A PROGRESSIVE STEP TEST TO PREDICT
MAXIMUM OXYGEN INTAKE

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PREFACE

This dissertation is concerned with developing a field test to predict maximum oxygen intake. The specific test chosen was a progressive cadence step test which has as its advantages: ease of administration, economy of time and money, and submaximal work levels. Maximum oxygen intake has been shown to be the best criteria of physical fitness and for this reason was chosen as the criterion measure in this endurance test.

All of us, in this phase of our educational development, wish to add knowledge to our chosen discipline. Because physical education is my discipline, and realizing sedentary man must have physical fitness through exercise, I feel it of utmost importance to assess the physical fitness status of our individual students. In this manner we may determine what type of program they need to meet the demands of everyday living efficiently.

I would like to take this opportunity to thank my advisory committee, Dr. A. B. Harrison, Dr. Albin Warner, Dr. John Bayless, Dr. John Hampton, and Dr. Kenneth Wiggens, for their very valuable guidance in the development of this study. Indebtedness is also acknowledged to those whose help made this study possible, and especially to those forty men who participated in the study.

In addition, I would like to thank Ann Waughtal for her typing excellence and advice.

Finally, I would like to express appreciation to my wife, Dee, and

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Physical fitness is a term which seems to elude a strict definition as authorities cannot agree upon one precise definition. Consequently there are as many definitions as authors, but they all do seem to agree that when a person exhibits physical fitness he is in a state of "well-being," capable of meeting emergencies.

Cureton tells us that physical fitness means a great deal more than freedom from sickness or passing a medical inspection. In addition to freedom from germinal or chronic disease, possessing good teeth, good hearing, good eye sight, and normal mentality, physical fitness means ability to handle the body well and the capacity to work hard over a long period of time without diminished efficiency.[1]

Dr. Cureton lists five aspects of physical fitness, and to this researcher his phase of motor fitness has much meaning for this study. He breaks motor fitness into six categories which are: (1) endurance, (2) strength, (3) power, (4) agility, (5) flexibility, and (6) balance. Cureton tells us that these items "emphasize the fundamental or gross big muscles movements that are dominated by kinesthetic sense, and suppleness of major tissues and joints, i.e., those aspects which are fundamental to athletic or work skills rather than the higher refine-

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[1]T. K. Cureton, Physical Fitness Appraisal and Guidance, St. Louis: The C. V. Mosby Co., 1947, p. 18.

ments pertaining to specialized small muscle skills which require years to perfect. Specifically it means the capacity for efficient performance in the basic requirements of running, jumping, dodging, falling, climbing, swimming, lifting weights, carrying loads and enduring under sustained effort in a variety of situations. Quick and efficient control of the body in an emergency may save the life of one individual or many.[2]

According to Balke, "in evaluating physical fitness many criteria are used, frequently in any combination. Considering their descriptive value we usually reject many of them as inadequate. For instance, speed alone, or muscle strength, or flexibility and elasticity, or even "health" based on "normal" organic conditions are by no means true indicators or measures of fitness. And neither is "endurance," a quality which can mean many different things."[3]

There must be a characteristic feature that might permit a detection of differences in intra-individual conditions or of differences in the conditions among individuals or among groups of individuals. If we imagine a natural catastrophe that could force people to leave their sheltered life and to escape certain death by marching for many days under very unfriendly environmental conditions--who would last longer--or, who would survive, if there were any chances of survival? All essential conditions being equal, we would give the greatest

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[2] Ibid., p. 21.

[3] B. Balke, "The Effect of Physical Exercise on the Metabolic Potential, a Crucial Measure of Physical Fitness," _Exercise and Fitness, A Collection of Papers Presented at the Colloquium on Exercise and Fitness_, the University of Illinois College of Physical Education and the Athletic Institute, 1960, p. 73.

chances of survival to individuals possessing the greatest physical reserves. It can be postulated, therefore, that the size of physical reserves and the general adaptability to great physical demands must be a determining factor of physical fitness. In other words, physical fitness depends on the individual's biodynamic potential which is composed of his functional and of his metabolic potential. The best test of physical fitness would be man's ability to survive under extra-ordinary biological demands.[4]

The President's Council of Physical Fitness stated, "In a technical sense, physical fitness can be viewed as a measure of the body's strength, stamina and flexibility. In more meaningful personal terms, it is a reflection of your ability to work with vigor and pleasure, without undue fatigue, with energy left for enjoying hobbies and recreational activities, and for meeting unforseen emergencies. It relates to how you look and feel and, because the body is not a compartment separated from the mind, it relates to how you feel mentally as well as physically."[5]

As viewed by Dr. Kenneth Cooper, the runner or cyclist represents the best kind of fitness, overall fitness. We call it endurance fitness, or working capacity, the ability to do prolonged work without undue fatigue. It assumes the absence of any ailment, and it has little to do with pure muscular strength or agility. It has very much to do with the body's overall health, the health of the heart, the lungs, the entire cardiovascular system and the other organs, as well

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[4]Ibid., p. 74.

[5]__________, Adult Physical Fitness, President's Council on Physical Fitness, 1963, p. 5.

as the muscles.[6]

According to the American Medical Association's Committee on Exercise and Physical Fitness, physical fitness is the general capacity to adapt and respond favorably to physical effort.[7]

Nagle, Balke, and Naughton tell us physical fitness is the potential capacity for making adequate functional adjustments to increased metabolic demands.[8]

Brouha, Fradd and Savage divide physical efficiency or fitness into three categories: (1) medical fitness, (2) specific fitness, and (3) functional or dynamic fitness. Their third category, functional or dynamic fitness, is defined as the ability to sustain strenuous exercise and to recover from it rapidly.[9]

This study was confined to functional or dynamic efficiency which is at times referred to as endurance. In conjunction with the preceding definitions it is noted that endurance is of two types: (1) muscular, and (2) organic or cardio-respiratory. The cardio-respiratory aspect is felt to be of greatest importance in this study, as this type of endurance refers to the ability of the organs of the body to provide the necessary fuel for the muscles to continue long

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[6]Kenneth H. Cooper, Aerobics, New York: M. Evans and Co., 1968, p. 8.

[7]Allan J. Ryan, "The Components of Physical Fitness," Fitness for Living, Emmaus, Penn: Rodale Press, Inc., May, June, 1969, 3:3:46.

[8]F. J. Nagle, B. Balke and J. P. Naughton, "Gradational Step Tests for Assessing Work Capacity," Journal of Applied Physiology, (July, 1965), p. 745.

[9]L. Brouha, N. W. Fradd and B. M. Savage, "Studies in Physical Efficiency of College Students," Research Quarterly, XV (Oct., 1944), p. 211.

and extended periods of contraction. Brassfield believes that, in the final analysis, physical fitness appears to be limited by the cardio-respiratory system.[10]

Oberteuffer has pointed out that the United States is now in the fourth discernible period in the twentieth century of intensified interest in the role of physical education in physical fitness.[11] These periods are: (1) Theodore Roosevelt's advocacy of the vigorous life to make this nation strong; (2) draft statistics following World War I, which shocked legislatures throughout the land into passing state laws requiring physical education in the schools; (3) the all-out effort during World War II to prepare the population to wage total war, initiated by Franklin D. Roosevelt; and (4) since 1955, when Dwight D. Eisenhower and, later, John F. Kennedy, Followed by Lyndon B. Johnson, took executive actions to establish and continue a President's Council on Physical Fitness. President Kennedy stated, "we do know what the Greeks knew: that intelligence and skill can only function at the peak of their capacity when the body is healthy and strong; that hardy spirits and tough minds usually inhabit sound bodies."[12]

The latest period of intensified interest in physical fitness was triggered by the results of a minimal test of muscular fitness with which Dr. Hans Kraus and associates compared United States

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[10]Charles R. Brassfield, "Some Physiological Aspects of Physical Fitness," Research Quarterly, XIV (March, 1943), p. 111.

[11]Delbert Oberteuffer, "The Role of Physical Education in Health and Fitness," American Journal of Public Health, 52, No. 7 (July, 1962), p. 1155.

[12]John F. Kennedy, "The Soft American," Sports Illustrated, 13, No. 26 (December 26, 1960), p. 15.

children with children from Austria, Italy, and Switzerland, much to the discredit of American youth. Similar surveys with the Kraus test followed with comparable results.[13] The President's Council on Physical Fitness took dynamic action to alert the public to the national danger resulting from this situation; a tremendous push for physical fitness emphasis in the schools and colleges of the country ensued. The need for this emphasis has been demonstrated; the essential precaution that must be taken by physical educators is to achieve balance among objectives and not permit their physical education programs to become restricted to physical fitness only.

Physiological tests, especially of cardiovascular-respiratory nature, have been experimented with in this country since 1884, when Angelo Mosso, an Italian physiologist, invented the ergograph. Mosso's original premise was that the ability of a muscle to perform was dependent upon the efficiency with which fuel is supplied to the muscles and waste materials are carried away. Since then, many other experimenters have worked in this field, claiming that tests based upon the cardiovascular function measured qualities variously described by such terms as functional health, physiological efficiency, organic condition, and circulatory endurance.[14]

During vigorous exercise, the blood circulation quickens, blood

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[13] H. Harrison Clarke, "Contributions of Physical Education to Physical Fitness," American Academy of Physical Education, Professional Contributions, No. 8 (1963), pp. 1-14.

[14] H. Harrison Clarke, Application of Measurement to Health and Physical Education, Englewood Cliffs, N. U.: Prentice-Hall, Inc., (1967), p. 8.

and lymph stream through the muscles supplying the cells with oxygen and nutrition and removing waste products. The heart's activity is accelerated, exercising and strengthening its own fibers, as well as pumping the blood and stimulating its circulation. Muscles are enlarged and their endurance is increased through strenuous exercise. The gain in the endurance of a muscle, however, is out of all proportion to its size. Therefore, the quality of contractions must be improved through such factors as: fuel being made available in greater amount; becoming more abundant owing to improved circulation of blood through the muscle; better coordination of the individual muscle fibers and more complete use of all muscle fibers being realized. Thus, the cardiovascular system performs a vital service in the performance of sustained muscular activity.[15]

Physical educators have long been concerned with the measurement of cardiovascular, or circulatory endurance. Cardiovascular endurance involves the continued activity of the entire organism, during which major adjustment of the circulatory and respiratory systems are necessary, as in running, swimming, climbing, and the like. This form of endurance is not only dependent upon the strength of the muscles involved in the activity but must rely greatly on the effective functioning of the circulatory system. As a consequence of this relationship, many tests involving responses to exercise of various aspects of the cardiovascular and respiratory systems have been proposed as measures of circulatory endurance.[16]

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[15]Ibid., p. 179.

[16]Ibid., p. 180.

Cureton notes that, cardio-respiratory tests should be used in accordance with the evidence of factor analysis, i.e., to reflect a given fitness or function at rest; in postural change; in moderate work; in fast, hard work, comparable to virtually all-out athletic effort; and to evaluate recuperation after work.[17]

Johnson, Brouha and Darling feel that whatever exercise is used to assess work capacity must put the cardiovascular system under considerable stress, and that it must be of such intensity that about one-third of all subjects stop from exhaustion within five minutes.[18] Brouha, Graybiel and Heath add their support to this contention as they believe a satisfactory estimate of a man's fitness can be obtained by exposing him to a standard exercise that no one can perform in a "steady state" for more than a few minutes.[19]

Adversely, Shephard feels that the choice of a load which is exhausting for a proportion of the subjects may increase discrimination in terms of psychological factors such as motivation.[20] Because of this he believes that in studies of the fitness of the ordinary citizen the purer cardiac responses to submaximal exercise seems a more suitable

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[17] T. K. Cureton, "Comparison of Various Factor Analyses of Cardio-Vascular-Respiratory Test Variables," Research Quarterly, XXXVII (Oct., 1966), p. 322.

[18] R. R. Johnson, L. Brouha and R. C. Darling, "A Test of Physical Fitness for Strenuous Exertion," Revue Canadienne De Biologie, I (June, 1942), p. 494.

[19] L. Brouha, A. Graybiel and C. W. Heath, "The Step Test," Revue Canadienne De Biologie, II (Feb., 1943), p. 86.

[20] R. J. Shephard, "On the Timing of Post-Exercise Pulse Readings," Journal of Sports Medicine and Physical Fitness, VI (March, 1966), p. 26.

basis for evaluation.[21]

De Vries and Klafs agree with Shephard and note the following advantages of a submaximal working capacity test: (1) motivation could be eliminated as a factor, and (2) older subjects, unfit or unconditioned subjects could be tested without the discomfort and possible hazards attendant upon a maximum work load. They concluded that for active college men, maximal oxygen intake and, consequently, physical working capacity can be predicted with a reasonable error of prediction from a submaximal test.[22]

The methods known for assessing or evaluating physical efficiency may be classified as field or laboratory tests. Nagle, Balke and Naughton, believe that physical fitness is most accurately assessed in the laboratory by making physiological measurements on an individual while he is either walking on a motor-driven treadmill or riding a stationary bicycle ergometer.[23]

There have been several step tests administered to people of all ages and sexes, but never one which has proven to be practical for mass testing in our schools. It was the intent of this study, to see if there could be found a sub-maximal cut-off point in a progressive cadence step-test which would predict the cardio-respiratory efficiency of an individual. If this could be done, it was felt it would be possible to move into the schools and conduct mass testing of cardio-

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[21]Ibid.

[22]H. A. De Vries and C. E. Klafs, "Prediction of Maximum Oxygen Intake from Submaximal Tests," Journal of Sports Medicine and Physical Fitness, V (Dec., 1965), p. 207.

[23]Nagle, Balke and Naughton, p. 745.

respiratory efficiency without all of the elaborate equipment that is necessary in the majority of the other step tests. As mentioned above, there have been several step tests devised to measure endurance levels; however, only six will be discussed at this point. The ones chosen are: the Harvard Step Test, the Astrand-Rhyming Step Test, the Tuttle Pulse-Ratio Test, the Waxman Step Test, the Balke Step Test, and the O.S.U. Progressive Step Test.

The Harvard Step Test was developed for college age men. A stepping rate of 30 steps per minute on a 20 inch high bench for a five minute period was the design of the test. The test is terminated at the end of five minutes, or sooner if the subject reaches exhaustion. Whichever the case, the time in seconds is recorded. Upon completion of the exercise, the subject sits on a chair and recovery pulse is counted 1 to 1½, 2 to 2½, and 3 to 3½ minutes, with a Physical Efficiency Index computed from these results. In general, the correlation between scores on this test and measures of endurance have been low.[24]

In 1954, Astrand and Rhyming constructed a nomogram for predicting the maximal oxygen consumption (aerobic capacity) of healthy individuals between the ages of 18 and 30, simply by measuring the heart rate and oxygen consumption during a submaximal rate of work. Their bench height was 33 cm. for females and 40 cm. for males, and the stepping rate was 22.5 per minute for a five to six minute period. They noted best results were obtained when the work level is of such severity that the heart rate during the steady state is between 125 and 170

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[24] C. Frank Consolazio, Robert E. Johnson, and Louis J. Pecora, <u>Physiological Measurements of Metabolic Functions in Man</u>, N.Y., McGraw-Hill, 1963, pp. 181-283.

beats per minute.[25]

The Tuttle Pulse-Ratio Test is performed on a 13 inch high bench. The first phase of the test is stepped at 20 steps per minute for boys and 15 steps per minute for girls for a period of one minute. The subject's pulse is recorded for two minutes as soon as both feet touch the floor at the end of the one minute of exercise. This pulse is divided by the resting pulse and is the first Pulse-Ratio. When the pulse has returned to normal the subject again steps for one minute, but at a rate of 40 steps per minute for boys and 35 for girls. The subject's recovery pulse is again recorded for two minutes as soon as both feet touch the floor, and the Pulse-Ratio is again computed. The Pulse-Ratio has been shown to agree well with the findings of physicians concerning the status of the cardiovascular system; however, little evidence is available to support the use of the test as a measure of general physical condition.[26]

Waxman in conjunction with Cureton developed a Progressive Pulse-Ratio Test to assess physical fitness development of members of the Cleveland, Ohio, YMCA. The test was administered by stepping on a 17 inch high bench at the rates of 12, 18, 24, 30 and 36 steps per minute. At the end of each minute of exercise the subject's pulse is counted for two minutes. The Progressive Pulse-Ratio has shown a .71 correlation

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[25] Ibid., p. 390.

[26] Peter Karpovich, Physiology of Muscular Activity, Phil., W. B. Saunders Co., 1965, p. 239.

to maximum oxygen intake.[27]

Balke experimented with a portable stepping devise using both healthy and cardiac male subjects. He started these subjects stepping at floor level, and raised the step interval two centimeters per minute. The results of this test indicated a high correlation with those of the more elaborate treadmill test also devised by Balke.[28]

Bayless utilized the motorized stepping device which Balke had initiated, in conducting his study at O.S.U. The starting height of the O.S.U. Test was four inches and the height of the step was elevated one inch every minute. It was concluded from this study that this test was a valid measure of metabolic functioning for elementary school boys.[29]

The Progressive Cadence Step Test of this study will differ from the tests mentioned above in that it may be administered with a minimum of cost and expertise. It also differs in that all work will be done submaximally and the height of the step interval (14") will remain constant. It is closely aligned to both the Tuttle Pulse-Ratio and Waxman Progressive Pulse-Ratio in that cadences are progressive, but is more discriminating because of the greater breakdown in the cadences to 12, 15, 18, 21, 24, 27, 30, 33, 36 and 39 steps per minute. Each of

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[27] W. W. Waxman, "Physical Fitness Development for Adults in the YMCA," Exercise and Fitness, A Collection of Papers Presented at the Colloquim on Exercise and Fitness, The University of Illinois College of Physical Education and the Athletic Institute, 1960, pp. 185-186.

[28] Nagle, Balke, and Naughton, p. 745.

[29] J. G. Bayless, "A Metabolic Functional Capacity Test for Upper Elementary-Age Boys," (Unpublished D.Ed. Disseration, Oklahoma State University, May, 1966), p. 45.

these cadences will have a 30 second seated recovery, with heart rates recorded from the fifth to twentieth second of recovery for ease of finding and recording these heart rates.

Dr. A. B. Harrison, professor of physical education and exercise physiology researcher, has been very interested in this type of testing in the research laboratory at Oklahoma State University and through his efforts there has been much work already completed in the step test field. Dr. Harrison contended that through use of the Progressive Cadence Step Test, it would be possible to monitor only heart rates and at a certain submaximal point, terminate the test and predict maximum oxygen intake of a subject. For this to be feasible, it was necessary to develop a procedure and validate the Progressive Cadence Step Test through use of an already established maximum oxygen intake test. The Balke Treadmill Test was chosen as the criterion, and air samples were collected the last three minutes of the test, when a subject's heart rate approached 170 beats per minute, to determine maximal oxygen intake of each subject. It was because of Dr. Harrison's hypothesis that this study was undertaken.

Statement of Problem: To establish and validate a procedure for a progressive cadence step test which can be used to predict maximum oxygen intake of college age males. This test utilized an increased stepping rate to increase the work load. Validity was determined by correlating pulse rates following each work load and maximum oxygen intake as measured by the Balke Treadmill Test.

Significance of the Study

Physical educators are conscious at all times of the physical fitness level of their students. There have been many step tests and other different types of apparatus designed to test for physical fitness, but none of such magnitude that an instructor could mass test his pupils in his own locker room. This, of course, is what this test attempted to make possible. As this was a submaximal test and pulse rates following each minute of work are being recorded, instructors will have a chance to screen out individuals that may have deficient heart action. This is a safeguard not found in maximal tests. The only factors that would limit the mass testing, through the use of the Progressive Cadence Step Test, are the number of assistants, stethoscopes, benches, and a metronome. These devices are well within the budget of any school, and would be a small price to pay indeed, to be able to predict the level of physical fitness of their students.

The sub-problems of this study were:

1. establishment of norms for college age males

2. determining the mean heart rate that a subject attains before he reaches his maximum oxygen intake

3. determining the actual maximum oxygen intake of each subject

Limitations

1. Environmental factors such as eating and sleeping were not regulated.

2. Emotional and nervous states, such as worry, fear, and anger, could not be controlled.

3. The number (40) of subjects in the test was relatively small for establishing norms.

CHAPTER II

REVIEW OF RELATED LITERATURE

Great care must be exercised in the administration of circulatory-respiratory measures in order to obtain reliable results. It is generally agreed by experimenters that many factors influence the elements included in the cardiovascular-type test. Larson, in his review of the cardiovascular-respiratory function pointed out that both heart rate and blood pressure are affected by the following: exercise, age, sex, diurnal changes, season and climate, altitude, in body posture, digestion, air and water movements, loss of sleep, respiration, metabolism, and emotional and nervous conditions.[1]

There have been many physical fitness tests developed in recent years to assess maximum oxygen intake. The most familiar of these are: (1) Balke's Treadmill Test, (2) Astrand's Bicycle Ergometer Test, (3) Balke and Cooper's fifteen and twelve minute running tests, respectively, and (4) Step Tests (Tuttle Pulse-Ratio and Harvard Step Test).

Dr. Balke's Treadmill Test was used in validating the Progressive Cadence Step Test. In this test, the subject is tested to determine his aerobic capacity for maximum functional demands. The

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[1]Leonard A. Larson, "Cardiovascular-Respiratory Function," Supplement to the Research Quarterly, 12, No. 2 (May, 1941), p. 456.

stress factor is walking on the motor-driven treadmill at a rate of 3.4 miles per hour, with the grade increased by one percent each minute. The test is terminated when the subject's heart rate reaches 180 beats a minute. Balke has found at this point an individual encounters his maximum oxygen intake.[2]

Astrand's Bicycle Ergometer Test consists of riding a stationary bicycle at a set work load for a period of time (until the pulse rate levels or drops).[3] Maximum oxygen intake can then be predicted from the pulse rate. Dr. Kenneth Cooper does not believe the Bicycle Ergometer Test to be practical for use in the United States because of the weakness of our leg muscles.[4]

The 15 minute run of Balke[5] and the 12 minute run of Cooper[6] are both based on fitness evaluation determined by the distance an individual can cover in these set times. These are very appropriate tests as have been shown, but parents are often times opposed to having their children exposed to this type of endurance testing. Another problem is it is very difficult to motivate an individual to give his or her best performance.

The fact has been well demonstrated that the physical condition

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[2] B. Balke, "The Effect of Physical Exercise on the Metabolic Potential," Exercise and Fitness, ed. The Athletic Institute (Illinois, 1960), pp. 73-81.

[3] P. O. Astrand, Ergometry-Test of "Physical Fitness," AB Cykelfabriken Monark, Varberg, Sweden (1964), pp. 15-16.

[4] Cooper, p. 29.

[5] B. Balke, "A Simple Field Test for the Assessment of Physical Fitness," Report to the Federal Aviation Agency, Civil Aeromedical Research Institute, Oklahoma City, Okla., pp. 1-2.

[6] Cooper, pp. 33-34.

of an individual has a definite effect upon both the rate of the heart beat and the time required for the rate to return to normal after the cessation of exercise. It has also been shown that a well-trained individual is less effected by a given amount of exercise than an individual in poor physical condition. Because of this the pulse-ratio tests have been justified, as these tests are based upon the ability of the heart to compensate for exercise. The first of this type of testing was conducted in a hospital in London, England. Following this, several tests of this type began in the United States. The two of particular importance were the Tuttle Pulse-Ratio Test and the Harvard Step Test.[7]

The Tuttle Pulse-Ratio Test has been found to agree well with the findings of physicians concerning the status of the cardiovascular system. Little evidence is available, however, to support the use of the test as a measure of general physical condition. In the test the amount of exercise is standardized by requiring the subject to step on and off a 13 inch high stool or bench, for one minute, at a rate of 20 steps for boys and 15 steps for girls. Immediately after the cessation of exercise, the subject is seated and his pulse is counted for two minutes. The total pulse rate for two minutes after exercise is divided by the normal pulse for one minute. After the pulse has returned to normal, a second pulse-ratio is obtained by stepping again for one minute, at a rate of 40 steps for boys and 35 for girls.[8]

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[7]Clarke, p. 187.

[8]W. W. Tuttle, "The Use of the Pulse-Ratio Test for Rating Physical Efficiency," Research Quarterly, 2, No. 2 (May, 1931), p. 5.

Tuttle and Dickinson found that the ratio from a single stepping performance of 30 to 40 steps of exercise is nearly as satisfactory as the ratio obtained from the two stepping exercises.[9]

The Harvard Step Test was originally constructed for college men. The subject steps 30 times a minute on a 20 inch high bench, and the exercise continues for five minutes unless the subject is forced to stop sooner due to exhaustion. In either case the duration of the exercise in seconds is recorded. Immediately after completing the exercise, the subject sits on a chair and the recovery pulse is counted 1 to 1½, 2 to 2½, and 3 to 3½ minutes. Then a Physical Efficiency Index is computed. In general, correlations between scores on the Harvard Step Test and various measures of physical strength and endurance have been low; this may be due to the fact that, while the step performance is vigorous, the score is based entirely on pulse rate evaluation.[10]

Astrand has contended that it is theoretically incorrect to evaluate the efficiency of the circulatory system by the net pulse. To support this contention, he pointed out that ten pulse beats at rest with a stroke volume of 60 milliliters is not the equivalent of ten pulse beats at work with a stroke volume of 150 milliliters. For similar reasons, the recovery pulse rate should not be mixed up with the work pulse rate as is done in the step tests.[11]

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[9] W. W. Tuttle and R. E. Dickinson, "A Simplification of the Pulse-Ratio Technique for Rating Physical Efficiency and Present Condition," Research Quarterly, X (May, 1938), p. 73.

[10] Clarke, p. 189.

[11] P. O. Astrand, "Human Fitness with Special Reference to Sex and Age," Physiological Reviews, 36, No. 3 (July, 1956), p. 325.

Because of the above statements and other factors, Astrand and Ryhming proposed a step test utilizing submaximal efforts in the measurement of aerobic capacity (maximum oxygen intake). The measurement of maximum oxygen intake is not necessary for this test, as this capacity may be obtained from a nomogram.[12]

Two height progression step tests in which the cadences remained constant were conducted by Bayless and Balke. Bayless conducted a step test at Oklahoma State University in 1966, which consisted of stepping on a motorized stepping device with a starting height of four inches and increasing the height of the step interval one inch every minute. Bayless concluded from this study, as determined from the termination heart rate of 180 beats per minute, that this test was a valid measure of metabolic functioning for elementary school boys.[13] Balke devised the motorized stepping device mentioned in the O.S.U. study, but his stepping height began at floor level and increased two cm. per minute. It was concluded from this study that it also was a valid measure of metabolic functioning.[14]

Shephard has conducted a progressive step test but in this test he utilized either a double nine inch step or a single 18 inch high step. His stepping rates progressed from ten steps per minute for two minutes to 15, 20, and 25 steps per minute, each for three minutes (11 minutes total). Shephard concluded from his study that the rate

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[12] P. O. Astrand and Irma Ryhming, "A Nomograph for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate During Submaximal Work," Journal of Applied Physiology, 7, No. 2 (September, 1954), p. 218.

[13] Bayless, p. 45.

[14] Nagle, Balke and Naughton, p. 746.

of stepping seemed a more important determinant of efficiency than the height of the step.[15]

Waxman modified the Progressive Pulse Ratio Test, originated by Cureton, to show physical fitness development for adults in the YMCA of Cleveland, Ohio. This test consists of stepping up and down on a 17 inch high bench at the rates of 12 steps per minute with the aid of a metronome. After ten seconds, the time it takes to turn off the metronome and adjust the stethoscope, the heartbeats are taken for two minutes. The subject rests for a while until his pulse stabilizes within eight to twelve beats of his standing normal. 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.[16]

In summary, there have been many questions raised concerning the procedures that have been used in the past to assess the endurance levels of subjects. Many of the earlier studies dealt with the anaerobic phase of exercise, but through Dr. Balke's efforts much of the latest research has been concerned with the aerobic phase of exercise. In Dr. Balke's tests, however, there was a need for elaborate and sophisticated equipment; it is hoped by this researcher that this test proves a valid and reliable test procedure for others to follow to assess the physical fitness level of subjects easily and economically.

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[15] R. J. Shephard, "The Prediction of Maximal Oxygen Consumption Using a New Progressive Step Test," Ergonomics, X (January, 1967), p. 7.

[16] Waxman, pp. 185-186.

CHAPTER III

METHOD AND PROCEDURE

Establishment of Testing Procedure

The first requirement in the establishment of this test was to develop a procedure. The procedure followed was to ask for eight female volunteers (secretaries from the Health, Physical Education, and Recreation Department) and have them participate in the Progressive Cadence Step Test with the same criteria of termination; if the heart rate reached 180 beats per minute or they were unable to keep cadence with the metronome the test was stopped. In another period of testing, the subjects were asked to come to the Exercise Physiology Laboratory to participate in the Astrand Bicycle Ergometer Test for the calculation of their maximum oxygen intake. From these preliminary test periods it was concluded that the cadence of 27 steps per minute would give the best prediction of maximum oxygen intake, of female subjects in this age range (18-22). The bench height in the preliminary test was set at 14 inches and this height was also chosen for the final research, for the reason that it was felt most schools would have this height bench in their locker rooms. In the preliminary test the subjects were asked to exercise at each cadence (12, 18, 24, 30 and 36) for a one minute period with a two minute rest period between each.

Through later periods of testing to develop a final procedure, it was decided to use a one and a half minute exercise period as the heart rate was shown to plateau at each work level, and to record recovery heart rates for a 15 second period immediately following the minute and half of exercise, as McArdle et al.[1] have shown that the longer you wait to take recovery heart rates, the less accurate your readings will be.

Selection of Subjects

After the procedure was determined, the researcher randomly selected 40 subjects from Willham North, a men's residence hall on the Oklahoma State University campus which had a population of 705 men. The men were randomly selected by including all names from an alphabetical roster and drawing 60 names from the "hat." It was decided to send an invitation to the first 40 men selected and the ones that could not participate would be replaced by the next man in line. As an example, if ten men out of the chosen 40 could not participate, the next ten names would be sent invitations. This method was followed until 40 affirmative notes were placed in the researcher's mail box. At the time of the study the researcher held the position of Head Resident of Willham North. A specimen copy of the invitation is shown in the appendix (p. 55).

Following the invitations, each of the 40 subjects was sent a questionnaire to complete and return, and a date to meet in the exercise Physiology Laboratory was determined. All 40 subjects met with the researcher in the Laboratory to discuss the testing procedure and

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[1]William D. McArdle, Linda Zwiren, and John R. Magel, "Validity of Postexercise Heart Rate as a Means of Estimating Heart Rate During Work of Varying Intensities," Research Quarterly, XXXX (Oct., 1969), pp. 523-527.

become familiar with the equipment. It was felt that if the subjects met collectively, they could see exactly what they would be doing and psychological variables would be at a minimum. An example of the questionnaire is shown in the appendix (p. 56).

Administration of the Test

Upon arriving at the Laboratory the subjects were asked to remove their shirts, sit down and rest quietly for five minutes while the electrodes for the E & M Telemetry were attached to their sternum and rib cage. The transmitter was taped onto the side just behind the rib electrode and an ace bandage was applied to keep skin movement to a minimum. Following the attachment of the electrodes, the E & M Telemetry Receiver was adjusted for the best possible Physiograph reading. The Physiograph was set to have a .5 centimeter per second paper speed and the second counter marking each second. Resting heart rates were recorded on the Physiograph through Telemetry as well as being taken through a stethoscope to compare results.

Following the resting recordings the testing of exercise began. The subject was introduced once again to the stepping procedure, and was told to step up and down to the beat of the metronome as recorded on tape. The tape recording started with: ready 12, begin <u>NOW</u>, the cadences up, up, down, down were given audibly the first 30 seconds of each exercise period, with the next minute of exercise done only to the beat of the taped metronome sound. Upon completion of the minute and half of exercise, the command was taped for the subject to: ready <u>STOP</u>, please sit down; the researcher was given five seconds to put the stethoscope in place, the command was given to begin count <u>NOW</u>;

a 15 second recovery pulse was recorded until the command to stop count now was given, and in the next ten seconds the subject readied himself for the next cadence period. The same procedure was followed for each of the succeeding cadences until the subject's heart rate reached 180 beats per minute or the subject was unable to keep time to the metronome beat. For this test to prove feasible it must be possible for the researcher to obtain the heart rates during the 30 second recovery with a stethoscope. Because of this, the stethoscope readings of each cadence recovery period were recorded to compare to the Physiograph recordings of each cadence period.

As mentioned previously, the step test consisted of stepping on a 14 inch high bench for a period of one and a half minutes as this was shown in preliminary testing to be the point where heart rates plateau at each work load. The step test used was a progressive cadence test with the different cadences of 12, 15, 18, 21, 27, 30, 33, 36 and 39 steps per minute. Each step constituted an up-up-down-down movement, i.e., the twelve step cadence was in reality 48 steps per minute, the 15 step cadence, 60 steps per minute, and so on throughout the test. The test was used as a submaximal test, and for the reason that different authorities agree that a pulse rate of over 180 begins anaerobic work (work without oxygen) this was chosen as the point to cease stepping if any of the subjects pulse rates reached this point. Nagle and Bedecki used the Balke test and compared the results to those obtained from an all-out test. These men found that the correlation between the time needed to reach the 180 pulse rate and the time of the all-out run was .85 and that the difference in oxygen consumption was seven percent.[2] A 14 inch stepping bench was chosen as it was felt schools would have this piece of equipment available. A stethoscope and metronome are the only other necessary instruments.

At the completion of the step test, five of the 40 subjects were randomly selected for retest to check reliability, and then, the second phase of testing began.

The second phase of testing consisted of the Balke Treadmill Test which was conducted five days later and is described on pages 16 and 17. When the subjects reported to the Physiology of Exercise Laboratory they again were asked to take off their shirts and assume a relaxed sitting position. The subject was fitted once again with the E & M Telemetry electrodes on their sternum and rib cage with the transmitter taped into place and held rigid with an ace bandage. A sitting resting heart rate was recorded on the Physiograph and the Balke Test was then explained once again to the subject. They were instructed to begin the test when the time clock was straight up twelve. Following this, the subject went through the Balke Treadmill Test using the Balke Treadmill Test procedure, with the exception that air samples were collected the last three minutes of exercise in a Collins 100 Liter Tissot Tank for the purpose of calculating actual oxygen consumption. Because of this, it was necessary to have a minimum of two people present to administer the Treadmill Test. One individual operated the Physiograph and Treadmill, while the other individual operated the Tissot Tank and took expired air samples for three minutes

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[2] F. J. Nagle and T. G. Bedecki, "Use of the 180 Heart Rate Response as a Measure of Cardio-Respiratory Capacity," <u>Research Quarterly</u>, XXXIV (1963), p. 361.

when a subject's heart rate approached 170 beats per minute, which included removing and adding rubber sample bags for each sample.

As the subject had been introduced to walking on the Treadmill at an earlier date, it was not felt necessary to have him practice walk at this time. It was felt necessary, however, to have the subject become somewhat accustomed to breathing into the breathing valve for the collection of air samples. Therefore, the subject was given the opportunity to breath into the breathing valve with the noseclip in place the second and third minutes of exercise. After this, the subject simply walked until the heart rate approached 170 beats per minute and the noseclip and breathing valve were again put in place for collection of the last three minutes of exercise air samples. It was assumed that in three minutes after the heart rate approximated 170 beats per minute that each subject would reach his maximum oxygen intake.

Analysis of Expired Air

Air expired during the last 30 seconds of each of the last three minutes of the Balke Treadmill Test was collected in the Collins 100 Liter Tissot Tank. Volume of this expired air was calculated from reading the recording kymograph. Samples were taken from the Tissot Tank in rubber bags for analysis. These samples were analyzed by the Godart Pulmo-Analyzer method[3] for oxygen and carbon dioxide percentages to determine individual maximum oxygen intakes. To assure that the Pulmo-Analyzer was validly balanced, it was turned on and allowed to

[3]Godart Pulmo-Analyzer, Instrumentation Associates, Inc., 17 West 60th Street, New York, N.Y. 10023, pp. 7-9.

warm-up one hour before analysis was to be carried out. This was necessary as the Pulmo-Analyzer uses atmospheric air to stabilize its thermoconductivity platinum wires. After the power and pump switches were turned on, the absorber tubes were filled with soda lime and calcium chloride, and the Pulmo-Analyzer was ready for oxygen and carbon dioxide deflection readings. The pen deflection for carbon dioxide is divided by 6.63 to give the percentage of carbon dioxide in the sample, and the oxygen deflections are multiplied by .086 and this figure is then multiplied by the quotient of one minus the percentage of carbon dioxide over one minus the percentage of oxygen in atmospheric air (this is always a constant of .7907). The product arrived at after these two multiplications is subtracted from 20.93 (percentage of oxygen in atmospheric air) to give the actual oxygen present in the sample. These two figures, oxygen and carbon dioxide percentages, are then used to determine respiratory quotient and true oxygen (read from the Harvard Line Chart) to calculate the oxygen intake of each of the last three minutes of exercise, to determine at which point the subject reached his maximum oxygen intake.

At least two readings of each of the three rubber sample bags were taken to assure reliability. As experience was gained in the use of the Pulmo-Analyzer, it was found not to be necessary to check all samples twice unless there was some hint of inconsistency.

Oxygen intake, was determined according to the procedure described by Consolazio.[4] The calculation sheet is shown in the appendix (p. 57).

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[4]Consolazio, pp. 8-9.

Grouping and Analysis of Data

Upon completion of all tests and metabolic calculations, the data were put into table form for ease of observing comparisons on the two tests. Graphs and charts were constructed to show the data obtained including heart rates, oxygen and carbon dioxide percentages, and respiratory quotients.

In order 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.

A suggested test procedure for others to follow was outlined with tentative norms based on the heart rates following the cadence of 30 steps per minute as the criterion. The data as shown by tables and graphs in the summary were analyzed for supportive evidence for validity of cut-off points.

CHAPTER IV

RESULTS

This study has attempted to establish a test which could be used by physical educators in the field to assess the physical fitness status of their students easily and economically.

The data in Table I illustrate the closeness of heart rates as monitored through a stethoscope and on the Physiograph during the Progressive Cadence Step Test. In a 15 second counting period, it may be seen that at the most, the heart rates were never more than one count apart. This is a strong indication that a stethoscope is all that is necessary for field testing, as far as monitoring heart rates.

TABLE I

MEAN HEART RATES AT EACH WORK LEVEL OF PROGRESSIVE CADENCE STEP TEST

Cadence	Physiograph	Stethoscope
12	25.33	25.45
15	27.68	27.70
18	29.48	29.68
21	32.95	32.90
24	35.70	35.65
27	38.68	38.78
30	41.83	41.90
33	44.72	44.67
36	44.89	44.74
39	46.00	46.17

One of the sub-problems of this study was to find how long the subjects could participate in the Progressive Cadence Step Test before reaching their crest-load. The data in Figure 1 show that the largest number of subjects (15) reached crest-load at 33 steps per minute with the next higher numbers at 30 (12) and 36 (9) steps per minute, respectively. Crest-load was determined from the heart rate of 180 beats/min.

In a preliminary study to gain information relative to the Progressive Cadence Step Test, the researcher conducted a study in the fall of 1968, with secretaries (age range, 18-25) from the Department of Health, Physical Education and Recreation. It was concluded from this study that the heart rates following the cadence of 27 steps per minute was the best indicator of physical fitness status of females in this age range.

To determine if the crest-load, or some sub-maximal heart rate, but actually the best predictor of maximum oxygen intake, it was necessary to correlate the heart rates after each cadence with maximum oxygen intake. The procedure followed in correlating these results was three fold. First, the heart rates following each cadence up to and including crest-load was correlated with maximum oxygen intake, omitting all scores above crest-load. Second, all scores, even those above crest-load that had been recorded for the next cadence were included in the correlation with maximum oxygen intake. Third, the Cadence for crest-loads were correlated with maximum oxygen intakes.

After correlating the heart rates of each cadence with the actual maximum oxygen intakes, it was found that even though the largest number of subjects had reached crest-load at 33 steps per minute, this was not the highest correlation found (-.692 when omitting all scores

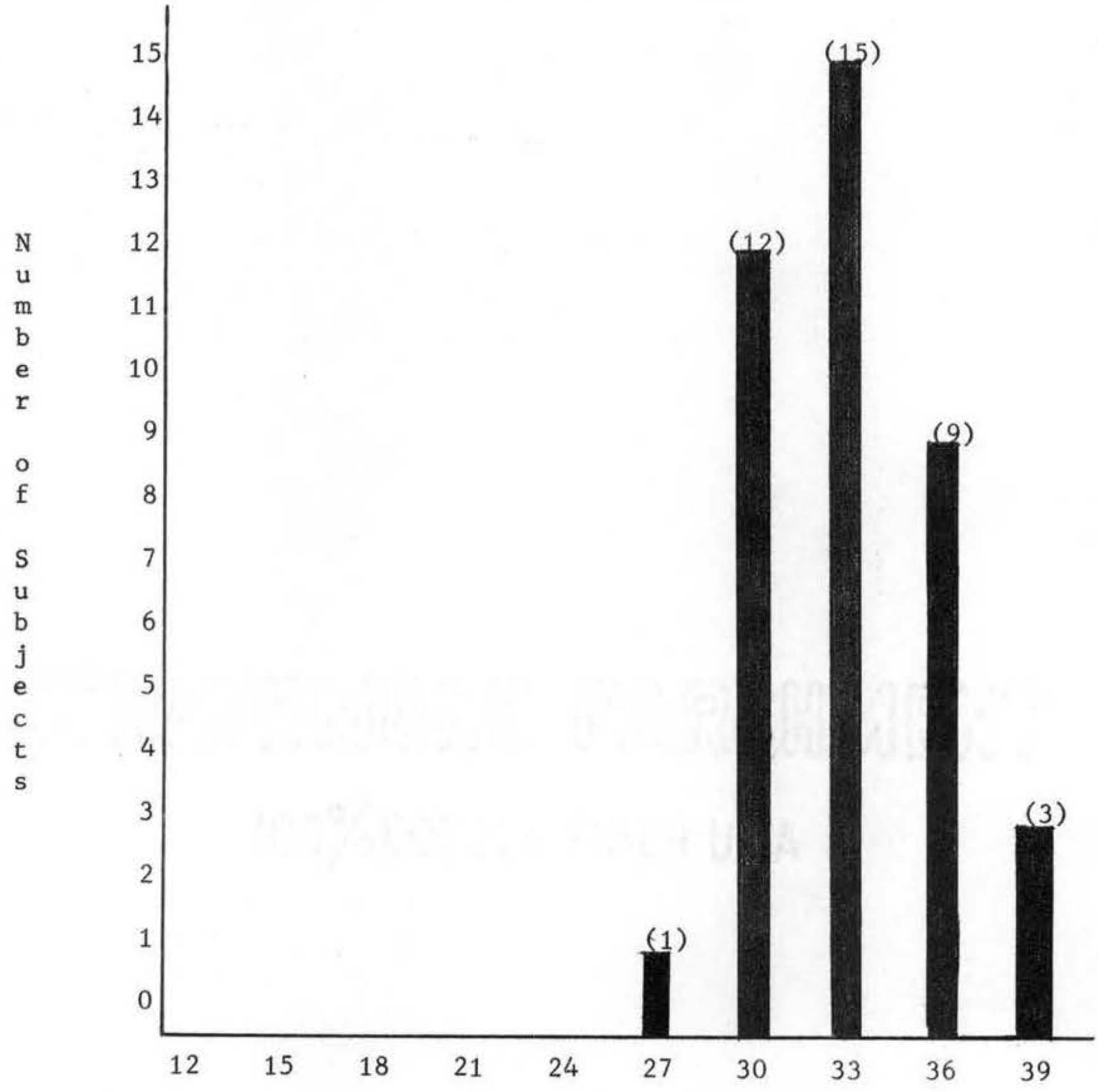

Figure 1. Total Number of Subjects' Crest-Loads for Each Progressive Cadence

above crest-load and -.726 when including all scores above crest-load). The largest correlation was found when comparing the results of 30 steps per minute with actual maximum oxygen intake. This correlation was -.757 when including all scores above crest-load and -.751 when omitting scores above crest-load.

Negative correlations were found when correlating heart rates against maximum oxygen intake for the reason that these two variables are inversely related. This means that the quicker a subject reaches crest-load (heart rate, 180), the smaller amount of maximum oxygen intake he will have. Inversely, the subjects who can continue exercise for longer periods before reaching crest-load (heart rate, 180) will have larger maximum oxygen intakes. If it were the purpose to correlate one subject's heart rate with his maximum oxygen intake, a positive correlation would result; however, in a group, the lower heart rates yield higher maximum oxygen intakes, while the larger heart rates yield lower maximum oxygen intakes.

The third correlation of interest in this study was between the cadences in which crest-load was reached and maximum oxygen intake. This correlation was +.715. It was shown from this that the heart rates following the cadence of 30 steps per minute (-.757) was the best predictor of the endurance level of subjects in this study.

Figures 2 and 3 illustrate the various correlations found at each cadence.

As mentioned previously, the heart rate of 180 beats per minute was used as the cut-off for crest-load in both the Progressive Cadence Step Test and the Balke Treadmill Test. Upon calculating actual maximum oxygen intake when the heart rate surpassed 170 beats per minute,

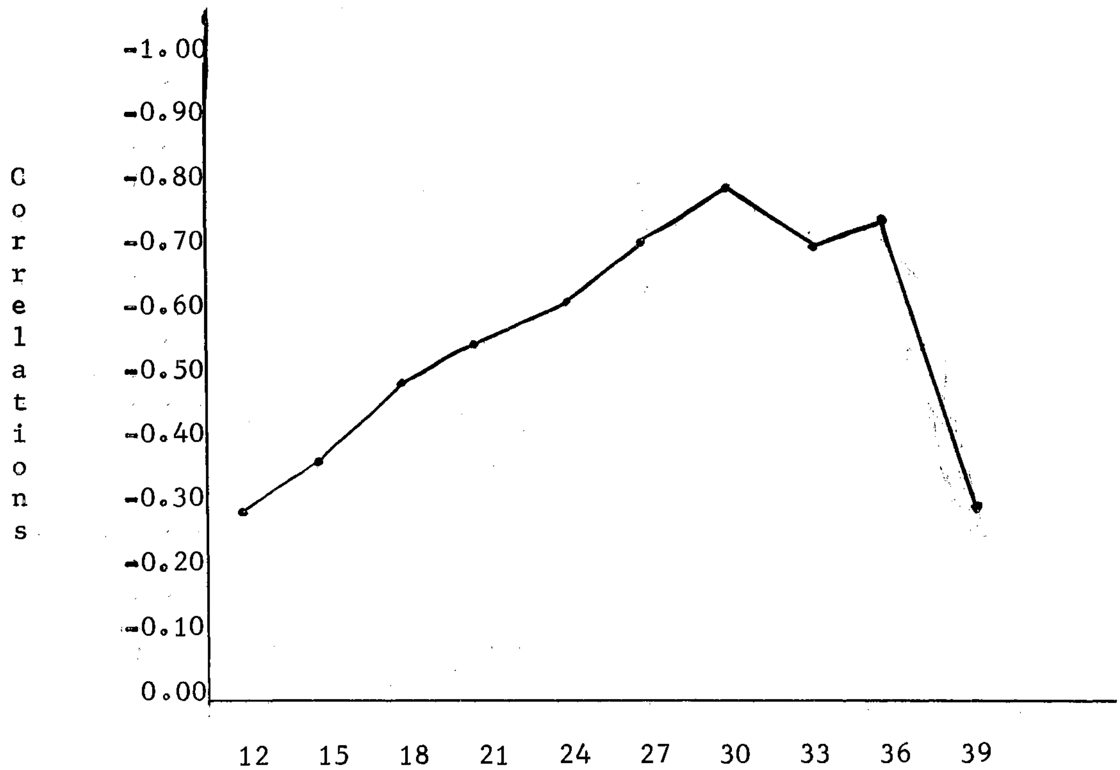

Figure 2. Correlations of Heart Rates with Scores Above Crest-Load Omitted

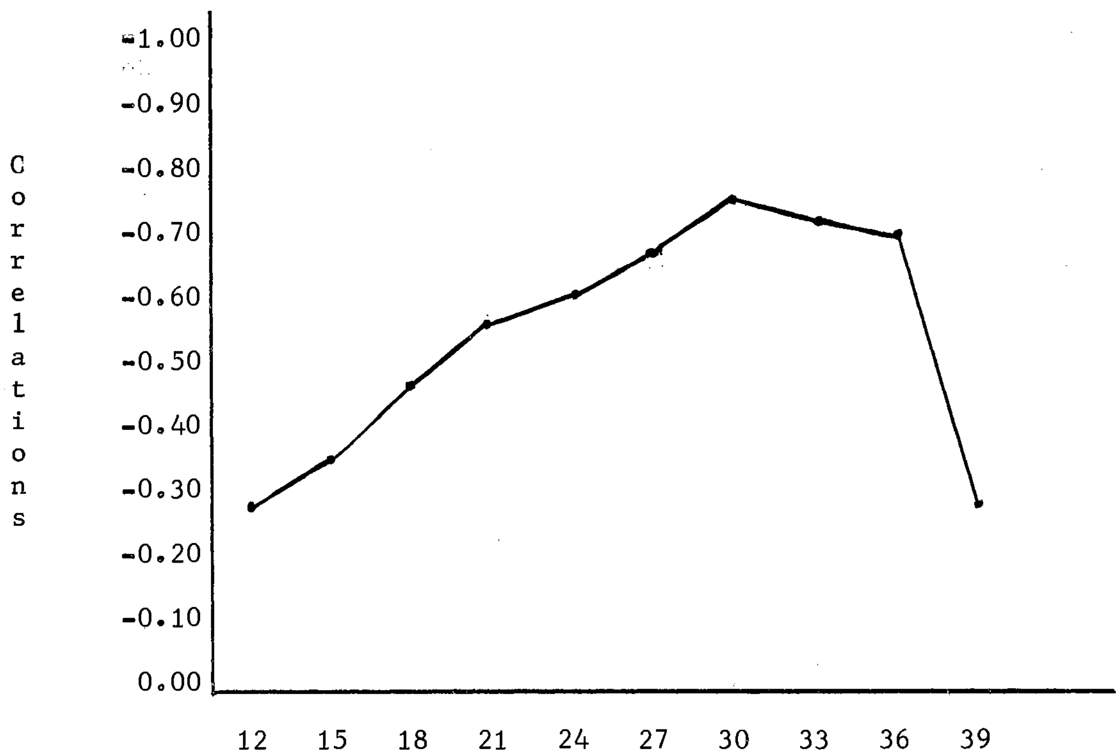

Figure 3. Correlations of Heart Rates with Scores Above Crest-Load Included

in the final three minutes of the Treadmill test, it was found that the subjects' mean heart rate for their actual maximum oxygen intake was 184.7 beats per minute. This figure is somewhat higher than Balke's, but well within an acceptable range, as the heart rates were recovery rates, not work rates.[1]

As a sub-problem of this study, a correlation was computed between actual measured maximum oxygen intake and predicted maximum oxygen intake. It was shown that the actual maximum oxygen intake, as measured by the final three minutes of exercise, had a +.898 correlation with Balke's predicted maximum oxygen intake as determined from the percent of grade a subject could walk on his Treadmill Test. This correlation is in agreement with other studies which have shown Dr. Balke's Test to have high validity for predicting maximum oxygen intake.

There are several key measures that are necessary to ascertain when calculating maximum oxygen intake of a subject. These key measures are: (1) oxygen percentage of expired air, (2) carbon dioxide percentage of expired air, (3) respiratory quotient, (4) true oxygen, (5) corrected ventilation, and (6) maximum oxygen intake. The following six paragraphs will discuss these measures and an illustration of the oxygen intake calculation sheet may be seen in the appendix (p. 57).

Atmospheric air contains 20.93 percent oxygen and any deviation from this percentage indicates oxygen has been used by the body to do work. During normal resting states, the oxygen uptake

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[1]Nagle, p. 745.

ranges around one-third liter per minute, and the difference between expired and inspired oxygen percentage is small. However, when an individual begins to do work, the oxygen percentage of expired air gradually drops until a leveling off occurs and at this point the subject has reached his crest-load or "steady state." It is at this point that an individual attains his maximum oxygen intake. The highest oxygen percentage found at crest load in this study was 18.02, with the smallest percentage being 15.01. The mean oxygen percentage was found to be 16.61, and these three percentages are shown in Table II below.

TABLE II

OXYGEN PERCENTAGES AT CREST LOAD

Crest-Load Oxygen Measures	Percentage
Highest Percentage	18.02
Lowest Percentage	15.01
Mean Percentage	16.61

The percent of carbon dioxide in atmospheric air has been shown to be 0.03. Like oxygen, any deviation from its percentage point indicates the body has done work. As a body does work, the percentage of carbon dioxide will increase. This increase will remain constant until a leveling off or drop occurs, and like oxygen, when this does occur, the individual has reached his crest-load or "steady state." Again, it is at this point that an individual attains his maximum oxygen intake. The largest carbon dioxide percentage found in this test at crest-load was 5.73, with the smallest percentage being 3.06.

The mean carbon dioxide percentage was shown to be 4.23, and these percentages are illustrated below in Table III.

TABLE III

CARBON DIOXIDE PERCENTAGES AT CREST LOAD

Crest-Load CO_2 Measures	Percentage
Highest Percentage	5.73
Lowest Percentage	3.06
Mean Percentage	4.23

Respiratory quotient, or R.Q., is the ratio of carbon dioxide to oxygen. Karpovich[2] tells us that if exercise is of short duration or long, but not exhaustive, the respiratory quotient rises. During prolonged or exhaustive work, the respiratory quotient goes steadily down toward the 0.70 value, indicating a steady increase in dependence on fats. This was indicative of the results of our test, in that, as each subject began work, his R.Q. steadily rose until crest-load was reached and then leveled off or dropped slightly. Whenever the volumes of oxygen and carbon dioxide are the same, the respiratory quotient will be 1.0. This indicates that carbohydrates are being burned as fuel for the body to do work. This may also be due to what is called spurious R.Q. Karpovich notes that "if expired air is collected for a minute after an intensive exercise, the R.Q. may be as high as 1.5. This is a spurious R.Q., resulting from overbreathing. Because of violent post-exercise breathing, more carbon dioxide is removed than

[2]Karpovich, p. 47.

is produced.[3] The results of this test indicate that for a few of the subjects this was more than a submaximal test. The largest respiratory quotient recorded was 1.18, with the smallest being .63. A respiratory quotient as small as .63 is unusual, but may be accounted for by the following two explanations. First, this may have been a prolonged or exhaustive work period for the subject, and as was mentioned above, during prolonged or exhaustive work, the respiratory quotient rises steadily to 1.0, but then goes steadily down toward the 0.70 value. Second, there may have been an error in measurement. The mean respiratory quotient was .98 which indicates as mentioned above, that carbohydrates were being utilized. These three figures are shown in Table IV below.

TABLE IV

RESPIRATORY QUOTIENTS AT CREST LOAD

Crest-Load R.Q. Measures	Ratio
Largest R.Q.	1.18
Smallest R.Q.	.63
Mean R.Q.	.98

Respiratory quotient mentioned above and true oxygen are both determined by the oxygen and carbon dioxide percentage of expired air, and in this study were determined through use of the Harvard Line

[3] Ibid., p. 47.

Chart.[4] Consolazio[5] tells us:

> "True oxygen represents the number of milliliters of oxygen consumed for every 100 ml. of air expired. It is based on the following considerations: One desires to know the quantity of oxygen that is removed from expired air, but the only measurements made are the volume of air expired and its oxygen, carbon dioxide, and nitrogen content. The volume of inspired air usually does not have the same composition as that of expired air. The factor (%N in expired air X 0.265 - %O_2 in expired air) is the true oxygen."

This would be one manner of arriving at true oxygen, but as was mentioned above, true oxygen in this study was ascertained from the Harvard Line Chart. The largest true oxygen reading found at crest-load in this study was 6.02, with the smallest being 2.85. The mean true oxygen was found to be 4.36. These figures are shown in Table V.

TABLE V

TRUE OXYGEN AT CREST LOAD

Crest-Load True Oxygen Measures	Percentage
Largest True Oxygen	6.02
Smallest True Oxygen	2.85
Mean True Oxygen	4.36

Ricci notes that ventilation is defined as the volume of air which is drawn into and expelled from the lungs per unit time; and up to "steady state" (crest-load), a linear relationship has been shown to exist between ventilation and oxygen consumption.[6] This agrees well

[4] Consolazio, p. 10.

[5] Ibid., pp. 8-9.

[6] Ricci, p. 122.

with Karpovich[7] and Morehouse and Miller[8] who note that the breathing rate per minute increases proportionately to the load of work up to crest-load. With these statements in mind, it was decided to correlate corrected ventilation with maximum oxygen intake. The correlation computed was .33, which indicates that for these subjects, these two variables are not highly related. This tendency was noticed in this study and at crest-load, the largest corrected ventilation was 116.05 L/min., and the smallest 48.66 L/min. The mean corrected ventilation was 76.07 L/min. and these figures are shown in Table VI which follows.

TABLE VI

CORRECTED VENTILATION AT CREST LOAD

Corrected Ventilation Measures	L/min.
Largest Corrected Ventilation	116.05
Smallest Corrected Ventilation	48.66
Mean Corrected Ventilation	76.07

With the preceding items recorded for each subject, it was possible to attain their actual maximum oxygen intake. Karpovich has told us that maximum oxygen intake depends on the degree of physical fitness of an individual, and that when maximum oxygen intake is reached, the individual is in a "steady state"; and as long as a "steady state" can be maintained, the exercise is said to be within

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[7] Karpovich, p. 111.

[8] Laurence E. Morehouse and Augustus T. Miller, Physiology of Exercise, St. Louis, C. V. Mosby Company, 1967, p. 142.

the range of a "normal load." The greatest normal load is called "crest-load," and during this state, the oxygen intake is equal to the oxygen expenditure.[9] The largest actual maximal oxygen intake in this study was found to be 64 ml/kg/min., and the smallest recorded was 28 ml/kg/min. The mean actual maximum oxygen intake was 41.28 ml/kg/min., and is shown in Table VII.

TABLE VII

CALCULATED MAXIMUM OXYGEN INTAKE AT CREST LOAD

Actual Maximum O_2 Intake	L/min.	Ml/kg/min.
Largest Calculated	4.55	64
Smallest Calculated	2.12	28
Mean Calculated	3.24	41.28

To determine if the maximum oxygen intake in this study would show a close relationship to an already established test, results of calculated maximum oxygen intake of the 40 subjects were correlated with predicted maximum oxygen intakes following the Balke Treadmill Test. The result of this correlation was +.898, which indicates a good relationship between these two variables. The largest predicted maximum oxygen intake from walking time on the Treadmill Test was 66 ml/kg/min., and the smallest was 31 ml/kg/min. The mean predicted maximum oxygen intake was 42.01 ml/kg/min., and for ease of comparison of these two variables, results of predicted maximum oxygen intake are shown in Table VIII.

[9] Karpovich, p. 57.

TABLE VIII

PREDICTED MAXIMUM OXYGEN INTAKE AT CREST LOAD

Predicted Maximum O_2 Intake	Ml/kg/min.
Largest Predicted	66
Smallest Predicted	31
Mean Predicted	42.01

Upon comparing the results of the Progressive Cadence Step Test with the Astrand-Ryhming Nomogram, it was found that the two tests gave comparable results when looking at maximum oxygen intakes. It was necessary to equate the work-load of the Progressive Cadence Step Test to the work-load of the Astrand-Ryhming Step Test, as the height of their bench was 40 cm. (15.7 in.), while the Progressive Cadence Step Test bench height was 14 inches. The predicted maximum oxygen intake from the Astrand Nomogram was 3.0 L/min., and actual calculated maximum oxygen intake from this study was 3.2 L/minute.

Means were calculated on each phase of testing at the observable cut-off point, which was a heart rate of 180 beats per minute. This point was chosen as Balke and others have found in adults that their functional limitations become apparent when the heart rate reaches approximately 180 beats per minute. At this heart rate per minute, the time for ventricle filling with blood between contractions becomes so short, that due to reduced blood volume, the pulse pressure falls off. At this point, individuals also encounter their maximum capacity for breathing, and this marks the point where aerobic processes cease and anaerobic processes begin.[10] The test was, therefore, terminated at the heart rate of 180 beats per minute as this has been shown to be the dividing line between aerobic and anaerobic function in man. Table IX shows the means at cut-off point for the total group.

TABLE IX

MEAN CREST LOAD FOR TOTAL GROUP

Tests Given	Means
Pulse Rate	44-46 per 15 sec.
Oxygen Percentage	16.61
Carbon Dioxide Percentage	4.23
Respiratory Quotient	.98
True Oxygen	4.36
Corrected Ventilation	76.07 L/min.
Maximum Oxygen Intake	41.28 Ml/kg/min.

It was necessary to check the reliability of this test procedure; consequently, five randomly selected subjects were asked to return to the laboratory following both the Progressive Cadence Step Test and Balke Treadmill Test. The same measurements were included and were almost identical to those of the first test, which indicates this is a reliable test procedure. Table X gives the scores for the first and second tests.

[10] Stacy H. Mathews, Physiology of Muscular Activity and Exercise, The Ronald Press Co., New York, 1964, p. 363.

TABLE X

CREST-LOAD MEASUREMENTS FROM ORIGINAL TEST AND RETEST

Subjects Tested		Heart Rates from Progressive Cadence Step Test	Treadmill--Actual L/min. Maximum Oxygen Intake	
Subjects Tested	Cadence 1st 2nd	Heart Rates 15-sec. count 1st 2nd	1st	2nd
01	33-33	45-44	2.83	2.76
02	33-33	46-46	2.55	2.61
03	33-33	46-47	3.53	3.46
04	33-33	46-45	2.37	2.41
05	30-30	45-43	3.26	3.37

Three scales were constructed for a norm table so as to allow the physical educator in the field freedom to choose the one which fits his needs best. The three scales chosen to categorize the endurance levels of college age men were the sigma, T, and percentile scales. A percentile scale was included for the reason that students and parents can more easily understand what is meant by this scale, than either the sigma scale or T-scale. Table XI gives norms based on the preceding results, and is based upon the subject's heart rate at the cadence of 30 steps per minute. To become acquainted with the test procedure, please refer to the appendix (p. 58).

TABLE XI

PROGRESSIVE CADENCE STEP TEST NORMS
FOR COLLEGE-AGE MEN

Heart Rate After 30 steps/min.	Endurance Classification	Sigma Scale	T-Scale	Percentile Scale
126	Superior	100	80	100
134	Good	90	74	98
143		80	68	93
151	Above Average	70	62	77
160		60	56	56
168	Average	50	50	50
176	Below Average	40	44	43
185		30	38	23
193	Poor	20	32	8
202		10	26	2
210	Very Poor	0	20	0
Mean	168.2			
Standard Deviation	14.06			
N	40			

An explanation of the three scales used above may be found in a variety of test and measurement textbooks.

As a hypothetical example, imagine administering the test to a subject, who following the cadence of 30 steps per minute, had a heart rate of 132 beats per minute: on each of the three scales, the sigma, T, and percentile, the subject would rate good to superior. Inversely, if a subject had a heart rate of 184 beats per minute following the cadence of 30 steps per minute, he would rate below average on each of the three scales. This method of assigning ranks is used for any heart rate monitored, following the cadence of 30 steps per minute.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

This study has produced results which indicate that the step test procedure utilized is a valid predictor of the endurance facet of physical fitness. It is hoped that these data will give the researcher in the laboratory supplemental information with which to work, but more especially, it is hoped this study will help the physical educator in the field to easily and economically assess the physical fitness functional capacity of college age men.

The Progressive Cadence Step Test was found to be a valid measure of working capacity and cardiovascular efficiency of college age students, as indicated by maximal oxygen intake. The relationship of the Step Test to maximum oxygen intake and different magnitudes of training were shown to agree well with previously established criteria of other investigators. The highest correlation shown between the Step Test and calculated maximum oxygen intake was -.757, which was found at the progressive cadence of 30 steps per minute. Matthews, Professor and Coordinator of Research in Physical Education, The Ohio State University, notes that a test may be reliable without being valid, and that validity coefficients may be interpreted as: fair to good from .70 to .79, very good from .80 to .85, and excellent above .85. The Progressive Cadence Step Test had a coefficient of -.757

which falls in the middle of the fair to good range.[1] Smithells notes that quite a number of acceptable validity coefficients may appear in the range .70 to .79, as their worth is dependent upon the complexity of the variables involved (the administrator, time of day, nearness of last meal, nervousness, fatigue).[2]

In the review of literature it was made apparent that there was a need to have a valid test of endurance as well as an inexpensive one. The Progressive Cadence Step Test meets both these criteria as the only equipment needed for the administration of the test is: (1) a 14 inch bench, (2) a metronome, and (3) a stethoscope. Besides ease of administration and economy of time and money, the Progressive Cadence Step Test has been shown to be reliable, valid, submaximal, and consequently, free from various motivational and risk factors involved in all-out exhaustive tests.

The subjects involved in the study were at first apprehensive of the testing procedure; however, the introductory meeting before testing actually began overcame this variable and the subjects seemed at ease during testing periods. The testing itself became so interesting to the subjects that the researcher feels this could be a motivating influence for the acquiring of physical conditioning of students. Upon completion of the testing, a majority of these subjects engaged in some form of activity to increase their fitness levels; consequently, many asked to be tested once again to ascertain if any improvement in

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[1]Donald K. Mathews, Measurement in Physical Education, W. B. Saunders Co., Phil. and London, 1968, p. 22.

[2]Philip A. Smithells and Peter E. Cameron, Principles of Evaluation in Physical Education, Harper and Brothers, New York, 1962, p. 234.

their physical fitness had occurred. In all instances, it had.

With the retest of five subjects showing such a close relationship to the original test results, it would appear that the test has satisfactory reliability. The heart rate following the stepping cadence of 30 steps per minute indicated the subject's metabolic function capacity or endurance level. The accurate prediction of maximum oxygen intake from submaximal heart rate response to exercise tests are affected by a variety of factors. The most important factor results from individual variations of heart rate to exercise.

On the basis of these data collected and the results of these data, the following conclusions were made:

1. Each cadence (exercise period) should be one and one-half minutes duration, as preliminary laboratory testing has shown the vast majority of heart rates to plateau at each cadence during this time period.

2. This test offers a valid measure of the endurance status of college age men. ($r = -.757$ with maximum O_2 intake)

3. The test procedure is reliable.

4. The cadence of 30 steps/min. is recommended as the cut-off point for college age men.

5. The correlation between calculated maximum oxygen intake of the subjects in this study and their predicted (Balke) maximum oxygen intake was +.898.

RECOMMENDATIONS

The following recommendations for using the Progressive Cadence Step Test as an instrument for the testing of endurance by the physical educator in the field may be made as a result of the data collected in this study.

1. It is highly recommended that programs have some type of device to ascertain student physical fitness levels. It is the recommendation of this study that the Progressive Cadence Step Test be used to assess endurance levels of students.

2. After assessing the endurance level of students, the physical educator would be alerted to any students not "measuring up," and could put this student in a remedial or adapted program.

3. It is recommended that after testing, the students should be made aware of where they stand as to norms. It was found in testing that subjects are very interested in where <u>they</u> stand, and in improving their status.

4. The test could be used as a motivational device for students to improve their scores through physical conditioning.

5. If one of the objectives of a physical education class was that of physical fitness, a pre-test and post-test could be given through use of the Progressive Cadence Step Test to determine if this objective had been met.

6. For ease of test administration, it is recommended that the Progressive Cadence Step Test procedure be placed upon a tape to give the administrator freedom to monitor heart rates.

7. It is recommended that stethoscope readings be taken at a 45 degree angle down, one inch to the subject's right of his left nipple.

RECOMMENDATIONS FOR FURTHER STUDY

The following recommendations for further investigations of the

Progressive Cadence Step Test as a device for testing endurance in physical fitness are made as a result of this study:

1. The same test should be given again, but air samples should be taken following the Progressive Cadence Step Test for calculation of maximum oxygen intake; these results should then be correlated with maximum oxygen intake as predicted from Balke's Treadmill Test.

2. A Progressive Cadence Step Test without the recovery period included should be correlated with the Balke Treadmill Test. Air samples would be collected during the Progressive Cadence Step Test for calculation of maximum oxygen intake figures. This test is now being conducted by N. D. Matthews at Oklahoma State University.

3. Norms for this same test should be established for both boys and girls at the secondary and elementary school levels, as well as middle aged population.

4. An investigation of this test on college age men in another geographic location for comparison of results.

5. This same Progressive Cadence Step Test, with the exception of utilizing another bench height, should be conducted. The bench height could range between 15 to 20 inches.

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Dear ________________________: (room number)

You have been randomly selected from 705 men in Willham North to perform in a Doctor of Education Dissertation as a subject. If you are interested, please check (x) below, sign your name at the bottom of this note, and have a desk clerk put it in my box. If you are <u>not</u> interested, please check (x) the appropriate place and return this note to my box.

Yes, I am interested __________

No, I am not interested __________

Thank you,

Al Lewis

PERSONAL DATA SHEET
(Please Print)

Name ____

Date of Birth ________________ Age ________ Weight ________

Height ________________ Circle College Year: 1, 2, 3, 4 Grad

College ______________________ Phone No. ____________

Stillwater Adress ______________________________________

Home Address ____

Medical History:

Check if you have had any of the following:

________	Asthma	________	Shortness of breath on exertion
________	Frequent colds	________	Swelling of feet
________	Fainting or dizzy spells	________	Back trouble
________	Epilepsy	________	Joint trouble
________	Tuberculosis	________	Rheumatic Fever
________	Pleurisy	________	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? No. of yrs. ________
Sports ____

____

Did you have organized high school physical education? ________
If so, how many years? ________________________________
Do you participate in intramurals at O.S.U.? ________ 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.

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_2% ____________

CO_2% ____________

RQ ____________ (from Harvard line chart)

True O_2 __________ (from Harvard line chart)

Vent./min. = $\frac{\_\_\_\_}{10}$ (Kymo. mm.) = ____ x 1.332 = ____ L/min.

Corrected vent. = $\underset{\text{corr fact}}{\_\_\_\_\_\_}$ x $\underset{\text{vent}}{\_\_\_\_\_}$ = __________ L/min.

O_2 Intake = True O_2 x vent. = $\frac{\_\_\_\_}{100}$ x ____ = ____ L/min.

2. SECOND MINUTE:

O_2% ____________

CO_2% ____________

RQ ____________ (from Harvard line chart)

True O_2 __________ (from Harvard line chart)

Vent./min. = $\frac{\_\_\_\_}{10}$ (Kymo. mm.) = ____ x 1.332 = ____ L/min.

Corrected vent. = $\underset{\text{corr fact}}{\_\_\_\_\_\_}$ x $\underset{\text{vent}}{\_\_\_\_\_}$ = __________ L/min.

O_2 Intake = True O_2 x vent. = $\frac{\_\_\_\_}{100}$ x ____ = ____ L/min.

3. THIRD MINUTE:

O_2% ____________

CO_2% ____________

RQ ____________ (from Harvard line chart)

True O_2 __________ (from Harvard line chart)

Vent./min. = $\frac{\_\_\_\_}{10}$ (Kymo. mm.) = ____ x 1.332 = ____ L/min.

Corrected vent. = $\underset{\text{corr fact}}{\_\_\_\_\_\_}$ x $\underset{\text{vent}}{\_\_\_\_\_}$ = __________ L/min.

O_2 Intake = True O_2 x vent. = $\frac{\_\_\_\_}{100}$ x ____ = ____ L/min.

PROGRESSIVE CADENCE STEP TEST PROCEDURE

The following procedure is recommended when the Progressive Cadence Step Test is to be used by the physical educator in the field.

I. Locate a 14-inch high bench.

II. Acquire a stethoscope.

III. Have access to a metronome.

A. It may be advisable to tape the Progressive Cadence Step Procedure for playback, as this will allow the administrator more freedom to monitor heart rates.

B. If it is decided to tape the procedure, it may be done in the following manner.

1. As the beginning cadence is 12 steps per minute, and each step constitutes four counts (up, up, down, down), each cadence must be multiplied by four to acquire the metronome setting. As an example, the metronome setting for the cadence 12 would be (12 x 4 = 48), for the cadence 15 (15 x 4 = 60), and so on throughout the test for each progressive cadence.

2. To begin taping, set the metronome on 48 (12 steps per minute), turn on the tape, and begin the taping by saying:

a. Ready 12, begin NOW, audibly state the cadence, up, up, down, down, for the first 30 seconds of each cadence.

b. The next one minute of exercise is done only to the beat of the metronome.

c. When the one and one-half minutes of exercise is nearing completion, record: ready-stop-NOW, please be seated.

d. As there is a 30 second recovery period between each cadence and a 15 second heart rate must be monitored, the recovery period may be taped as follows:

(1) On the fourth second of recovery, record, begin count NOW.

(2) From the fifth to twentieth second of the recovery period, monitor heart rates.

(3) At the nineteenth second of the recovery period, record, stop count NOW. Write down the recovery heart rate.

(4) The twentieth to twenty-ninth second of recovery is used to ready the subject or subjects for the next cadence.

(5) At the twenty-ninth second of recovery, record, ready-15-begin NOW. Remember, the cadences are audibly recorded the first 30 seconds of each cadence.

3. This procedure is followed in making the tape up to and including the cadence of 30 steps per minute.

IV. Before actual testing begins, it is advisable to acquaint the subjects with the test procedure.

V. As this test was devised for mass testing, it would be advisable to divide the class into two equal groups. In this way you could assign one-half to be counters, and the other half to be subjects. When the first testing period was concluded, the counters could be subjects, and the subjects could be counters for the next testing period.

VI. When ready to administer the test, have the subjects sitting quietly behind their bench position for a two to three minute resting period.

VII. Before turning on the tape or metronome, have the subjects stand, making certain each subject has at least three feet of bench to exercise upon.

VIII. Begin the testing session.

IX. Make certain each subject is in step with the metronome beat and that they are straightening the legs and back on each step.

X. The subject should lead off with the same foot each time, and not try to alternate feet.

XI. The subject must not touch anything with his hands, but may actively move his arms.

XII. The subject will perform the cadences: 12, 15, 18, 21, 24, 27, and 30, at which point the test will terminate.

A. The recovery heart rate from the cadence of 30 steps per minute, will be compared to the norm chart to ascertain the physical fitness level of the subject.

TABLE OF RESULTS

Subject	Resting	12	15	Heart Rates Step Rest 18	21	24	27	30	33	36	39	O_2%	CO_2%	R.Q.	True O_2	Cor. Vent.	M O_2 I L/min	Actual O_2 Ml/Kg/min	Pred. O_2 Ml/Kg/min
Brooks, Robert	72	104	120	124	140	148	164	180	180	188		16.87	4.28	1.06	4.01	81.05	3.25	33	37
Burlison, Ron	68	100	108	116	132	148	164	172	184	188		16.56	4.37	.99	4.38	74.77	3.28	44	46
Buttle, Dave	96	124	136	140	148	152	164	172	180	184		15.56	3.70	.63	5.83	96.54	5.63	47	44
Cleaver, Riley	80	104	108	116	132	136	152	160	168	180		16.14	4.37	.88	4.92	84.36	4.15	46	44
Cravens, Tom	84	96	100	100	112	116	120	140	156	172	188	16.77	4.06	.96	4.2	73.75	3.10	51	51
Dewey, Carl	76	96	100	108	120	124	144	152	172	184		17.1	4.18	1.01	3.74	63.23	2.37	43	43
Dickson, Don	76	104	120	128	144	156	168	180	196			16.55	4.6	1.05	4.35	53.35	2.32	35	31
Due, Steve	72	80	88	96	108	120	132	152	172	180		16.94	4.07	1.03	3.92	89.46	3.51	45	46
Dunham, Ron	84	100	108	120	128	140	156	168	180	192		15.01	5.43	.90	6.02	54.06	3.26	43	43
Eden, Bill	84	116	120	132	140	144	156	164	180	192		16.85	3.92	.94	4.13	62.86	2.60	44	43
Farris, Steve	92	116	128	132	136	144	148	160	180	188		16.55	4.68	1.07	4.31	70.41	3.04	46	41
Ferrell, Dennis	72	100	112	112	132	144	160	176	188			16.20	4.37	.9	4.85	66.37	3.22	44	44
Flippo, Norman	96	124	132	140	156	164	176	184	192	196		15.93	4.75	.93	5.1	62.29	3.18	37	35
Godlove, Jim	84	124	128	140	152	156	172	180	184			17.40	3.88	1.11	3.44	102.16	3.51	36	34
Goltra, Pete	80	80	92	96	116	132	156	168	180	192		16.96	3.95	.98	3.98	64.15	2.55	40	43
Hauert, Steve	84	100	100	108	112	128	136	152	156	180		16.81	4.18	1.1	4.12	63.44	2.61	40	43
Hoffsommer, Monty	80	96	104	116	136	156	168	184	192	200		16.0	4.65	.92	5.02	60.90	3.06	38	37
Jones, Bob	84	104	112	116	128	140	140	152	160	180	176	15.26	4.83	.81	5.92	80.36	4.76	53	50
Karp, Gary	92	104	120	128	144	156	172	180				16.61	4.22	.96	4.36	48.66	2.12	28	31
Kimball, Mike	76	96	104	116	132	140	156	164	184	196		17.12	4.07	1.08	3.75	80.05	3.0	40	35
Lair, Robert	60	80	84	104	112	124	140	160	172	180		16.95	3.85	.95	4.02	65.44	2.63	36	41
Langer, Larry	96	128	132	140	160	172	188	192	204			16.11	4.71	.96	4.87	62.74	3.06	35	33
Lauderdale, Luther	72	76	84	92	104	108	124	132	140	152	180	16.20	4.30	.88	4.86	93.57	4.55	64	66
Lewis, Toby	80	92	108	120	132	148	156	172	180			17.52	3.62	1.07	3.36	103.36	3.47	38	39
Lundquist, John	76	104	108	128	140	156	172	188	196			17.03	4.30	1.12	3.81	66.86	2.55	34	33
Magnuson, Leonard	84	120	120	120	132	136	140	156	164	172	180	17.14	4.06	1.08	3.72	97.51	3.63	49	46
Mathis, Bill	80	124	128	136	148	160	168	180	192	190		15.78	4.37	.8	5.37	78.95	4.24	47	41
Miller, Keith	84	100	112	120	128	140	148	164	180	200		16.09	4.30	.85	5.01	58.85	2.95	41	43
Morrison, Ron	84	96	104	120	136	144	156	168	180			17.11	4.37	1.18	3.67	101.09	3.71	41	43
Overall, Mickey	76	104	116	116	132	148	164	176	184	196		17.64	3.17	.94	3.37	100.88	3.40	45	44
Penn, Larry	84	112	124	132	144	160	172	188				17.76	3.62	1.17	3.06	92.27	2.82	29	35
Prince, John	80	100	104	108	120	128	140	156	172	184		18.02	3.09	1.06	2.85	116.05	3.31	44	39
Pulfrey, Bob	56	72	84	88	96	108	128	140	160	184	196	16.13	5.05	1.05	4.76	86.23	4.11	51	48
Roark, Roy	68	80	92	96	120	132	140	160	168	180		17.47	3.06	.84	3.56	77.53	2.76	40	43
Russell, John	56	108	128	128	144	160	168	176	184	192		17.5	3.85	1.15	3.32	82.70	2.75	41	39
Sampson, Kent	72	100	108	116	132	148	164	172	180			15.24	5.73	.98	5.76	55.97	3.22	42	39
Skaggs, James	80	92	100	104	120	128	148	164	184	192		16.61	3.77	.83	4.47	57.14	2.55	39	37
Thannhausen, Chuck	96	120	128	136	144	160	172	180	188			16.17	4.42	.89	4.96	71.21	3.53	35	31
Traylor, Terry	96	116	128	136	144	156	168	180	190			16.83	4.15	1.0	4.10	68.91	2.83	37	39
Willard, Jerry	84	104	120	132	148	160	172	184	196	196		15.99	4.90	1.0	4.95	73.23	3.63	40	43

VITA

2

Albert Lester Lewis

Candidate for the Degree of

Doctor of Education

Thesis: A PROGRESSIVE STEP TEST TO PREDICT MAXIMUM OXYGEN INTAKE

Major Field: Higher Education

Biographical:

Personal Data: Born at Burlington, Kansas, August 16, 1939, the son of Albert and Delores Lewis.

Education: Attended elementary school in Strawn, Kansas (1), Reese, Kansas (2), Leroy, Kansas (3), Matfield Green, Kansas (4), Delphos, Kansas (5 and 6); attended junior high school at Longton, Kansas; graduated from Sabetha High School in 1957; received the Bachelor of Arts degree from Ottawa University, Ottawa, Kansas, with a major in Physical Education in June, 1961; received the Master of Science degree, as a National Science Foundation Fellow, with a major in Natural Science at Oklahoma State University in May, 1968; completed requirements for the Doctor of Education degree in July, 1970.

Professional experience: Appointed classroom teacher in the Plains Public Schools, Plains, Kansas, in 1961; taught in the secondary school system; graduate assistant in Department of Health, Physical Education, and Recreation, Oklahoma State University, 1969; appointed Head Resident at Oklahoma State University in May, 1970; Member of the American Association of Health, Physical Education, and Recreation; Oklahoma Association of Health, Physical Education, and Recreation; National Education Association; and the Oklahoma Education Association.