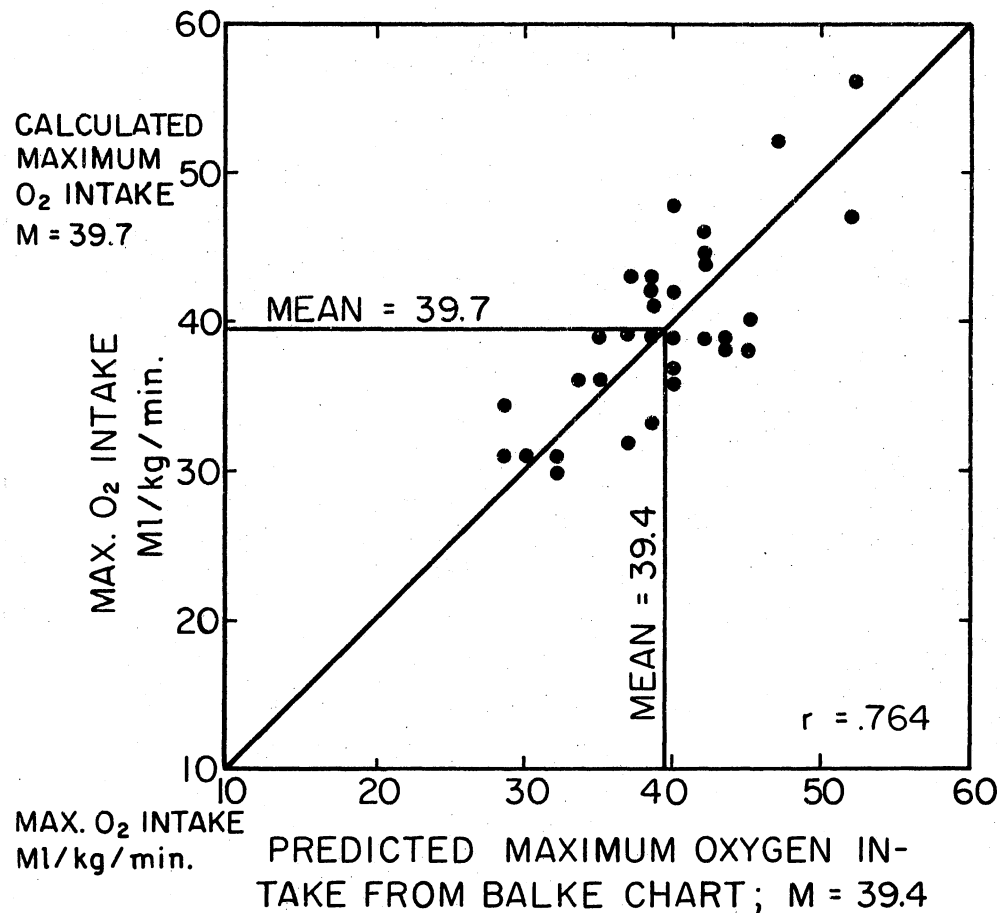


Figure 14. Comparison of Calculated Maximum O<sub>2</sub> Intake and Predicted Maximum O<sub>2</sub> Intake

A product moment correlation was computed between actual calculated maximum oxygen intake and predicted maximum oxygen intake from the Balke Charts. The computation showed that the actual calculated maximum oxygen intake, as measured during the last minute of exercise when the

subject's heart rate reached 180 beats per minute, had a  $+0.764$  correlation with Balke's predicted maximum oxygen intake, as is shown in Figures 9 and 14. This correlation indicated a good relationship between the two sets of scores. The largest calculated maximum oxygen intake was 56  $\text{Ml/kg/min.}$  at a treadmill elevation of  $24^{\circ}$ . The predicted maximum oxygen intake at this elevation was 52.3  $\text{Ml/kg/min.}$  The smallest calculated maximum oxygen intake was 30  $\text{Ml/kg/min.}$  at a treadmill elevation of  $12^{\circ}$ . The predicted maximum oxygen intake at this elevation was 32  $\text{Ml/kg/min.}$  The mean calculated oxygen intake was 39.7  $\text{Ml/kg/min.}$  and the mean predicted oxygen intake was 39.4  $\text{Ml/kg/min.}$

For the vast majority of the subjects in this study, all three step tests were submaximal, as indicated by the mean heart rates for the Michael and Adams One-Minute Step Test, Lewis Progressive Step Test, and the arbitrary termination point of 150 heart beats per minute used in the Ohio State University Step Test (see Table I).

TABLE I  
EXERCISE HEART RATE

	Michael-Adams One-Minute 36 Steps/Min. 17" Bench	Lewis Pro- gressive 30 Steps/Min. 14" Bench	Ohio State Univ. 18 Innings 15" & 20" Bench Terminate at 150 Beats Per Minute
Highest Heart Rate or Innings Completed	188	192	19
Lowest Heart Rate or Innings Completed	128	100	8
Mean Heart Rate or Innings Completed	152.5	158.8	13.7

In summary, the purpose of this study was to compare three methods of assessing physical fitness through the use of submaximal step tests. The step tests used were the Michael and Adams One-Minute Step Test, the Lewis Progressive Step Test, and the Ohio State University Step Test. Thirty-six subjects performed each of the step tests and the criterion test, maximal oxygen intake, using the Balke treadmill procedure.

On the basis of the results found in this study, the Michael and Adams One-Minute Step Test was not a reliable testing instrument,  $r = .77$ . Michael and Adams found  $r = .82$ . The correlation coefficient between the Michael and Adams One-Minute Step Test and maximum oxygen intake was  $-.441$ , which indicated only a moderate relationship between these two variables. The test was relatively easy to administer; all that was needed in the way of equipment was a 17-inch bench, a metronome, and a stop watch. Counting the heart beat by palpation at the carotid artery eliminated the need for a stethoscope.

The time needed to administer the Michael and Adams One-Minute Step Test including a demonstration, all instructions, and testing was ten minutes. The cadence of 36 steps per minute was difficult to negotiate for some subjects. This cadence takes the heart rate up rapidly with no opportunity for the test administrator to terminate the test in cases where the heart rate exceeds 180 beats per minute.

The Ohio State University Step Test proved to be a reliable testing instrument,  $r = .94$ . The correlation established for the original Ohio State University Step Test was  $r = .945$ , nearly the same as found in this study. The correlation coefficient between the Ohio State University Step Test and maximum oxygen intake was  $.71$ , which indicated satisfactory validity. The correlation established for the original Ohio State

University Step Test was  $r = .94$ , a higher validity than found in this study. The test was relatively easy to administer. The stepping device was simple and inexpensive to build. The 15-inch stepping bench, using 20 and 30 steps per minute, was within the capacities of the subjects being tested; however, the 30-step cadence on the 20-inch bench resulted in leg cramps and instability in stepping for some subjects.

The time needed for administering the Ohio State University Step Test was 20 minutes and was limited to testing only one subject at a time. Termination of the test at a heart rate of 150 beats per minute eliminated the possibility of heart rates going beyond the recommended cut-off of 180/min.

The Lewis Progressive Step Test proved to be a reliable testing instrument,  $r = .96$ , which substantiates the high reliability claimed for the Lewis Progressive Step Test. The correlation coefficient between the Lewis Progressive Step Test and maximum oxygen intake was  $-.752$ . Lewis found a correlation coefficient of  $-.757$ , nearly the same as found in this study. This  $-.752$  was the best validity found between maximum oxygen intake and any one of the three step tests in this study. The test was relatively easy to administer. All that was needed in the way of equipment was a 14-inch bench, which was easy and inexpensive to construct, a metronome, and a stop watch. Heart rates were monitored at the end of each work load making it possible to terminate the test should the subject's heart rate exceed the recommended cut-off point of 180 beats per minute. The heart beat may be counted by palpation at the carotid artery. Testing time, including demonstration and all instructions, was 22 minutes. The 14-inch bench can be any length desired, within the limits of stability, making it possible to test large numbers

of subjects at one time. The stepping cadence of 12 steps per minute was a difficult cadence to step for some subjects as it was a slow cadence not normally encountered in everyday life. Table II summarizes the results from tests in this study.

Based upon the data collected in this study, data is shown in Table II, the researcher believes the Lewis Progressive Step Test to be the best of the three tests under investigation, and the researcher highly recommends this test for predicting endurance physical fitness. The Lewis Progressive Step Test meets all the feasibility criteria best.

The Ohio State University Step Test was rated second and nearly equal to the Lewis Progressive Step Test except that only one subject can be tested at a time, and the 30 steps per minute cadence on the 20-inch bench was a difficult stepping cadence for some subjects.

The Michael and Adams One-Minute Step Test had unsatisfactory validity with maximum oxygen intake and had questionable reliability.

The correlation coefficient between the Michael and Adams One-Minute Step Test and the Lewis Progressive Step Test was .605; the Michael and Adams One-Minute Step Test and the Ohio State University Test was .71; and the Lewis Progressive Step Test and Ohio State University Step Test was .80.

The subjects involved in this study had a mean physical fitness category ranging close to the 50th percentile, and this placed them in the average fitness category.

A product moment correlation was computed between actual calculated maximum oxygen intake and predicted maximum oxygen intake from the Balke Charts. This correlation was .764.

TABLE II  
SUMMARY OF THREE STEP TESTS RESULTS

Feasibility Factors	Michael-Adams One-Minute Step Test	Ohio State University Step Test	Lewis Progressive Step Test
Reliability	.77	.94	.96
Validity	-.441	.71	-.752
Time Needed to Administer	10 Minutes	20 Minutes	22 Minutes
Equipment	17-Inch Bench	Two-Level Bench With Hand Bar One 15-Inch One 20-Inch	14-Inch Bench
Ease of Administration	Good	Good	Good
Test Administrators Needed	One	One	One
Number of Subjects that can be tested at one time	Limited only by Length of Bench	One	Limited only by Length of Bench
Problems	1) 36 step was difficult for some subjects 2) No opportunity to terminate test at 180 heart beats per minute	1) 30 step cadence on 20-inch bench was difficult for some subjects	1) 12 Step cadence was a rather slow cadence, not normally encountered



## CHAPTER V

### CONCLUSIONS AND RECOMMENDATIONS

Physical fitness is of growing concern to many people in the United States. A review of the literature with regard to this study showed cardiovascular disease to be one of the greatest threats to the lives and health of the American population today. Becoming physically fit is a goal that should appeal to every normal person. This necessitates physical fitness programs that can be administered during the growth and development years of a person's life.

One of the major problems in physical education programs is the measurement of physical condition. This problem is compounded in the typical school because of the lack of facilities and the large numbers of students in the classroom. Physical fitness step tests help resolve these problems. Step tests eliminate the need for elaborate laboratories and make it possible for the physical educator to test large numbers of students in a short period of time at a minimal cost to the school system.

In Chapter II, Review of Literature, it was shown that there are a variety of step tests. The varying of stepping heights, exercise work loads, progressive step procedures, design of stepping devices, and validity and reliability of these step tests has led to confusion for the typical physical educator as to which test is best suited to meet the needs of a physical fitness testing program. Results produced in

this study indicate that the step test can be used as a valid predictor of cardiorespiratory fitness.

This study was initiated to determine if one of three previously developed step tests was a better indicator of maximum oxygen intake than another and, if so, which one was most feasible in terms of (1) length of time necessary to administer the test; (2) equipment needed to administer the test; (3) cost of equipment; (4) number of test administrators needed; (5) reliability of the test; and (6) validity of the test.

The highest correlation,  $-.752$ , found in this study was between the Lewis Progressive Step Test and calculated maximum oxygen intake.

Sheehan notes that validity coefficients may be interpreted as:  $\pm .20$  to  $\pm .40$  indicates low relationship;  $\pm .40$  to  $\pm .70$  indicates moderate relationship;  $\pm .70$  to  $\pm 1.00$  indicates high to perfect correlation.<sup>1</sup>

On the basis of the data collected in this study and the interpretation of the data, the following conclusions were made:

#### Lewis Progressive Step Test

1. The Lewis Progressive Step Test was a valid measure of the endurance aspect of physical fitness, ( $r = -.752$  with maximum oxygen intake). An  $r = -.752$  indicates satisfactory validity.
2. The test procedure was reliable, ( $r = .96$ ).
3. The test was relatively easy to administer; one test administrator was needed.

---

<sup>1</sup>Sheehan, pp. 131-132.

4. The equipment needed to administer the test was a 14-inch bench, a tape recorder, and a stethoscope.

5. The stepping bench was inexpensive to construct.

6. Total testing time was 22 minutes.

7. Large numbers of subjects can be tested at the same time.

#### Ohio State University Step Test

1. The Ohio State University Step Test was a valid measure of the endurance aspect of physical fitness, ( $r = .71$  with maximum oxygen intake). An  $r = .71$  indicates satisfactory validity.

2. The test procedure was reliable, ( $r = .94$ ).

3. The test was easy to administer; one test administrator was needed.

4. Equipment needed to administer this test was a two-level stepping device, one level 15 inches in height and the other 20 inches in height, with a hand bar. A tape recorder and stethoscope was needed.

5. The stepping device was inexpensive to construct.

6. The 30 step cadence on the 20-inch bench was a difficult cadence for many subjects.

7. Total testing time was 20 minutes and was limited to testing one subject at a time unless the stepping device could be modified to test more subjects.

#### Michael and Adams One-Minute Step Test

1. The Michael and Adams One-Minute Step Test had an unsatisfactory validity correlation coefficient with maximum

oxygen intake, ( $r = -.441$ ).

2. The test-retest reliability was .77 and was of questionable reliability.

3. The test was easy to administer; only one test administrator was needed.

4. The equipment needed to administer the test was a 17-inch bench, a tape recorder, and a stethoscope.

5. The stepping bench was inexpensive to construct.

6. Testing time was 10 minutes.

7. Large numbers of subjects can be tested at one time.

8. The cadence of 36 steps per minute was difficult to negotiate for some subjects.

9. The 36 step cadence takes the heart rate up rapidly with no opportunity to terminate the test in cases where the heart rate exceeds 180 beats per minute.

The correlation coefficient between the Michael and Adams One-Minute Step Test and the Lewis Progressive Step Test was .605. The correlation coefficient between the Michael and Adams One-Minute Step Test and the Ohio State University Step Test was .71. The correlation coefficient between the Progressive Step Test and the Ohio State University Step Test was .80.

The subjects involved in this study had a mean physical fitness category of average, based upon norms established for each of the three step tests.

The correlation coefficient between calculated maximum oxygen intake and predicted maximum oxygen intake from the Balke Charts was .764.

## Recommendations

Based upon the data gathered in this study, the following recommendations are made:

1. The Lewis Progressive Step Test should be used in placing subjects in homogeneous groups for designing physical fitness exercise programs to meet the individual needs of subjects. The Lewis Progressive Step Test proved to be the best test of the three under investigation; it had the highest validity and reliability for predicting maximum oxygen intake. The Lewis Progressive Step Test meets all of the feasibility criteria, shown in Table II.

2. Both a pretest and a post-test should be given on a semester basis with the subject being made aware of his endurance status. The test could then be used as a motivational device.

3. Testing procedures should be taped for playback to establish consistency in administering the test and to free the test administrator for other duties relating to the testing procedure.

4. The heart rate could be taken by palpation at the carotid artery. The researcher found that the heart rate never varied more than one beat whether counted by stethoscope or by palpation at the carotid artery.

## Recommendations for Further Study

The following recommendations for further investigation are made as a result of this study:

1. Norms should be established for elementary and secondary school girls and boys using the Lewis Progressive Step Test.

2. Norms should be established for college-age women using the Lewis Progressive Step Test.

3. The Lewis Progressive Step Test should be compared with other established step tests in addition to the step tests used in this study.

A SELECTED BIBLIOGRAPHY

- Astrand, P. O., and Irma Ryhming. "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) From Pulse Rate During Submaximal Work." Journal of Applied Physiology, Vol. 7, No. 2 (September, 1954), p. 218.
- Bayless, J. G. "A Metabolic Functional Capacity Test for Upper Elementary-Age Boys." (Unpublished Ed.D. dissertation, Oklahoma State University, 1966.)
- Brassfield, Charles R. "Some Physiological Aspects of Physical Fitness." Research Quarterly, Vol. 14 (March, 1943), pp. 106-111.
- Brouha, Lucien. "The Step Test: A Simple Method of Measuring Physical Fitness for Muscular Work in Young Men." Research Quarterly, Vol. 14, No. 1 (March, 1943), pp. 31-36.
- Brouha, L., A. Graybiel, and C. W. Heath. "The Step Test, A Simple Method of Measuring Physical Fitness for Hard Muscular Work in Adult Man." Revue Canadienne De Biologie, Vol. 2 (February, 1943), pp. 86-97.
- Consolazio, C. Frank, Robert E. Johnson, and Louis J. Pecora. Physiological Measurements of Metabolic Functions in Man. New York: McGraw-Hill, 1963.
- Cooper, Kenneth H. Aerobics. New York: M. Evans and Company, 1968.
- Cooper, Kenneth H. The New Aerobics. New York: M. Evans and Company, 1970.
- Cotten, Doyice J. "A Modified Step Test for Group Cardiovascular Testing." Research Quarterly, Vol. 42, No. 1 (March, 1971), pp. 91-95.
- Cureton, Thomas K. Physical Fitness Workbook for Adults. Champaign: Stipes Publishing Company, 1970.
- Cureton, Thomas K. Physical Fitness Workbook. St. Louis: C. V. Mosby Company, 1947.
- Day, James P. "A Statistical Investigation of the Ryhming Step Test." Research Quarterly, Vol. 38, No. 4 (December, 1967), pp. 539-543.

- deVries, Herbert A., and Carl E. Klafs. "Prediction of Maximal Oxygen Intake from Submaximal Tests." Journal of Sports Medicine and Physical Fitness, Vol. 5 (December 1965), pp. 207-214.
- deVries, Herbert A. Physiology of Exercise for Physical Education and Athletics. Dubuque: Wm. C. Brown, 1966.
- Doolittle, D. L., and Rollin Bigbee. "The Twelve-Minute Run-Walk: A Test of Cardiorespiratory Fitness of Adolescent Boys." Research Quarterly, Vol. 39, No. 3 (October, 1968), pp. 491-495.
- Fox, Edward, and Donald Mathews. Interval Training. Philadelphia: W. B. Saunders Company, 1974.
- Frye, Mary L. "A Progressive Step Test for Elementary School Girls." (Unpublished Master's thesis, Oklahoma State University, 1966.)
- Gallagher, J. Roswell, and Lucien Brouha. "A Simple Method of Testing the Physical Fitness of Boys." Research Quarterly, Vol. 14 (1943), pp. 23-30.
- Godart Pulmo-Analyzer. New York: Instrumentation Associates, Inc.
- Jensen, Clayne R., and Gordon W. Schultz. Applied Kinesiology. New York: McGraw-Hill, 1970.
- Karpovich, Peter V., and Wayne E. Sinning. Physiology of Muscular Activity. Philadelphia: W. B. Saunders Company, 1971.
- Keen, E. N., and A. W. Sloan. "Observations on the Harvard Step Test." Journal of Applied Physiology, Vol. 13 (1958), pp. 241-243.
- Kurucz, Robert L., Edward L. Fox, and Donald K. Mathews. "Construction of a Submaximal Cardiovascular Step Test." Research Quarterly, Vol. 40, No. 1 (March, 1969), pp. 115-121.
- Larson, Leonard A. "Cardiovascular-Respiratory Function in Relation to Physical Fitness." Supplement to the Research Quarterly, Vol. 12, No. 2 (May, 1941), pp. 456-467.
- Lewis, Albert Lester. "A Progressive Step Test to Predict Maximum Oxygen Intake." (Unpublished Ed.D. dissertation, Oklahoma State University, 1970.)
- Maksud, Michael G., and Kenneth D. Coutts. "Application of the Cooper Twelve-Minute Run-Walk Test to Young Males." Research Quarterly, Vol. 42, No. 1 (March, 1971), pp. 54-59.
- Mathews, Donald K., and Edward L. Fox. The Physiological Basis of Physical Education and Athletics. Philadelphia: W. B. Saunders Company, 1971.



- Matthews, N. D. "A Progressive Step Test for Assessing the Cardio-respiratory Fitness of College Men." (Unpublished Ed.D. dissertation, Oklahoma State University, 1972.)
- Michael, Ernest D., and Adran Adams. "The Use of a One-Minute Step Test to Estimate Exercise Fitness." Ergonomics, Vol. 7, No. 2 (April, 1964), pp. 211-215.
- Miller, Waldo A., and Edwin R. Elbel. "The Effect Upon Pulse Rate of Various Cadences in the Step-Up Test." Research Quarterly, Vo. 17 (December, 1946), pp. 263-269.
- Montoye, Henry J. "The 'Harvard Step Test' and Work Capacity." Revue Canadienne de Biologie, Vol. 11 (1952), pp. 491-499.
- Morehouse, Laurence E., and Augustus T. Miller. Physiology of Exercise. St. Louis: C. B. Mosby Company, 1971.
- Nagle, Francis J., and Thomas G. Bedeck. "Use of the 180 Heart Rate Response as a Measure of Circulorespiratory Capacity." Research Quarterly, Vol. 34, No. 3 (1963), pp. 361-369.
- Sheehan, Thomas J. An Introduction to the Evaluation of Measurement Data in Physical Education. Reading: Addison-Wesley Publishing Company, 1971.
- Shephard, R. J. "The Prediction of 'Maximal' Oxygen Consumption Using A New Progressive Step Test." Ergonomics, Vol. 10, No. 1 (January, 1967), pp. 1-15.
- Skubic, Vera, and Jean Hodgkins. "Cardiovascular Efficiency Test for Girls and Women." Research Quarterly, Vol. 34, No. 1 (1963), pp. 191-197.
- Tuttle, W. W. "The Use of the Pulse-Ratio Test for Rating Physical Efficiency." Research Quarterly, Vol. 2, No. 2 (May, 1931), pp. 5-17.
- Waxman, W. W. "Physical Fitness Development for Adults in the YMCA." Exercise and Fitness, A Collection of Papers Presented at the Colloquium on Exercise and Fitness. Urbana: The University of Illinois College of Physical Education and the Athletic Institute, 1960, pp. 185-186.
- Woods, Francis James. "The Validation of the Ohio State University Cardiovascular Fitness Test." Dissertation Abstracts, 29A, Pt. 5 (March-April, 1969), p. 2990A.

APPENDIX

TO: Male Residents of Kerr Hall

FROM: Charles Hundley  
Box 503, Kerr Hall

DATE: June 10, 1974

SUBJECT: Volunteers for Physical Fitness Tests

As a graduate student in Health and Physical Education at Oklahoma State University, I am gathering data for my dissertation. I need male volunteers between the ages of 18 and 25 to participate in physical fitness tests, which I am administering in the laboratory in the Colvin Physical Education Center.

These tests consists of three stepping exercises--subject steps at various rates and different heights upon benches--and walking on a treadmill to determine maximum oxygen intake. Only about two hours of your time would be needed spread out over the entire summer school session. No more than 30 minutes of your time would be needed in any test session. The tests would be administered at your convenience.

THE BENEFIT YOU WOULD RECEIVE FROM THESE TESTS WOULD BE A PERSONAL DETERMINATION OF YOUR PHYSICAL FITNESS CATEGORY AS MEASURED BY THESE TESTS.

If you would be willing to participate, this poor, struggling doctoral student would appreciate it. If you will participate, please put your name and room or phone number at the bottom of this paper and return it to post office box 503. You will be contacted by me.

(Signed) Charles Hundley

---

Name of Participant

---

Room or Phone

PERSONAL DATA SHEET  
(Please Print)

Name \_\_\_\_\_ Number \_\_\_\_\_

Date of Birth \_\_\_\_\_ Age \_\_\_\_\_ Weight \_\_\_\_\_

Height \_\_\_\_\_ Circle College Year: 1, 2, 3, 4, Grad.

College/Major \_\_\_\_\_ Phone No. \_\_\_\_\_

College Address \_\_\_\_\_

Home Address \_\_\_\_\_

Medical History:

Check if you have had any of the following:

<input type="checkbox"/> Asthma	<input type="checkbox"/> Shortness of breath on exertion
<input type="checkbox"/> Frequent Colds	<input type="checkbox"/> Swelling of feet
<input type="checkbox"/> Fainting or dizzy spells	<input type="checkbox"/> Back trouble
<input type="checkbox"/> Epilepsy	<input type="checkbox"/> Joint trouble
<input type="checkbox"/> Tuberculosis	<input type="checkbox"/> Rheumatic Fever
<input type="checkbox"/> Pleurisy	<input type="checkbox"/> Infantile Paralysis

Are you now under treatment? \_\_\_\_\_ Who is caring for you? \_\_\_\_\_

Do you take any medicine regularly? \_\_\_\_\_ If so, what? \_\_\_\_\_

Were you excused from physical education in high school because of any disability? \_\_\_\_\_ If so, what? \_\_\_\_\_

Describe briefly any physical condition you have which might make it inadvisable for you to participate in physical education. \_\_\_\_\_

Do you smoke? \_\_\_\_\_ If so, how much?  
(Circle one) Under 10, 10-15, 15-20, over 20.

Sports History:

Did you participate in high school athletics? \_\_\_\_\_  
If so, what sports and for how many years? \_\_\_\_\_

Did you have organized physical education in high school? \_\_\_\_\_  
If so, how many years? \_\_\_\_\_

Do you participate in intramurals at college? \_\_\_\_\_ If so, how many and what years? \_\_\_\_\_

Do you engage in regular physical activity? \_\_\_\_\_ If so, how often per week, and in what activities? No. hrs/wk \_\_\_\_\_ Duration of workout: \_\_\_\_\_  
Activities \_\_\_\_\_

Thank You

OKLAHOMA STATE UNIVERSITY  
PHYSIOLOGY OF EXERCISE LABORATORY  
INFORMED CONSENT FORM

Subject's Name \_\_\_\_\_ Date \_\_\_\_\_

I hereby authorize Charles Hundley to perform the following procedure(s):

Three physical fitness evaluations as determined by performing a stepping exercise upon stepping benches and a treadmill walking test to predict maximal oxygen intake capacity,

on \_\_\_\_\_  
Subject

The procedure(s) have been explained to me by Charles Hundley.

I understand the procedure(s) involve the following possible risks and discomforts:

All tests except the treadmill walk involve no unusual risk or discomfort. The treadmill test involves walking at a gradually increasing grade up to a target heart rate of 180 beats per minute. An EKG is monitored during the treadmill walk and the test is terminated upon signs of cardiac distress. The subject is free to terminate the test at any time at his own discretion.

I also understand that all test records will be kept confidential and will not be released to anyone without permission of myself or family. Test results will be tabulated for research purposes as group data and in no case will a subject's personal identity be associated with his test results without his express permission.

I understand that the potential benefits of the investigation are as follows:

The results of the test battery will give the subject a view of his current fitness status as determined by step tests and the treadmill test. Test results will be explained and interpreted to the subject. Guidance concerning exercise programs will be given.

I understand that I may terminate my participation in the study at any time.

\_\_\_\_\_  
Subject's Signature

SUBJECT DATA SHEET  
STEP TESTS

Name \_\_\_\_\_ Sequence \_\_\_\_\_

ONE - MINUTE STEP TEST Date \_\_\_\_\_

Resting Heart Rate \_\_\_\_\_; 5 Seconds After Exercise \_\_\_\_\_  
 1 Minute After Exer. \_\_\_\_\_; 2 Minutes After Exercise \_\_\_\_\_  
 3 Minutes After Exer. \_\_\_\_\_; Total Heart Rate \_\_\_\_\_

PHYSICAL FITNESS RATING ACCORDING TO NORMS: \_\_\_\_\_  
 .....

PROGRESSIVE STEP TEST Date \_\_\_\_\_

Resting Heart Rate _____	21-Step Heart Rate _____
12-Step Heart Rate _____	24-Step Heart Rate _____
15-Step Heart Rate _____	27-Step Heart Rate _____
18-Step Heart Rate _____	30-Step Heart Rate _____

PHYSICAL FITNESS RATING ACCORDING TO NORMS: \_\_\_\_\_  
 .....

OHIO STATE UNIVERSITY STEP TEST

(End point is 150 heart beats/minute or 18 innings, whichever occurs first)

Date \_\_\_\_\_

Resting Heart Rate \_\_\_\_\_  
 PHASE I: 24 Steps/Minute; 15-Inch Bench

Inning 1 heart rate _____	Inning 10 heart rate _____
Inning 2 heart rate _____	Inning 11 heart rate _____
Inning 3 heart rate _____	Inning 12 heart rate _____
Inning 4 heart rate _____	PHASE III: 30 Steps/Min., 20-Inch Bench
Inning 5 heart rate _____	Inning 13 heart rate _____
Inning 6 heart rate _____	Inning 14 heart rate _____

PHASE II: 30 Steps/Minute; 15-Inch

Inning 7 heart rate _____	Inning 15 heart rate _____
Inning 8 heart rate _____	Inning 16 heart rate _____
Inning 9 heart rate _____	Inning 17 heart rate _____
	Inning 18 heart rate _____

PHYSICAL FITNESS RATING ACCORDING TO NORMS: \_\_\_\_\_

MICHAEL AND ADAMS ONE-MINUTE STEP TEST  
PERCENTILE SCALE NORMS

Score	Percentile
150	100
165	95
180	90
195	85
210	80
225	75
240	70
255	65
270	60
285	55
300	50
315	45
330	40
345	35
360	30
375	25
390	20
405	15
420	10
435	5
450	0

## Fitness Classification:

- A score below 210 is EXCELLENT
- A score between 210-270, GOOD
- A score between 270-330, AVERAGE
- A score between 330-400, FAIR
- A score above 400, POOR

## LEWIS PROGRESSIVE STEP TEST NORMS

Heart Rate After 30 Steps/Minute	Percentile	Classification
126	100	Superior
134	98	Good
143	93	Good
151	77	Above Average
160	56	Above Average
168	50	Average
176	43	Below Average
185	23	Below Average
193	8	Poor
202	2	Poor
210	0	Very Poor

## OHIO STATE UNIVERSITY STEP TEST

Innings	Classification
Under 5	Poor
5 - 9	Fair
10 - 14	Average
15 - 17	Good
18	Excellent



## LABORATORY METABOLIC CALCULATION

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

Age: \_\_\_\_\_ Height: \_\_\_\_\_ Weight: \_\_\_\_\_

B. P. (mm. Hg.): \_\_\_\_\_ Temp. (C. degrees): \_\_\_\_\_

Correction factor by Harvard line chart: \_\_\_\_\_

## 1. FIRST MINUTE:

O<sub>2</sub>% \_\_\_\_\_CO<sub>2</sub>% \_\_\_\_\_

RQ \_\_\_\_\_ (from Harvard line chart)

True O<sub>2</sub> \_\_\_\_\_ (from Harvard line chart)Vent./min. =  $\frac{\text{_____}}{10}$  (Kymo. mm.) = \_\_\_\_\_ x 1.332 = \_\_\_\_\_ L/min.Corrected vent. =  $\frac{\text{_____}}{\text{corr fact}} \times \frac{\text{_____}}{\text{vent}}$  = \_\_\_\_\_ L/min.O<sub>2</sub> Intake = True O<sub>2</sub> x vent. =  $\frac{\text{_____}}{100} \times \text{_____}$  = \_\_\_\_\_ L/min.

## 2. SECOND MINUTE:

O<sub>2</sub>% \_\_\_\_\_CO<sub>2</sub>% \_\_\_\_\_

RQ \_\_\_\_\_ (from Harvard line chart)

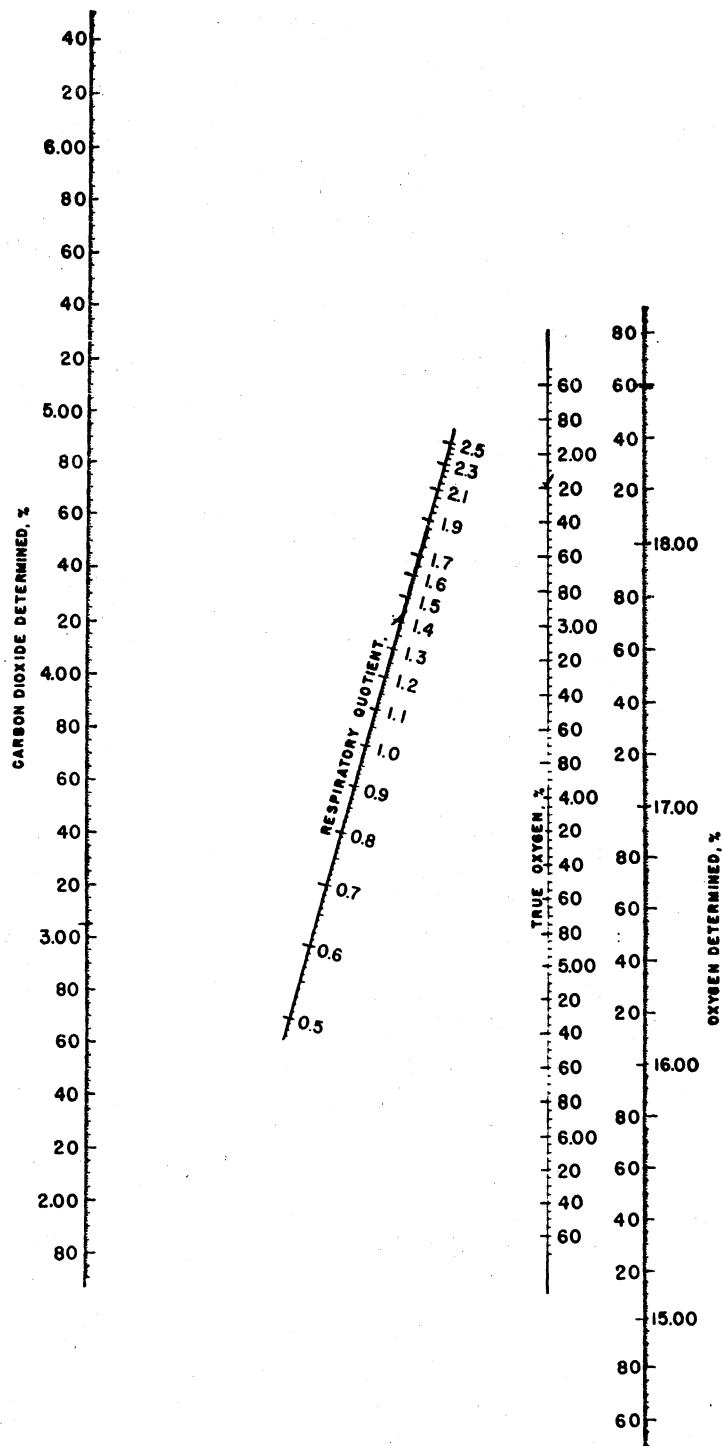
True O<sub>2</sub> \_\_\_\_\_ (from Harvard line chart)Vent./min. =  $\frac{\text{_____}}{10}$  (Kymo. mm.) = \_\_\_\_\_ x 1.332 = \_\_\_\_\_ L/min.Corrected vent. =  $\frac{\text{_____}}{\text{corr fact}} \times \frac{\text{_____}}{\text{vent}}$  = \_\_\_\_\_ L/min.O<sub>2</sub> Intake = True O<sub>2</sub> x vent. =  $\frac{\text{_____}}{100} \times \text{_____}$  = \_\_\_\_\_ L/min.

## 3. THIRD MINUTE

O<sub>2</sub>% \_\_\_\_\_CO<sub>2</sub>% \_\_\_\_\_

RQ \_\_\_\_\_ (from Harvard line chart)

True O<sub>2</sub> \_\_\_\_\_ (from Harvard line chart)Vent./min. =  $\frac{\text{_____}}{10}$  (Kymo. mm.) = \_\_\_\_\_ x 1.332 = \_\_\_\_\_ L/min.Corrected vent. =  $\frac{\text{_____}}{\text{corr fact}} \times \frac{\text{_____}}{\text{vent}}$  = \_\_\_\_\_ L/min.O<sub>2</sub> Intake = True O<sub>2</sub> x vent. =  $\frac{\text{_____}}{100} \times \text{_____}$  = \_\_\_\_\_ L/min.



Harvard Line Chart for calculating RQ and true oxygen from analyses of expired air.

TABLE OF RESULTS

Subject	Pred. Max. O <sub>2</sub> ml/kg/min.	Act. Max. O <sub>2</sub> ml/kg/min.	M-A 1-Min. Resting HR	M-A 1-Min. Exercise HR	Fitness Category	Lewis Prog. Resting HR	Lewis Prog. Exercise HR	Fitness Category	Ohio St. Univ. Resting HR	Ohio St. Univ. Training Comp.	Fitness Category
SA	42	42	76	152	Good	68	140	Good	66	14	Av.
JA	32	30	84	152	Av.	80	176	B.Av.	78	9	Fair
SB	37	39	84	168	Av.	92	184	B.Av.	84	9	Fair
KB	33.5	36	64	160	Av.	64	168	Av.	66	11	Av.
BB	42	46	80	144	Av.	72	132	Good	78	18	Ex.
PB	32	31	76	156	Fair	80	184	Av.	78	13	Av.
LB	28.5	34.5	80	188	Fair	76	176	B.Av.	78	9	Fair
JB	35	36	88	164	Av.	84	172	B.Av.	90	9	Fair
DB	37	32	76	160	Av.	84	180	B.Av.	66	14	Av.
MC	45	38	60	156	Av.	60	152	A.Av.	60	16	Good
DC	45	40	64	152	Good	68	156	A.Av.	66	14	Av.
DCh	42	44.5	72	156	Good	68	148	Good	60	16	Good
JC	38.5	43	72	148	Good	84	168	Av.	66	13	Av.
TD	30	31	80	148	Av.	80	172	Av.	78	10	Av.
BD	37	37	68	152	Av.	56	148	A.Av.	66	13	Av.
TD	52.3	56	60	136	Good	64	128	Sup.	72	19	Ex.
ME	40	42	72	160	Good	72	156	A.Av.	66	13	Av.
EE	42	44	60	132	Good	64	128	Good	66	18	Ex.
BF	43.5	38	64	140	Good	80	172	Av.	72	16	Good
RF	38.5	39	76	148	Av.	64	164	A.Av.	72	13	Av.
RG	37	43	72	168	Fair	68	152	A.Av.	66	15	Good
GH	40	36	60	160	Fair	68	168	Av.	60	13	Av.
DH	43.5	39	76	132	Good	72	164	A.Av.	72	17	Good
JH	38.5	33	84	172	Fair	64	176	B.Av.	90	9	Fair
AL	52	47	56	128	Ex.	52	100	Ex.	54	19	Ex.
PM	45	45	72	164	Av.	64	144	A.Av.	66	13	Av.
SM	40	36	60	144	Good	60	168	Av.	60	13	Av.
DP	40	37	80	136	Av.	84	168	Av.	84	13	Av.
WR	28.5	31	80	188	Fair	72	192	Poor	78	8	Fair
GR	38.5	41	68	156	Good	60	144	A.Av.	60	15	Good
FS	40	44	60	140	Good	64	144	A.Av.	60	17	Good
DS	38.5	42	88	168	Fair	84	176	B.Av.	78	11	Av.
BT1	47	52	56	136	Good	64	138	Good	60	19	Ex.
BT2	42	39	68	140	Good	76	148	Good	76	18	Ex.
LW	40	48	80	156	Av.	80	160	A.Av.	84	17	Good
KY	35	39	72	160	Fair	76	172	B.Av.	84	9	Fair

2  
VITA

Charles Hobert Hundley

Candidate for the Degree of

Doctor of Education

Thesis: A COMPARISON AMONG THREE SUBMAXIMAL STEP TESTS FOR PREDICTING  
MAXIMAL OXYGEN INTAKE

Major Field: Higher Education

Minor Field: Health, Physical Education, and Recreation

Biographical:

Personal Data: Born at Erick, Oklahoma, August 11, 1929, the son  
of Hobert and Margie Hundley.

Education: Graduated from Sayre High School, Sayre, Oklahoma, in  
1947; received the Bachelor of Science degree from Oklahoma  
State University, Stillwater, Oklahoma, with a major in  
Physical Education in May, 1951; received the Master of Science  
degree, with a major in School Administration, from Oklahoma  
State University in July, 1958; completed certification in  
Guidance and Counseling in summer 1962 at Oklahoma State Uni-  
versity; completed summer school graduate work: Western State  
College, Gunnison, Colorado, 1964 and 1965; Colorado State  
College, Greeley, Colorado, 1966; Arizona State University,  
Tempe, Arizona, 1968; completed requirements for the Doctor of  
Education degree at Oklahoma State University in May, 1975.

Professional Experience: Appointed classroom teacher, coach, and  
principal in Texola Public Schools, Texola, Oklahoma, in 1953;  
appointed classroom teacher and coach in the Hooker Public  
Schools, Hooker, Oklahoma, in 1954; appointed principal and  
counselor in the Hooker Schools in 1963; appointed to the  
position of assistant professor in the Health, Physical Educa-  
tion and Recreation Department at Southwestern Oklahoma State  
University, Weatherford, Oklahoma, in 1966. Member of the  
American Association of Health, Physical Education and Recrea-  
tion, Oklahoma Association of Health, Physical Education and  
Recreation, Higher Education Alumni Council, and the Oklahoma  
Education Association.

Service Experience: Served in the U. S. Air Force from 1951 to 1953 as a security courier; discharged with the rank of captain.