A PROGRESSIVE STEP TEST FOR ASSESSING THE CARDIORESPIRATORY FITNESS OF COLLEGE MEN

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PREFACE

The completion of this dissertation has been a long and arduous task. It is my opinion that a difficult assignment at the least is rendered much more so when one must be away from the adacemic location and must sandwich in the research work along with all other professional and family responsibilities. I might go so far as to say that this research paper would have been virtually impossible had it not been for the guidance, understanding and assistance of several individuals. Therefore, I would like to take this means of publicly thanking my advisory committee, especially the individual efforts of my chairman, Dr. Aix B. Harrison. The other members of my committee to whom I am grateful are Dr. Albin Warner, Dr. John Bayless, Dr. John Hampton and Dr. Gene Post. I am also greatly indebted to everyone else who contributed to this study, particularly the 54 subjects from Oklahoma State University and the 15 from Northwestern State College who volunteered their time and effort.

Finally, I would like to express my deep appreciation to my wife, Sis, and our daughter, Trayce, for their understanding and encouragement and whose sacrifices were very important in the preparation of this dissertation.

It is my sincere hope that the sum total effort which has been devoted to this accomplishment has not been in vain and that this research endeavor has in some small way contributed to the professional knowledge in the field of physical education.

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CHAPTER I

INTRODUCTION

Background of the Study

Since World War II there has been a growing concern over the physical fitness of the population of the United States. It was during that time that many of our young men and women who were called upon to serve in the armed forces discovered that they were not considered fit enough to meet the physical demands of military service.

In the years following, such importance was attached to this concern that, in 1957, President Eisenhower established a Youth Fitness Council aimed toward ensuring every American child the opportunity to make and keep himself physically fit--fit to learn, fit to understand, to grow in grace and stature, to fully live.[1] This direction was continued by President Kennedy throughout the next administration, but the name of the council was changed to the President's Council on Youth Fitness. Basically, the aim of the Council has been to encourage organized and supervised physical development on all educational levels, particularly elementary and secondary (K-12).

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[1] "Youth Physical Fitness." President's Council on Youth Fitness. U. S. Government Printing Office, Washington, D. C. (July 1961), p. 1.

Further evidence of the importance being placed upon physical fitness and its evaluation was demonstrated when the International Congress of Sport Science appointed a committee to set standards and construct instruments for the measurement of physical fitness. Larson stated that the purpose of this committee was to study and to determine the powers and the organic resources of the people living under greatly varying conditions over the world and to aid in noting the changes as the result of improved hygiene and ways of life.[2]

In regard to the alarming incidence of cardiovascular disease in recent years among middle-aged and elderly people, Kurucz, Fox and Mathews note that a number of epidemiological studies suggest physical inactivity as a predisposition toward coronary artery disease.[3]

There seems to be little doubt that the fitness of our nation's youth is improving from year to year through efforts such as these, but is it improving enough? How much is enough? What of the individuals who have not been afforded the opportunity to participate in such a program or who arrived too soon to become involved in one? Are they fit enough, or do they need more activity? How can they know? The answers to these questions seem to lie in a method of evaluation designed to determine a physical fitness level of each individual.

Once again the question of "fitness for what?" arises. Does fitness mean merely being able to make it from day to day, or does it mean

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[2] L. A. Larson, "An International Research Program for the Standardization of Physical Fitness Tests," Journal of Sports Medicine and Physical Fitness, VI (Dec. 1966), p. 261.

[3] R. L. Kurucz, E. L. Fox and D. K. Mathews, "Construction of a Submaximal Cardiovascular Step Test," Research Quarterly, 40:1 (March 1969), p. 115.

being physically capable of playing a football game or climbing a mountain? Rather than fitness, a term more meaningful of the intent of this study would be efficiency. This is meant to imply individual efficiency, or the ability of the individual to perform work in a physiologically efficient manner, not muscular strength nor specific skill ability. Nagle, Balke and Naughton define physical fitness as the potential capacity for making adequate functional adjustments to increased metabolic demands.[4] Brouha, Fradd and Savage divide physical efficiency or fitness into three categories: (1) medical fitness, (2) specific fitness, and (3) functional or dynamic fitness.[5] It is this third category which is the concern of this study, and these same authors further define functional or dynamic fitness as the ability to sustain strenuous exercise and to recover from it rapidly.[6]

A review of the literature disclosed many different methods of physiological evaluation which have been described as measurements of physical fitness. These measures were determined from activities such as running, treadmill, bicycle ergometer and stepping tests. Because there is an abundance of such instruments by so many authorities in the field, it is apparent that no one test satisfies everyone. From this information it appears that there was a definite need for

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

[5]L. Brouha, N. W. Fradd and B. M. Savage, "Studies in Physical Efficiency of College Students," Research Quarterly, XV (Oct. 1944), pp. 211-224.

[6]Ibid.

more such research if there is to be closer agreement in the future. It could also be that there is a need for all of these different methods of evaluation, plus many more, if the knowledge pertinent to the field of physical education is to be expanded.

It was the desire of this investigator to attempt to develop a unique method of evaluating physical efficiency with the hope that it would further contribute to the ever-broadening scope and importance of the field of physical education.

Purpose of the Study

As previously stated, this study was limited to the functional or dynamic efficiency aspect of overall individual fitness sometimes referred to as the endurance of the individual. Endurance can further be classified as one of two kinds: (1) muscular or (2) organic or cardiorespiratory. Muscular endurance refers to the ability of a muscle or group of muscles to continue contractions over an extended period of time. Organic or cardiorespiratory endurance refers to the ability of the organs of the body to provide the necessary fuel for the muscles to continue long and extended periods of contraction. Brassfield believes that, in the final analysis, physical fitness then appears to be limited by the cardiorespiratory system.[7]

According to Cureton, cardiovascular-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

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

moderate work; in fast, hard work, comparable to virtually all-out athletic effort; and to evaluate recuperation after the work.[8] Since no one test can possibly indicate the relative efficiency level of an individual in all of these attitudes, it seemed there might be a need for the development of valid measuring instruments in each.

Of primary interest to the writer in this respect was the so-called "normal" or "average" individuals of our population rather than the extremes of the "diseased" or physically "gifted". Therefore, one objective of this study was that the test developed be of the cardio-respiratory type to indicate the fitness of an individual for moderate work.

Theoretically a cardiorespiratory fitness test should do one of two things: (1) measure an individual's capacity to perform maximal work, or (2) measure his response to a fixed amount of moderate or sub-maximal work. There is a dichotomy of opinion as to which is the appropriate method.

Brouha, Graybiel and Heath believe that 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.[9] Johnson, Brouha and Darling agree that the exercise 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

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

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

exhaustion within five minutes.[10]

On the other hand, Shephard believes that the choice of a load which is exhausting for a proportion of the subjects may increase discrimination but at the expense of weighting discrimination in terms of psychological factors such as motivation.[11] For this reason he believes that in studies of the fitness of the ordinary citizen the purer cardiac response to submaximal exercise seems a more suitable basis for evaluation.[12] De Vries and Klafs agree with this viewpoint listing 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.[13]

According to Wilmore, maximal oxygen intake has become widely accepted as the primary physiological variable which best defines the efficiency or capacity of the cardiovascular and respiratory systems.[14] Balke agrees that the maximum oxygen intake available is the most

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[10] 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.

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

[12] Ibid.

[13] H. A. de Vries, and C. E. Klafs, "Prediction of Maximal Tests," Journal of Sports Medicine and Physical Fitness, V (Dec. 1965), p. 207.

[14] Jack H. Wilmore, "Maximal Oxygen Intake and Its Relationship to Endurance Capacity on a Bicycle Ergometer," Research Quarterly, 40:1 (March 1969), p. 203.

adequate criterion of work capacity.[15] Cooper also utilized this oxygen intake principle in establishing the norms for his aerobics program.[16]

De Vries and Klafs conclude that for active college men, maximal oxygen intake and, consequently, physical working capacity can be predicted with a reasonable error of prediction from submaximal tests.[17] Since these and other authorities in the field of exercise physiology such as Astrand, Balke, and Shepard also seem to agree that a submaximal test which predicts oxygen intake is the best criterion of physical fitness, and because this investigator is in agreement with this theory, a further objective of this study was that this test also be of submaximal intensity and based on the prediction of maximal oxygen intake.

The known methods of evaluating physical efficiency can be classified as either laboratory tests or field tests.

According to Nagle, Balke and Naughton, 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 erogmeter.[18] Obviously, these methods of laboratory testing are neither practical from the viewpoint

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[15] B. Balke, "A Simple Field Test for the Assessment of Physical Fitness," Report to the F.A.A., Civil Aeromedical Research Institute, Oklahoma City, (April 1963), p. 8.

[16] Kenneth H. Cooper, "A Means of Assessing Maximal Oxygen Intake: Correlation Between Field and Treadmill Testing," _Journal of the American Medical Association_, 203 (15 Jan. 68), p. 135.

[17] De Vries and Klafs, p. 214.

[18] Nagle, Balke and Naughton, p. 747.

of mass testing and time consumption nor within the financial scope of most investigators since expensive technical equipment is necessary.

On the other hand, Balke states that testing a large population, which is important for the establishment of standards, requires test procedures of simple design but capable of rendering results which are comparable to those of more complex and time consuming laboratory tests.[19] This description by Balke would encompass what has been referred to as field testing.

The experiments of Balke and Cooper indicate that 15 and 12 minute best-effort runs, respectively, can be utilized as substitutes for a standard work capacity test in the laboratory. Balke found that in seven out of nine subjects the performance criteria for both tests checked within a range of ± 5 per cent, and only in two subjects was the running performance about 7 per cent lower than the treadmill performance.[20] Cooper found a correlation of .897 for 115 subjects between his 12 minute run and measured oxygen consumption on the treadmill in the laboratory.[21] Another acceptable field test for standardizing and measuring workloads is bench stepping.[22] Both of these methods have satisfactory validity correlations, but each also has its advantages and disadvantages. Running is conducive to mass testing because it requires little in the way of facilities and equipment, but it is

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[19] Balke.

[20] Ibid, p. 5.

[21] Cooper.

[22] H. A. De Vries, Physiology of Exercise for Physical Education and Athletics, Dubuque: Wm. C. Brown Co., 1969, p. 146.

virtually impossible to determine whether the individuals being tested are putting forth their best effort in running for the specified period of time. Bench stepping is probably less desirable for mass testing, but it utilizes less space and practically eliminates the motivation factor since the workload is controlled and heart rate can be monitored during work bouts. The workloads of step tests can be controlled either by increasing the height of the step while maintaining a constant height bench. Another method used in bench stepping cadence, and the subject's efficiency is determined by the length of time he can exercise at these levels.

Treadmill testing is becoming a popular laboratory method of assessing efficiency. Karpovich noted that the coefficient of correlation between the time needed for reaching the 180 pulse on the Balke Treadmill Test and the time of the all-out run was .85, and difference in oxygen consumption was only 7 per cent.[23] This instrument consists of a motor-driven conveyor belt that is large and strong enough for a subject to walk or run upon. The treadmill permits a gradual increase of workload either by increasing the speed of the belt or by increasing its angle of incline, or both. Balke's Treadmill Test increases the angle of incline only while maintaining a constant speed. The progressive step test, as proposed in this study, gradually increases the workload by increasing the speed of stepping at a constant height.

Therefore, the final objective of this study was that this test be of the field type involving groups of the size one might encounter in

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[23] Peter V. Karpovich, Physiology of Muscular Activity, Philadelphia and London: W. B. Saunders Co., 1966, p. 76.

a college physical education class and employing relatively simple and inexpensive equipment.

From these stated objectives, then, it was the overall purpose of this study, based on the assumption that maximum oxygen intake is a valid measure of cardiorespiratory fitness, to establish a practical field-type submaximal progressive step test from which it would be possible to predict maximum oxygen intakes of college men from ages 18 through 30, thus determining efficiency (fitness) levels or work capacities.

Specific sub-problems of this study which needed to be resolved were:

1. Height of the bench
2. Stepping rates
3. Length of exercise time at each stepping rate
4. Relationship of the heart rates at the various cadences to maximum oxygen intakes
5. Establishment of fitness norms for college men (ages 18-30)
6. Computing regression equations for predicting maximum oxygen intake.

Significance of the Study

There are numerous significant factors associated with this study. The field version of the test would be practical and inexpensive to administer. The number of subjects which could be tested would be limited only by the number of stethoscopes, 14 inch benches, and assistants available. One metronome, or recording, would be sufficient to maintain the stepping cadences for the group being tested. Since this is not a maximum effort test, it would be safe for all subjects regardless of present fitness level.

As cited by Rasch and Pierson, Wahlund contends that any physical fitness test must satisfy seven criteria:

1. A large number of muscles must be involved.

2. Sufficiently heavy loads must be used to make it possible to estimate the maximal steady state level of the subject.

3. There must be a possibility for most of the subjects to attain a steady state during moderate loads.

4. The working time must not be so long as to cause carbohydrate exhaustion and hydrostatic changes of the blood distribution.

5. The test should not be one in which some individuals may have a much better mechanical efficiency than others.

6. The work load must be standardized and controlled.

7. For determination of the working intensity, oxygen consumption measurements must be made.[24]

For the aforementioned reasons and the fact that this test would meet Wahlund's criteria, it was felt that the development of such a test would be a valuable contribution to the field of physical education.

Delimitations

While the norms which were developed for this study may be considered a reasonable guide for college men of this age group, they

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[24]P. J. Rasch, W. P. Pierson, "Evaluation of a Submaximal Test for Estimating Physical Work Capacity," Ergonomics, III (Jan. 1960), p. 12.

would not be applicable to older, younger or female individuals. Therefore, the results obtained from this research cannot be generalized beyond this population.

Limitations

1. All subjects were volunteers.

2. A greater number of subjects would be desirable to increase accuracy of the study and for establishing norms.

3. The emotional states of the subjects could not be controlled.

CHAPTER II

REVIEW OF LITERATURE

A review of related literature revealed various methods of assessing physical efficiency which have been researched in recent years. Most of these utilized the bicycle ergometer, motor-driven treadmill, distance running or bench stepping, and involved the measurement of maximum oxygen intake, heart rate or a relationship of the two.

Since this study was concerned primarily with the development of a unique field type step test, this chapter was confined to a discussion of relevant research gleaned from the literature.

One of the original cardiovascular-respiratory efficiency tests employing stepping was the Schneider Cardiovascular Test. The Schneider Test was introduced in 1920 and resulted from work during World War I with 2000 aviators.[1] This test also included pulse rate and blood pressure readings in the horizontal and standing positions plus the recovery ability of the pulse rate after exercise. The exercise in this case was 5 complete steps in 15 seconds on an 18 inch bench. The scoring scheme was arbitrarily established and constructed on the assumption that fatigue and efficiency are shown in comparing the reclining heart rate with increase on standing; standing pulse

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[1] E. C. Schneider, "A Cardiovascular Rating as a Measure of Physical Fatigue and Efficiency," Journal of the American Medical Association, 74 (May 1920), p. 1507.

rate with pulse rate after exercise; return of pulse rate to normal; and systolic blood pressure standing compared with reclining. Because of the equipment and skill required to measure blood pressure, this would not be a practical field-type test.

A few years following the Schneider Test, the Pulse-Ratio Test was published by Tuttle.[2] This test utilized the ratio of the resting pulse rate to the pulse rate after exercise. In order to find the physical efficiency of an individual, the amount of standard exercise required to produce a 2.50 pulse ratio was determined. The conduct and scoring of this test consisted of an exercise of bench stepping at a height of 13 inches. First an exercise dosage was given which would yield a ratio of less than 2.50 (20 steps/min.), and then a work bout which would elicit a ratio of more than 2.50 was administered (40 steps/min.). These two ratios were then plotted, and the number of steps which would yield a 2.50 ratio was determined from the graph. This number of steps was then converted by formula into per cent efficiency. The results were interpreted as meaning that the individual requiring the least amount of exercise to produce a 2.50 ratio was least efficient, while the individual requiring the most exercise to produce this ratio was most efficient. The 2.50 ratio was adopted because experience showed that in most healthy individuals this figure fell somewhere between ratios resulting from light and strenuous exercise. Of the Tuttle Pulse-Ratio Test, Henry and Farmer concluded that the test in its present form was not as reliable as was desirable if

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[2] W. W. Tuttle, "The Use of the Pulse-Ratio Test for Rating Physical Efficiency," Research Quarterly, II (May 1931), pp. 5-17.

it was to be used for predicting individual scores, although for a group of 40 subjects a test-retest correlation resulted in a reliability coefficient of .823.[3]

The McCurdy-Larson Organic Efficiency Test was first published and also revised in 1935.[4] This physical efficiency test was based on the following five selected items: sitting diastolic blood pressure; breath-holding 20 seconds after exercise; pulse rate two minutes after exercise; standing pulse pressure; and vital capacity. The exercise equipment for this test was two 9 inch steps constructed in such a way that the subject ascended and descended them in the same direction and then turned around to repeat the procedure. The authors of this test found a validity coefficient of .833 between criterion groups in subjectively placing "typical" individuals in "poor" and "good" condition.[5] It is obvious that of necessity this would have to be considered a laboratory situation and not a field test.

In 1943, the Harvard Step Test was introduced by Brouha, Graybiel and Heath.[6] They explained that the Harvard Step Test was based on the principle that a satisfactory estimate of man's fitness could be obtained by exposing him to a standard exercise that no one could

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[3] F. Henry and D. Farmer, "Functional Tests: II. The Reliability of the Pulse-Ratio Test," Research Quarterly, 9:2 (May 1938), p. 86.

[4] J. H. McCurdy and L. A. Larson, "The Measurement of Organic Efficiency for the Prediction of Physical Condition in Convalescent Patients," Research Quarterly, 6 (Dec 1935), pp. 78-97.

[5] Ibid, p. 90.

[6] Brouha, Graybiel and Health, p. 7.

perform in a "steady state" for more than a few minutes and taking into account two factors: the length of time he could sustain it and the deceleration of his heart rate after exercise.[7] In this test the subject stepped up and down on a twenty inch bench at a rate of thirty steps per minute for five minutes, unless he stopped from exhaustion prior to the end of the five minute period. The pulse was then counted from one to one and a half, two to two and a half, and three to three and a half minutes after exercise. The results were substituted in a formula, and a circulatory appraisal was calculated. What this test purported to measure was the general capacity of the body, in particular the cardiovascular system, to adapt itself to hard work and to recover from what it had done. In a critique of the Harvard Step Test, Taylor stated that it depends chiefly on "face validity," that is that the length of time a man can work before becoming exhausted is self-evidently a criterion of his fitness for hard physical work. Therefore, he concluded this test to be valid only as long as it is of maximal intensity but of very limited value when submaximal.[8]

In 1963, Skubic and Hodgkins modified the Harvard Step Test in developing a Cardiovascular Efficiency Test for girls and women.[9] They tested 2360 college women using an 18 inch bench and a stepping rate of 24 steps per minute for a period of five minutes. Immediately after exercise the subjects rested one minute, and the pulse rate was then

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[7] Ibid.

[8] C. Taylor, "A Maximal Pack Test of Exercise Tolerance," Research Quarterly, 15-14 (Dec. 1944), p. 301.

[9] Vera Skubic and Jean Hodgkins, "Cardiovascular Efficiency Test for Girls and Women," Research Quarterly, 34:2 (May 1963), p. 191.

counted for 30 seconds. Skubic and Hodgkins also experimented with a shortened version of this test exercising the subjects for a period of just three minutes. With 196 subjects they found a test-retest coefficient of .82, and with 96 subjects they found a correlation of .79 between the three and five minute versions of their test.[10] In a later study that same year, these authors established norms for this test.[11]

In a modification of Cureton's Progressive Pulse Ratio Test, Waxman suggested progressive workloads of 12, 18, 24, 30 and 36 steps per minute on a 17 inch bench height.[12] Beginning ten seconds after each workload the heart beats were taken for two minutes. The subject then rested until his pulse stabilized to within eight to twelve beats of his standing normal before proceeding to the next workload. This Progressive Pulse Ratio Test was found to have a correlation of .71 relative to maximum oxygen intake.[13]

In 1964, Michael and Adams described the use of a one-minute step test to estimate exercise fitness.[14] Their test for men utilized a 17 inch bench, but the workload was only 36 steps per minute for a period

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[10] Ibid., p. 196.

[11] Jean Hodgkins and Vera Skubic, "Cardiovascular Efficiency Test Scores for College Women in the United States," Research Quarterly, 34:4 (Dec. 1963), p. 454.

[12] 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, The University of Illinois College of Physical Education and the Athletic Institute, 1960, pp. 185-186.

[13] Ibid.

[14] E. D. Michael, Jr. and A. Adams, "The Use of a One-Minute Step Test to Estimate Exercise Fitness," Ergonomics, VII (April 1964), pp. 211-215.

of one minute. After exercise, the recovery pulse rates were recorded for the first, second, and third minutes. For women the test was the same but the workload was reduced to 30 steps per minute. The authors 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 was not to predict all-out performance but rather fitness for moderately strenuous activities.[15] For 939 subjects, a test-retest procedure resulted in a correlation of .86.[16]

In more unique step test studies, Balke,[17] Harrison[18] and Bayless[19] utilized a motorized stepping machine which was devised by Balke. This electrically operated "stepper" permitted the workload to be increased during exercise by raising the height of the step, while the cadence of stepping remained constant. The field version of these step tests involved the monitoring of the heart rate during exercise much the same as did this author's study.

Another progressive step test based on recovery from exercise was conducted by Shephard in 1967.[20] He used either a double nine inch step or a single bench 18 inches in height. His stepping rates began

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[15] Ibid., p. 213.

[16] Ibid., p. 214.

[17] Nagle, Balke, Naughton.

[18] A. Harrison, "Swim for Fitness," Physical Educator, 22 (Oct. 1965), p. 129.

[19] J. G. Bayless, "A Metabolic Functional Capacity Test for Upper Elementary-Age Boys," (unpublished D.Ed. Dissertation, Oklahoma State University) (May 1966), p. 23.

[20] Shephard, pp. 23-27.

at 10 steps per minute for two minutes and then increased to 15, 20 and 25 steps per minute, each of these last three workloads continuing for three minutes. With his ten subjects, Shephard found a test-retest reliability correlation of .966, and a comparison of predicted to measured oxygen intakes resulted in a validity coefficient of .872.[21]

In 1969, Kurucz, Fox and Mathews published the Ohio State Step Test.[22] This submaximal test used a split level bench, one level being 15 inches high and the other 20 inches. The test comprised 18 innings of 50 second durations divided into three phases of six innings each. Each inning was divided into a 30 second work period and a 20 second rest period during which the subject's pulse was taken for 10 seconds. The first six innings were performed at 24 steps per minute on the 15 inch step; the second six innings were at the same height; but the cadence was increased to 30 steps per minute; and the final six innings were also at a cadence of 30 steps per minute but on the 20 inch step. The OSU Step Test was terminated in the inning where the subject's pulse reached 150 beats per minute. A test-retest correlation of this test resulted in a reliability coefficient of .94, and a validity comparison with the Balke Treadmill Test found a coefficient of .94. The sample group included 75 men between the ages of 18 and 60 years.[23] A modification of the OSU Test which would be satisfactory for mass testing in a high school class situation has been proposed

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[21] R. J. Shephard, "The Prediction of Maximal Oxygen Consumption Using a New Progressive Step Test," Ergonomics, 10 (Jan. 1967), p. 7.

[22] Kurucz, Fox and Mathews.

[23] Ibid.

by Cotten.[24]

In a step test study closely related to this author's, Lewis used the same bench height, 14 inches, and the same stepping cadences of 12, 15, 18, 21, 24, 27, 30, 33, 36 and 39 steps per minute.[25] On a sample of 40 college men Lewis established reliability by the test-retest method, and in an oxygen intake comparison with the Balke Treadmill Test he found a validity coefficient of .89.[26] This progressive cadence step test, however, was based on heart rate recovery after each workload as was the case with most of those previously cited.

As far as can be determined from the related literature, all of the bench stepping field tests which were reviewed, except those of Balke,[27] Harrison[28] and Bayless,[29] were based either on recovery rate or, in the case of the Ohio State University Step Test[30] and Lewis's Progressive Cadence Step Test,[31] heart rate during exercise but monitored during a rest period between work bouts.

McArdle, Zwiren and Magel noted that heart rate recovery is not similar for all individuals, and this variable may introduce serious

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[24]Doyice J. Cotten, "A Modified Step Test for Group Cardiovascular Testing," Research Quarterly, 42:1 (March 1971), pp. 91-95.

[25]A. L. Lewis, "A Progressive Step Test to Predict Maximum Oxygen Intake," (unpublished D.Ed. Dissertation, Oklahoma State University) (July 1970), p. 12.

[26]Ibid.

[27]Balke.

[28]Harrison

[29]Bayless.

[30]Kurucz, Fox and Mathews.

[31]Lewis.

errors when the post-exercise heart rate is used to infer the heart rate during exercise.[32]

Balke,[33] Harrison,[34] and Bayless[35] did monitor heart rates during exercise, but their workloads were increased by raising the step height while maintaining a constant stepping rate.

Therefore, in summary, the uniqueness of this author's study was established in that no other single bench stepping field test was found which followed the procedure of monitoring heart rates during the exercises and in which the workloads were increased by progressive stepping cadences at a constant height bench.

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[32]William D. McArdle, Linda Zinda Zwiren and John R. Magel, "Validity of the Postexercise Heart Rate as a Means of Estimating Heart Rate During Work of Varying Intensities," Research Quarterly, 40:3 (Oct. 1969), p. 523.

[33]Balke.

[34]Harrison.

[35]Bayless.

CHAPTER III

PROCEDURE

As is the case in the development of any reliable field test, the bases and procedures upon which this test was founded had to first be established and validated in the laboratory.

Since this researcher is professionally concerned primarily with male college students, it was decided that this would be the appropriate group for whom this test should be designed. In order to limit the size of such a group somewhat, the minimum and maximum ages of 18 and 30 were arbitrarily assigned which would include most college freshmen as well as many graduate students. These subjects were volunteers from various physical education classes at Oklahoma State University with no specific selective process employed.

Before utilizing these subjects, however, it was necessary to develop a testing procedure.

The workload or intensity of an exercise can be increased by different methods. An overload, such as the use of weights, is one example. Another method is the changing of body position to render an exercise more difficult. Still another known fact is that doubling the speed of an exercise quadruples the stress put upon the performer.[1]

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[1]G. T. Stafford and E. D. Kelley, Preventive and Corrective Physical Education, New York: Ronald Press Co., 1959, p. 61.

It was the latter principle upon which this study was based. As previously mentioned it was also the intent of the study that this test be of submaximal intensity, or aerobic, in nature.

The bench height was determined arbitrarily but based on the fact that 14 inches is a height at which all the subjects could perform comfortably from a mechanical advantage standpoint, and also that this is the height of a locker room bench which would probably be readily accessible at most colleges.

The stepping cadences and time of exercise at each which evolved were arrived at for several reasons. A direct influence on the workload selection, however, was Waxman's modification of Cureton's Progressive Pulse Ratio Test for which he used cadences of 12, 18, 24, 30 and 36 steps per minute.[2] This author added one workload between each of Waxman's and extended the test one more period. It was felt that the number of exercise periods (10) would cause such a gradual increase from one to the next that none of the subjects would experience physical discomfort in progressing to the next faster cadence. This would also result in more refined heart rate readings during exercise.

In order to allow the subjects' heart rates time to "plateau" (level off) at each workload and yet not prolong the test unnecessarily, different lengths of time at each workload had to be researched.[3] This was accomplished through preliminary testing of subjects in the laboratory and by analyzing the physiograph tracings of their

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[2] Waxman.

[3] Karpovich, p. 168.

heart rates throughout the test. It was finally determined that one and one-half minutes of exercise was an adequate length of time for the heart rates to adjust to each cadence of stepping. For these workloads, then, only those subjects in excellent physical condition would be able to continue the work aerobically over the duration of the test, while the others would be stressed to their "crest load" of oxygen intake and consumption at which point the test would be terminated for them. Crest load can be defined as the highest level at which an individual can maintain a "steady state" or balance between oxygen intake and oxygen expenditure. This termination point would be ascertained by a heart rate of 180 beats per minute. The energy expended when the pulse reaches the 180 mark is considered to be the physical capacity of the individual. Nagle and Bedecki[4] used the Balke Treadmill Test and compared the results with those obtained during an all-out test. They found that the coefficient of correlation between the time needed for reaching the 180 pulse and the time of the all-out run was .85. The maximum length of this test for those subjects completing it would be 15 minutes. This time element also permitted the test to meet the design previously stated of consuming a period of time from a minimum of 7 minutes to a maximum of at least 12 minutes, but not longer than 20 minutes, where Balke found the minimum point to be at which aerobic work capacity could be realistically assessed.[5]

On these bases, the duration of time for each stepping rate was

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[4]F. J. Nagle and T. G. Bedecki, "Use of the 180 Heart Rate Response as a Measure of Circulorespiratory Capacity," Research Quarterly, 34 (1963), p. 361.

[5]Balke, p. 8.

established at one and one-half minutes, and the continuous workload cadences of 12, 15, 18, 21, 24, 27, 30, 33, 36 and 39 steps per minute were decided upon, perhaps making this test somewhat more discriminating than other similar tests.

Since the development of this test in the laboratory required various physiological measurements on each subject employing sophisticated technical equipment, the aforementioned subjects were also used to authenticate the testing procedure and to increase the skill of the author in the use of the equipment. Having determined the necessary measures and operational procedures, the testing of the subjects defined in this study was begun.

The basic laboratory measurements obtained on each subject included the resting heart rate, heart rate at each workload during exercise and the collection of expired air samples during the last thirty seconds of the last two workloads, as determined from the physiograph. It was from the latter information that the measures of oxygen intake and the norms of the fitness levels were determined.

The amount of energy used for an activity can be found by a procedure known as calorimetry. It may be found directly by measuring the amount of heat produced, or indirectly by calculating it from the amounts of oxygen absorbed and carbon dioxide eliminated.

The direct method, although it is the basic method for research in energetics, is rarely used because it requires elaborate equipment and a large staff of workers. It is also not applicable to activities of short duration. For these reasons the indirect method was used for this investigation.

There are two subdivisions of the indirect calorimetry procedure: the closed circuit and the open circuit methods.

In the closed circuit method, the subject inhales oxygen from a special spirometer. The exhaled gases pass through a carbon dioxide absorbent and go back into the spirometer. Subtraction of the amount of oxygen after the experiment from that of before gives the amount used up during the experiment. According to De Vries, the closed circuit method has the advantage of simplicity, but its accuracy is not much better than ± 10 per cent of the true value.[6] Furthermore, no value for the carbon dioxide produced is obtained, and consequently the respiratory quotient must be estimated.[7]

In the open circuit method, which was used for this study, the subject breathed atmospheric air. By means of a breathing valve, the subject's exhaled air was directed into a tissot tank where it could be accurately measured. Samples of the expired air were then analyzed for their oxygen and carbon dioxide content on the Godart Pulmo-Analyzer. Since the composition of atmospheric air is constant, 20.93 per cent oxygen, .03 per cent carbon dioxide, and 79.04 per cent nitrogen, and since the amount of expired air is known, it is possible to calculate the total percentages of oxygen consumed and carbon dioxide given off. These are the essential measures which must be determined. When the subjects' air samples have been injected through the Pulmo-Analyzer and the oxygen and carbon dioxide values have been ascertained, the percentages of these gases can be calculated by means of the Godart

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[6]De Vries, p. 150.

[7]Ibid., p. 151.

formula as described later in this chapter. Since nitrogen does not enter into physiological reactions, it is not necessary to have a measure of this gas.

The major portion of this research testing was accomplished during the years of 1970 and 1971, and the 54 subjects of this investigation who were scheduled for their tests in the laboratory at one-hour intervals were instructed to wear gym clothes and gym shoes.

Upon arrival at the laboratory, each subject was weighed, asked to remove his shirt, be seated in front of the 14 inch bench and to relax for one minute, after which his "resting" heart rate was taken by ausculation (stethoscope). Karpovich indicated that one minute is a sufficiently long period of time for the return of the pulse to normal depending upon the intensity of the exercise and upon the condition of the individual.[8] Also, during this time, the subject was having two E and M electrodes attached to his left chest, one being located in the sternal area and the other on the left side of the rib cage. These electrodes were then connected to an E and M wireless transmitter which was attached to the left back of the subject. The electrodes and transmitter were then strapped to the subject with an Ace elastic bandage to keep their movement against the skin to a minimum.

On a nearby table an E and M AM/FM telemetry receiver was positioned and connected to a physiograph recorder so that the subjects' heart rates could be monitored throughout the entire test. The paper speed of the physiograph was set at .5 centimeter per second. Before

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[8] Karpovich, p. 168.

beginning the test, resting heart rates were also recorded on the physiograph.

For the purposes of determining ventilation rates and collecting air samples for analysis, a Collins 100 Liter water-filled spirometer (Tissot Tank) was located next to the stepping bench. A Collins one-way breathing valve through which the subject would be breathing during the entire test was connected to this tank by means of a flexible tubing allowing the subject to inhale room air and to exhale into the tank. A valve on the tank permitted the subjects' expired air to be either exhausted into the room atmosphere or directed into the tank for storage. To prevent exhalation through the nose, a nose clip was worn by the subjects throughout the test. Small rubber bags which fit over an outlet valve on this tank were used to collect the air samples.

The cadences for the different stepping rates were pre-recorded on a cassette tape from an electric metronome beat, and the tape player was located on a nearby table within easy hearing distance of the subjects.

When the subject was prepared for exercise, he was asked to stand in readiness in front of the bench. The tape recorder was then turned on and the command, "Ready, exercise" was heard, and the recorded "click" of the electronic metronome was begun at a cadence of 12 steps per minute. This cadence is actually 48 beats of the metronome per minute since each "bench step" consists of a four beat count, i.e., (1) left foot up, (2) right foot up, (3) left foot down, (4) right foot down. At the end of one minute the recorded voice would say "thirty", indicating to the administrator of the test that it was time to monitor the heart rate from the physiograph tracings and also alerting the subject that in thirty seconds the stepping rhythm would be increased another three steps per minute with no resting period between working loads. However, at the end of each workload period, the recorded command of "ready, change" would precede the cadence increase. This procedure was identical for each successive workload. When it was apparent from the physiograph readings that the heart rate of the subject would attain 180 beats per minute within the next two workloads, the test administrator would direct the expired air of the subject into the Tissot Tank during the last thirty seconds of these final two workloads so that samples of this air could be collected in the small rubber bags for analysis. The minute volume of lung ventilation was also recorded during these last two thirty second periods.

The only other apparatus utilized in the laboratory procedure was a Godart Pulmo-Analyzer into which the subjects' expired air samples were injected and from which were obtained the oxygen and carbon dioxide readings necessary to compute their oxygen intakes. This instrument was switched on and allowed to warm up for at least thirty minutes before use to assure stabilization. The absorber tubes were cleaned and filled with fresh soda lime and calcium chloride, and the analyzer was ready for making carbon dioxide and oxygen readings. To calculate these percentages by the Godart method, the stylus deflection for carbon dioxide was simply divided by 6.63. For oxygen, the deflection was first multiplied by .086. This figure was then multiplied by the quotient of one minus the percentage of carbon dioxide over a constant of .7907 (one minus the percentage of oxygen in atmospheric air). The product of this multiplication was then subtracted from 20.93 (% oxygen in atmospheric air) to determine actual oxygen content of the air sample.[9] The carbon dioxide and oxygen percentages were then plotted on the Harvard Line Chart to determine respiratory quotient and true oxygen. The respiratory quotient and true oxygen, the ventilation reading from the Tissot Tank, and the Harvard Line Chart correction factor for barometric pressure and temperature were then utilized to calculate the oxygen intakes of the subjects. This method of calculating oxygen intake follows the procedure as described by Consolazio.[10] The form sheet for this procedure can be found in the Appendix on page 62. Each air sample from the subjects' last two workloads was processed through the analyzer twice to insure reliability of the readings.

Thus was established the laboratory testing procedure upon which this study was based.

To ascertain the reliability of this laboratory testing procedure, the first ten subjects were retested a few days later following the same procedure, and the results of the two tests were correlated to determine reliability coefficients of both heart rates and oxygen intakes.

Upon completion of all the subjects' tests and to further confirm reliability, this test-retest procedure was repeated with the last nine subjects. The same correlations were then computed on these two groups combined.

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

[10] C. Frank Consolazio, Robert E. Johnson and Louis J. Pecora, Physiological Measurements of Metabolic Functions in Man, New York, McGraw-Hill, 1963, pp. 8-9.

To determine the reliability of the field version of this progressive step test, it was administered to fifteen male college students between the ages of 18 and 30 at the home school of the writer (Northwestern State College of Oklahoma). These subjects were then retested within a week, and their heart rates on the original test and the retest were correlated with no oxygen measures being taken.

In this determination of the reliability of this test, the feasibility of the field testing procedure was also checked out, and it was found practical to monitor the subjects' heart rates during exercise with a stethoscope, and Lewis has shown that this method closely parallels the recordings of heart rates on the physiograph.[11] This could be somewhat of a limiting factor, however, in mass testing.

Thus, on the basis of the previously described laboratory procedure was developed this unique submaximal field-type step test predicted on oxygen intake prediction as a valid measure of individual physical efficiency.

The data collected from the foregoing laboratory tests were then tabulated, and the heart rates at the various workloads were correlated with the subjects' maximum oxygen intakes to determine if one particular submaximum workload could be used as a predictor of maximum oxygen intake and serve as a termination point of this test.

Finally, since this workload produced the highest heart rate-maximum oxygen intake correlation, a norm table was constructed from appropriate statistical scales for heart rates at 33 steps per minute in order to categorize the cardiorespiratory fitness levels of this

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[11]Lewis, p. 29.

group of subjects. Also, in order to predict maximum oxygen intakes from heart rates, regression equations were computed for each workload. Predicted maximum oxygen intakes were actually calculated for the range of heart rates of these subjects which were found at the specific workload of 33 steps per minute.

CHAPTER IV

RESULTS

In this study an attempt has been made to develop a physical fitness test which could be used by physical educators in the field to accurately assess the cardiorespiratory fitness of their students economically from both the time and equipment standpoints.

Oxygen intake is a basic parameter in most studies pertaining to work physiology. The ability to measure oxygen intake is therefore of fundamental importance to the field of physical education, especially relative to fitness testing.

When exercise is moderate and uniform, oxygen intake rises gradually and within a minute or two levels off and remains at this level for the duration of the exercise. This is a situation known as "steady state," where the oxygen intake is equal to the oxygen expenditure. The maximum steady state of an individual is called "crest load," and its magnitude depends on individual differences and on states of training. As an individual performs work, the percentage of oxygen in his expired air decreases until he reaches crest load. It is here that he attains his maximum oxygen intake. The greatest oxygen percentage in expired air recorded at crest load in this study was 17.7, and the lowest percentage was 14.0. The mean oxygen percentage of expired air was 16.64. These percentages can be observed in Table I.

As is the case with oxygen, the percentage of carbon dioxide in an individual's expired air indicates that work is being done, except that the volume of carbon dioxide will increase until crest load is reached. Likewise, it is also at this point that the individual attains his maximum oxygen intake. The highest carbon dioxide percentage in expired air recorded at crest load in this study was 6.2. The lowest carbon dioxide percentage was 3.21, and the mean percentage of carbon dioxide at crest load was 4.37. These percentages are also shown in Table I.

In order to complete the calculation of maximum oxygen intake, however, it was also necessary to obtain values for the following three items: (1) true oxygen, (2) respiratory quotient, and (3) corrected pulmonary ventilation.

Consolazio, Johnson and Pecora[1] state:

> 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 quality 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 .265-% O_2 in expired air) is the true oxygen.

Thus, based on these measurements, true oxygen can be calculated. However, for the purposes of this study the true oxygen percentages were determined from the Harvard Line Chart. The highest true oxygen percentage found at crest load for these subjects was 6.35, and the lowest percentage was 2.83. The mean crest load true oxygen percentage was 4.32, and these data may be observed in Table I.

The ratio of carbon dioxide given off to oxygen consumed during

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[1]Consolazio, Johnson and Pecora, p. 10.

activity is called the respiratory quotient (R.Q.). Karpovich states that under ordinary circumstances, athletes and hard-working people depend on carbohydrates and fats as the source of muscular energy.[2] Through laboratory tests it is possible to determine how much of each of these nutrients is used during muscular activity.

It has been found that when carbohydrate is oxidized, the volumes of carbon dioxide produced and oxygen consumed are equal. Since the proportion of hydrogen and oxygen in the molecule is the same as that of water, extra oxygen is needed only for the oxidation of carbon. Therefore, for every molecule of oxygen used, a molecule of carbon dioxide is released, and the resulting R. Q. for carbohydrate is 1.0.

When fat is oxidized, there is more oxygen consumed than carbon dioxide produced. The amount of oxygen present in fat is not sufficient for the oxidation of its hydrogen, so oxygen from the inspired air must be used for this process as well as for the oxidation of carbon. A resulting R.Q. for fat has been found to be 0.7.

Karpovich further notes that if exercise is of short duration, or long but not exhaustive, the respiratory quotient rises, while during prolonged and exhaustive work the R. Q. goes steadily down toward the 0.7 value, indicating a steady increase in dependence on fats.[3]

As can be seen, respiratory quotients can be calculated from laboratory measurements, but, as was the case with true oxygen, R. Q.'s used for this study were obtained from the Harvard Line Chart. The highest R. Q. recorded for these subjects was 1.42 which is unusually high, but de Vries explains that in heavy exercise it is common to find

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[3] Ibid., p. 47.

R. Q.'s above 1.00 brought about by "blowing off" more carbon dioxide than is forming metabolically.[4] Apparently for some of the subjects this step test would be considered "heavy" exercise. The lowest recorded R. Q. was .725, and the mean R. Q. was .99. These measures are shown in Table I.

De Vries defines pulmonary ventilation as the volume of air breathed per unit of time and notes that this rate is adjusted to metabolic demands for oxygen.[5] Other authorities such as Karpovich[6] and Morehouse and Miller[7] agree that a linear relationship exists between this minute-volume of lung ventilation and the rate of oxygen consumption until the intensity of work is so great that a steady state can no longer be maintained. In light of this information a correlation of the corrected ventilations of these subjects at crest load with their maximum oxygen intakes was computed. A resulting coefficient of .66 was found which tends to corroborate those conclusions.

Among the subjects of this study the highest corrected ventilation at crest load was found to be 107.892 L/min. and the lowest was 39.853 L/min. The mean corrected ventilation was 71.391 L/min. These measures may be observed in Table I.

Having acquired all of these data as described, the maximum oxygen intakes of the fifty-four subjects of this study were calculated. The

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[4]De Vries, p. 159.

[5]Ibid., p. 112

[6]Karpovich, p. 110.

[7]Laurence E. Morehouse and Augustus T. Miller, Jr., Physiology of Exercise, St. Louis, C. V. Mosby Co., 1971, p. 148.

highest, lowest and mean maximum oxygen intakes calculated in both liters per minute and milliliters per kilogram of body weight per minute are presented in Table I.

As has been explained, this investigator has accepted the theory of established authorities that a heart rate of 180 beats per minute is the crest load level of work at which time individual aerobic processes cease and anaerobic processes begin, so it was at this point that this progressive step test was terminated. Therefore, it might be of value if all the measures which were recorded for these subjects at this termination point were compiled at this time. These data may be observed in Table I.

TABLE I

MEAN CREST LOAD MEASURES FOR ALL SUBJECTS (N=54)

Measure	Range	Mean	S.D.
Oxygen Percentage (Expired Air)	14.0-17.7	16.64	.6048
Carbon Dioxide Percentage (Expired Air)	3.21-7.2	4.37	.6048
True Oxygen (%)	2.83-6.35	4.32	.7019
Respiratory Quotient (Ratio)	.725-1.42	.99	.1212
Corrected Ventilation (L/min.)	39.853-107.892	71.39	14.1373
Maximum Oxygen Intake (L/min.)	2.04-4.97	3.06	.5787
Maximum Oxygen Intake (Ml/kg/min.)	24-63	42.41	7.8399

As previously mentioned, the reliability of the laboratory tests was established following a test-retest procedure utilizing both heart rates and oxygen intakes.

Table II illustrates the test-retest heart rate reliability coefficients of the first ten subjects, and Table III shows the results of the same computations on the last nine subjects.

TABLE II

TEST-RETEST RELIABILITY COEFFICIENTS OF
HEART RATES OF FIRST TEN SUBJECTS

Workloads	N	r (Heart Rates)
24 steps/min.	10	.82
27	10	.82
30	10	.84
33	8	.76
36	5	.85

TABLE III

TEST-RETEST RELIABILITY COEFFICIENTS OF
HEART RATES OF LAST NINE SUBJECTS

Workloads	N	r (Heart Rates)
21 Steps/min.	9	.86
24	9	.92
27	9	.96
30	8	.96
33	5	.64

As further confirmation of reliability, Table IV shows the coefficients obtained from these two groups combined.

TABLE IV

TEST-RETEST RELIABILITY COEFFICIENTS OF HEART RATES
OF FIRST TEN AND LAST NINE SUBJECTS COMBINED

Workloads	N	r (Heart Rates)
24 steps/min.	19	.86
27	19	.84
30	18	.85
33	13	.70
36	7	.87

Reliability coefficients of oxygen intakes were also determined for these three groups, and Table V shows these results.

TABLE V

TEST-RETEST RELIABILITY COEFFICIENTS OF OXYGEN INTAKES OF FIRST TEN AND LAST NINE SUBJECTS AND BOTH GROUPS COMBINED

Group	N	r (O_2 Intakes)
First Ten	10	.81
Last Nine	9	.91
Combined	19	.79

The field version of this test was administered to fifteen subjects, and the test-retest procedure for reliability was also employed with this group. Table VI illustrates the reliability coefficients obtained from their compared heart rates.

According to Scott and French, a reliability coefficient of .75 and above is considered adequate for most purposes.[8] Since most of the reliability coefficients of this study were found to be above this level, the researched test and procedures were considered to be reliable measures.

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[8]M. Gladys Scott and Esther French, Measurement and Evaluation in Physical Education, Dubuque: Wm. C. Brown Co., 1959, p. 26.

TABLE VI

FIELD TEST RELIABILITY COEFFICIENTS OF HEART RATES

Workloads	N	r (Heart Rates)
24 Steps/min.	15	.77
27	15	.85
30	14	.89
33	9	.81
36	6	.55

Since the objective of this test was to determine the workloads at which the subjects arrived at crest load (a heart rate of 180 beats per minute), it was of interest to note at which workloads the various numbers of subjects attained this level. As can be observed from Figure 1, (page 42), none of the fifty-four laboratory subjects had reached crest load through 24 steps per minute. The greatest number of subjects (17) reached crest load at 36 steps per minute followed in order by the workloads of 33 (16 subjects), 30 (15 subjects), 39 (4 subjects) and 27 (2 subjects).

The field version of this test which was administered to the fifteen subjects at the author's home school (Northwestern State College) showed a somewhat similar pattern except that more subjects (5) attained crest loads at a workload of 30 steps per minute rather than at 36 which was next highest with 4 subjects. Following in order came the workloads of 33 with 3 subjects, 39 with 2 subjects and 27

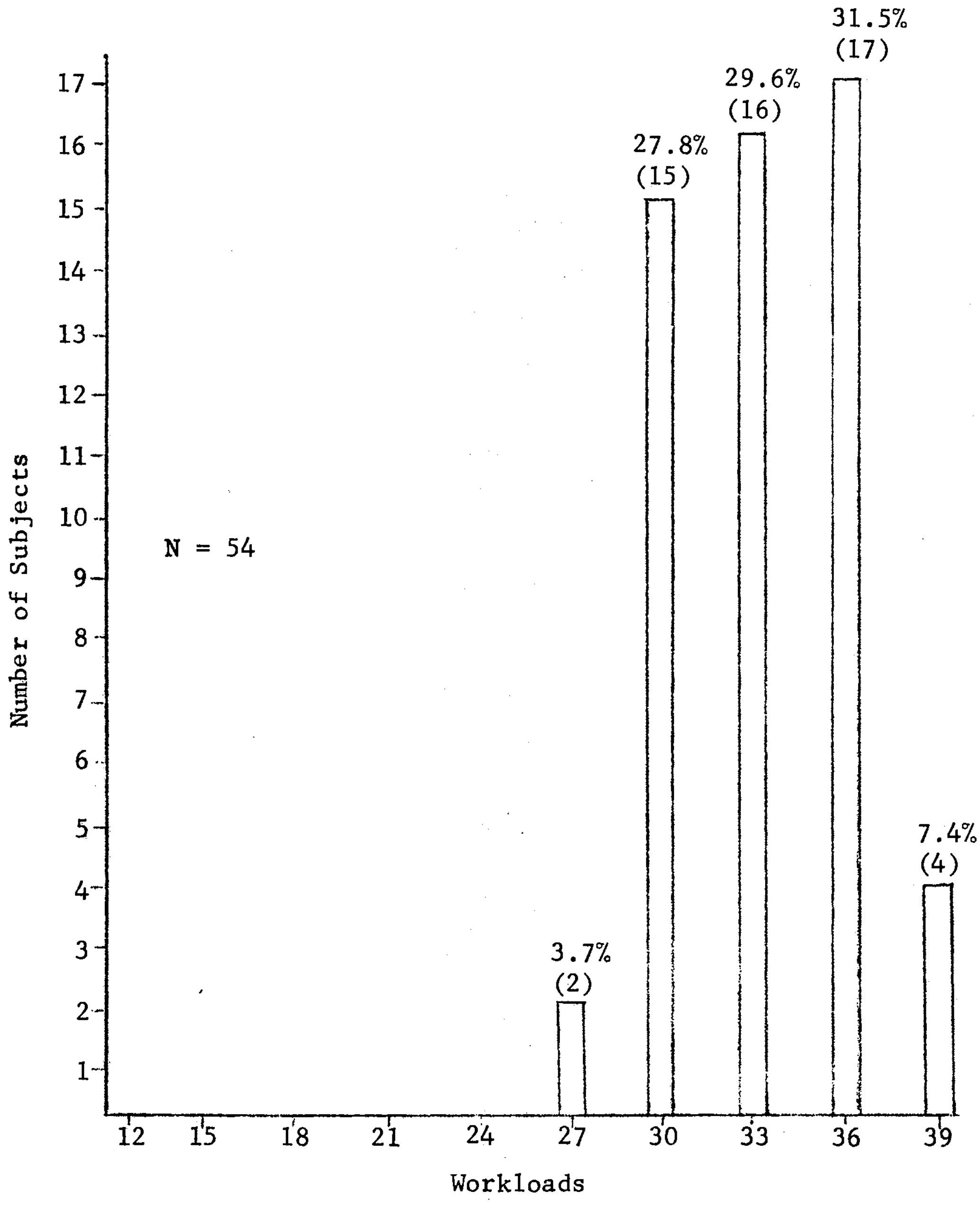

Figure 1. Workloads at which Laboratory Subjects Attained Crest Loads

with 1 subject. These results are graphically illustrated in Figure 2 (page 44).

To determine if there might be a specific workload from which a subject's cardiorespiratory fitness could be assessed whether or not he had attained crest load, it was necessary to correlate all the subjects' heart rates at each workload with their maximum oxygen intakes. It was discovered that, although the greatest number of subjects attained crest load at 36 steps per minute, the highest heart rate-oxygen intake correlation (-.76) was obtained at 33 steps per minute. These correlations for the other workloads, in descending order, were as follows: -.68 at 39 steps per minute, -.67 at 30 steps per minute, -.66 at 36 steps per minute, -.64 at 27 steps per minute, -.49 at 24 steps per minute, -.46 at 21 steps per minute, -.42 at 18 steps per minute, -.36 at 15 steps per minute and -.29 at 12 steps per minute. As was pointed out by Lewis,[9] these correlations are negative because for a group of subjects these two variables are inversely related. This means that the sooner a subject reaches crest load the smaller his oxygen intake will be compared with the other subjects who continue longer. However, for a single subject these two variables would have a positive relationship. The heart rate-maximum oxygen intake correlations at the various workloads are depicted in Figure 3.

Upon examination it can be observed that although the highest validity coefficient was found to be at 33 steps per minute, this workload actually yielded some of the lower reliability coefficients. However, since the heart rate-oxygen intake correlation of -.76 at 33

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[9] Lewis, p. 32.

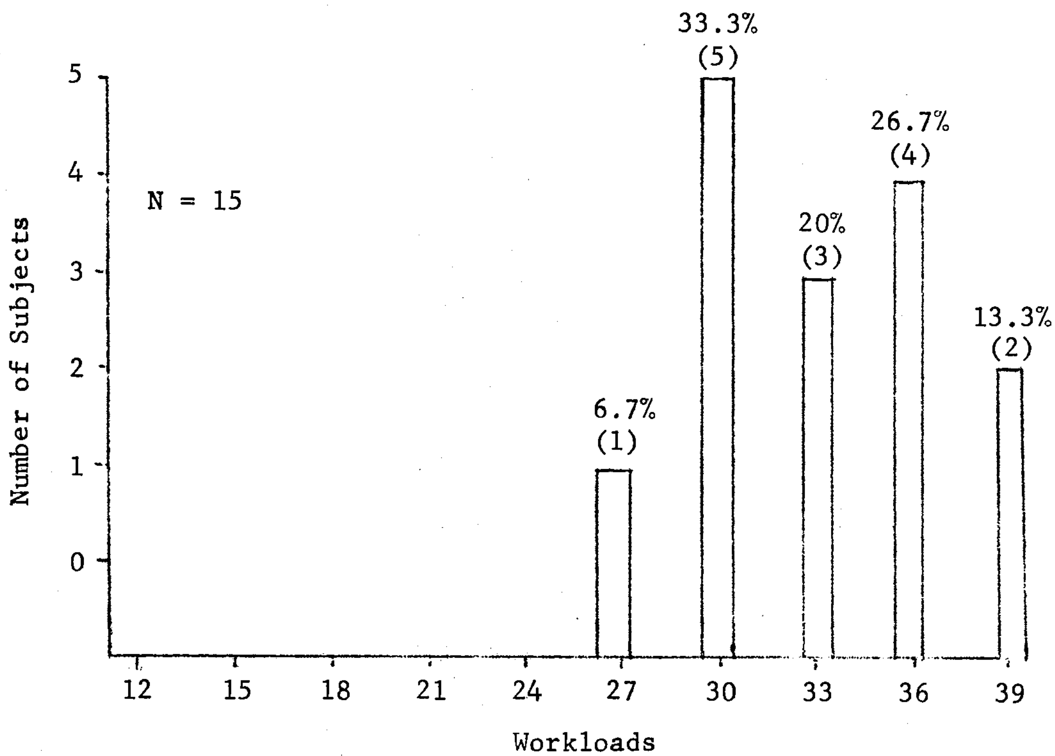

Figure 2. Workloads at which Northwestern State College Subjects Attained Crest Loads

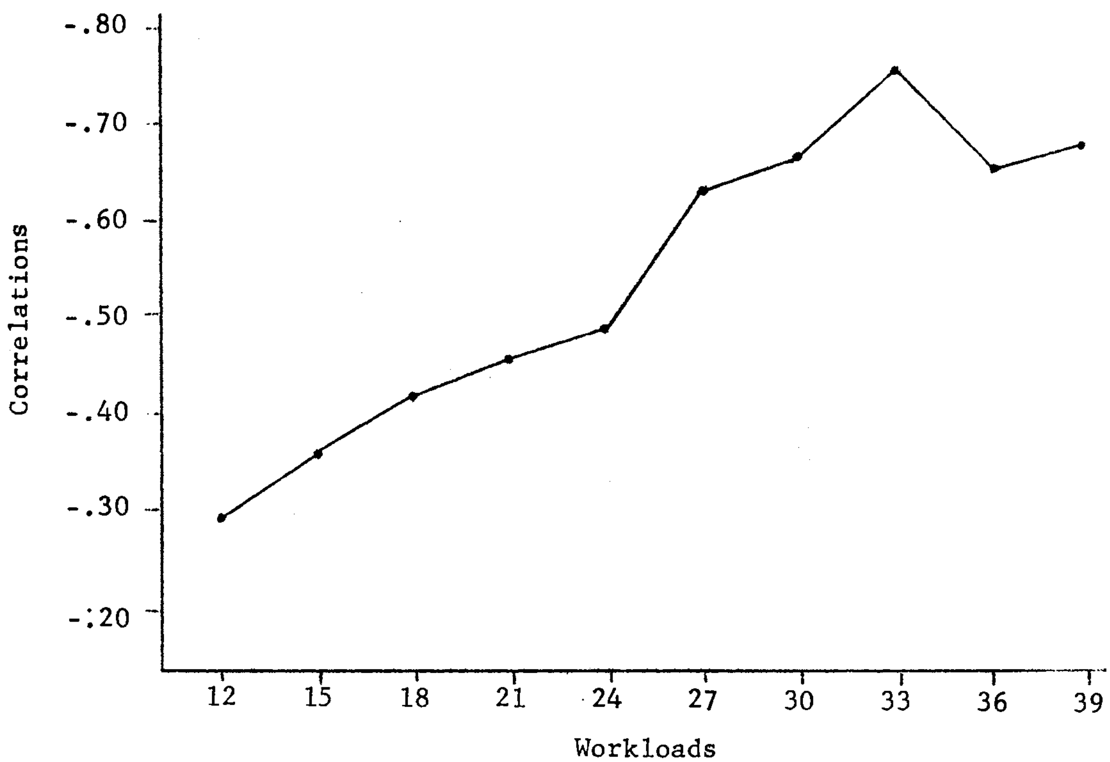

Figure 3. Heart Rate-Maximum Oxygen Intake Correlations at the Various Workloads

steps per minute was the only really adequate validity coefficient, this investigator is accepting the validity of this workload at the expense of better reliability coefficients of other workloads. This unusual consequence might have resolved itself with a greater number of subjects.

Based upon the foregoing information, it was decided that a workload of 33 steps per minute would serve as a satisfactory predictor of maximum oxygen intake for this test and this population. Thus the individuals being tested would not have to complete this progressive step test beyond that workload. At the cadence of 33 steps per minute the subject's heart rate would be determined by ascultation, and his cardiorespiratory fitness level could then be extrapolated from the constructed norms found in Table VII.

An example of the use of Table VII would be if a subject's heart rate at a workload of 33 steps per minute was monitored as 167 beats per minute, his cardiorespiratory fitness classification would be Above Average with a heart rate of 174 being Average. Numerically on the Sigma, T and Hull scales he would score 60, 56 and 55 respectively, with a score of 50 being the average.

According to Clarke, scales such as these, based upon standard deviation values of normal distributions, have been used extensively in health and physical education.[10] For these three scales the mean is 50; they differ in the positions of 0 and 100. Zero and 100 in the T-scale are minus and plus five standard deviations from the mean,

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[10] H. Harrison Clarke, Application of Measurement to Health and Physical Education, Englewood Cliffs, N. J., Prentice-Hall, Inc., 1967, p. 33.

while for the Sigma and Hull scales, these distances are three and 3.5 standard deviations below and above the mean respectively.

TABLE VII

PROGRESSIVE STEP TEST NORMS FOR MALE COLLEGE STUDENTS FROM 18-30 YEARS OF AGE

Heart Rate At 33 Steps/Min.	Cardiorespiratory Fitness Classification	Sigma Scale	T Scale	Hull Scale
141	Superior	100	80	95
148	Good	90	74	85
154		80	68	75
161	Above Average	70	62	65
167		60	56	55
174	Average	50	50	50
180	Below Average	40	44	45
187		30	38	35
194	Poor	20	32	25
200		10	26	15
207	Very Poor	0	20	5
Mean	173.9			
Standard Deviation	10.9			
N	39			

In order to further increase the worth of this progressive step test for the college physical educator, it was thought that it might be of value to be able to predict a subject's maximum oxygen intake from his heart rate as determined from any desired workload of this test. For this reason, using heart rates as the predictor variable and maximum oxygen intakes as the criterion variable, statistical regression equations and their standard errors of estimate were computed for each of the stepping rates. For the rationale and computational procedures of the regression technique, the reader is referred to Walker.[11] These workloads and their regression equations and standard errors of estimate are found in Table VIII.

As can be observed from Table VIII, the standard error of estimate for the workload of this study which was found to have the highest relationship with maximum oxygen intake (33 steps/min.) was computed to be ± 10.5692. This indicates that 68.3% of the time the actual measured maximum oxygen intake of a subject of this population will fall somewhere within ± 10.5692 Jl/kg/min. of the predicted maximum oxygen intake as determined from his heart rate for that workload.

For an example of the use of Table VIII, it would be possible to predict a subject's maximum oxygen intake from any of the workloads as shown in the table by merely substituting the monitored heart rate of the individual for the quantity X in the equation of the appropriate workload.

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[11]Ross Walker, A Compendium of Statistics for Physical Education, Champaign, Ill.: Stipes Publishing Co., pp. 101-116.

TABLE VIII

REGRESSION EQUATIONS AND STANDARD ERRORS OF ESTIMATE FOR PREDICTION OF MAXIMUM OXYGEN INTAKE FOR ALL WORKLOADS

Workloads	Regression Equations	Standard Errors of Estimate
12 steps/min.	$\tilde{Y} = -.1223\ X + 56.1865$	$\pm$ 9.6042
15	$\tilde{Y} = -.1776\ X + 63.6799$	$\pm$ 10.0693
18	$\tilde{Y} = -.2180\ X + 70.2387$	$\pm$ 10.1547
21	$\tilde{Y} = -.2193\ X + 72.3540$	$\pm$ 10.2269
24	$\tilde{Y} = -.2690\ X + 81.7711$	$\pm$ 10.5775
27	$\tilde{Y} = -.2877\ X + 88.2156$	$\pm$ 10.3474
30	$\tilde{Y} = -.3378\ X + 99.6391$	$\pm$ 10.1704
33	$\tilde{Y} = -.4383\ X + 119.7856$	$\pm$ 10.5692
36	$\tilde{Y} = -.0982\ X + 65.7583$	$\pm$ 7.4147
39	$\tilde{Y} = -.0779\ X + 64.9550$	$\pm$ 5.8337

Since this study found the workload of 33 steps per minute to have the highest validity correlation with maximum oxygen intake (-.76), and for the convenience of the reader, Table IX shows the predicted maximum oxygen intakes which have been worked out for the range of heart rates of these subjects found at this workload.

TABLE IX

PREDICTED MAXIMUM OXYGEN INTAKE TABLE FOR HEART RATES AT WORKLOAD OF 33 STEPS PER MINUTE

X (Heart Rate)	$\tilde{Y}$ (Predicted Maximum O_2 Intake)
130 beats/min.	63 Ml/kg/min.
135	61
140	58
145	56
150	54
155	52
160	50
165	47
170	45
175	43
180	41
185	39
190	37

As an example of the use of Table IX, if at the workload of 33 steps per minute a subject's heart rate was monitored as 150 beats per minute it can be observed that his predicted maximum oxygen intake would be 54 Ml/kg/min.

Both Balke[12] and Cooper[13] have developed norm tables for classifying an individual's cardiorespiratory fitness according to his maximum oxygen intake. These oxygen intake values and their fitness categories are reproduced in Tables X and XI, respectively.

TABLE X

BALKE'S MAXIMUM OXYGEN INTAKE NORMS AND CARDIORESPIRATORY FITNESS LEVELS

Maximum O_2 Intake	Cardiorespiratory Fitness Level
30-35 Ml/kg/min.	Poor
35-40	Average or Fair
40-45	Good
45-50	Very Good
50-55	Excellent

Thus, an administrator of this progressive step test would have at his disposal two options for determining the cardiorespiratory fitness of his subject. He could either monitor the subject's heart rate at the workload of 33 steps per minute and determine his cardiorespiratory fitness classification from the norm table for this step test found on

[12]Balke, p. 8.

[13]Kenneth H. Cooper, The New Aerobics, New York: M. Evans and Co., Inc., 1970, p. 28.

page 47, or if the subject's heart rate reached 180 beats per minute before this workload it would be necessary to determine his predicted maximum oxygen intake by employing the appropriate regression equation found in Table VIII. The subject's cardiorespiratory fitness level could then be determined from either Balke's or Cooper's maximum oxygen intake norms.

TABLE XI

COOPER'S MAXIMUM OXYGEN INTAKE NORMS AND CARDIORESPIRATORY FITNESS LEVELS

Maximum O_2 Intake	Cardiorespiratory Fitness Level
-25.0 Ml/kg/min.	Very Poor
25.0-33.7	Poor
33.8-42.5	Fair
42.6-51.5	Good
51.6+	Excellent

A comparison of these options reveals a marked similarity. For example, from the norm table of heart rates at 33 steps per minute a heart rate of 200 beats per minute is categorized as poor. Substituting this quantity in the regression equation for the same workload a predicted maximum oxygen intake of 32.1265 Ml/kg/min. results which would also fall into the poor categories of both Balke and Cooper. At the other extreme, a heart rate of 141 beats per minute at 33 steps per minute rates a superior classification from the norm table for that workload. From the regression equation a predicted maximum oxygen intake of 57.9862 Ml/kg/min. is obtained which falls into the excellent categories of both Balke and Cooper. Although Lewis' heart rate norm table was developed for the workload of 30 steps per minute, there is also a close similarity between his and the norm table of this author.[14]

[14]Lewis, p. 45.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Cardiorespiratory fitness or, as it is referred to by de Vries, the concept of physical working capacity (PWC),[1] has gained wide acceptance among physiologists, pediatricians, cardiologists and other members of the medical profession. Much could be gained by wider usage of this concept in the physical education profession. First, a unification of thought between physical education and the medical professions would be most beneficial to both. Second, this type of testing would provide a motivating factor for students in physical education who are not well enough endowed in the skill aspects to compete successfully with their peers.

That cardiorespiratory fitness testing is not widely used in physical education might be attributed to three factors: (1) physical educators' inability to perform these analyses, (2) lack of facilities and (3) classes that are too large to permit sufficient attention to individual testing. This progressive step test resolves those negative approaches to this concept.

A review of the literature also suggests a need for still another practical and inexpensive field-type test to further enable physical educators to assess and categorize the cardiorespiratory fitness levels

[1]De Vries, p. 205.

of their students. It can readily be seen that cardiorespiratory testing is needed in the well-rounded physical education curriculum.

Johnson and Nelson recognize correlation coefficients of ± .70 to ± .99 as indicating a high relationship depending upon the complexity of the dependent variables and other attendant factors.[2]

Upon these bases, then, this study has produced data which indicate that this progressive step test based on maximum oxygen intake is a reliable measure and valid predictor of the cardiorespiratory fitness of college men.

On the basis of these data collected in this study the following conclusions were made:

1. This is a reliable test procedure.

    a. laboratory test-retest of heart rates (.70).

    b. laboratory test-retest of oxygen intake measures (.79).

    c. field test-retest of heart rates (.81).

2. This progressive step test is a valid measure of the cardiorespiratory fitness of college men (-.76, heart rates to maximum oxygen intakes at 33 steps per minute).

3. The field test version of this test is reliable (.81).

4. Heart rates can be monitored by auscultation (stethoscope) during the work bouts.

5. One and one-half minutes is a sufficient length of time per workload for allowing heart rates to adjust, or plateau.

6. For this test heart rates at the workload of 33 steps per

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[2]Barry L. Johnson and Jack K. Nelson, Practical Measurements for Evaluation in Physical Education, Minneapolis: Burgess Publishing Co., 1969, p. 36.

minute are the best predictors of maximum oxygen intake.

7. The workload of 33 steps per minute should be the termination point for this test.

8. An estimated maximum oxygen intake can be predicted from heart rates at various workloads.

Recommendations

As a result of the data collected the following recommendations may be made to the physical educator wishing to use this progressive step test in the field:

1. Tape record the field test procedure and cadences (stepping rhythms). See Appendix for complete procedure.

2. Have all individuals who will be participating in this test practice both stepping and monitoring heart rates before the day of the test to eliminate or reduce apprehension and to avoid any misunderstanding of instructions.

3. If testing a group allow a space approximately 18 inches wide on the bench for each individual.

4. Stabilize the benches to prevent rocking or tipping in the event a subject trips while stepping.

5. Be sure subjects' knees and hips are completely extended on each step-up.

6. Post Norm Table and make known the results of the test to the subjects so they may determine how they are classified as to fitness.

Recommendations for Further Study

The following recommendations for further investigations of this progressive step test as an instrument for measuring cardiorespiratory fitness might be made as a result of this study:

1. If this test be replicated the calculated maximum oxygen intakes should be validated against the predicted maximum oxygen intakes as determined by the Balke-Treadmill Test.

2. Norms for this test should be established for college women as well as for boys and girls at the elementary and secondary educational levels.

3. Experimentation with higher benches of from 15 to 20 inches might shorten this test by increasing its intensity thus lowering the workload termination point from 33 steps per minute.

4. Further research of this step test might indicate that the first two workloads could be eliminated, also shortening the time necessary for its administration.

5. This progressive step test might be researched in different geographical locations for comparison of results.

It is the hope of this writer that as a result of this research another valid and reliable physical fitness assessing field test has been developed which will provide yet another vehicle for fulfilling someone's needs and/or which will provide a controversial issue which might evoke further research, thus contributing to the expansion of the knowledge in the profession of physical education.

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APPENDIXES

LABORATORY O_2 INTAKE CALCULATION

Subject________________________ Date________________

Age______________ Height________ Weight______________

Temperature (degree C.)_______ B.P. (mm.Hg.)________________

Correction factor by Harvard line chart______________________

A. Workload:_______________steps per min.

1. O_2% = ______________
2. CO_2% = ______________
3. R.Q. = ______________ (from Harvard line chart)
4. True O_2 = ____________ (from Harvard line chart)
5. Vent./min. = $\frac{\quad}{10}$(Kymo.mm.)=____x 1.332 = ____L/min.
6. Corr. vent. = $\frac{\quad}{\text{vent}}$ x $\frac{\quad}{\text{corr fact}}$ = L./min.
7. O_2 Intake = True O_2 x corr. vent. = $\frac{x}{100}$ = L./min.

B. Workload:_______________steps per min.

1. O_2% = ______________
2. CO_2% = ______________
3. R.Q. = ______________ (from Harvard line chart)
4. True O_2 = ____________ (from Harvard line chart)
5. Vent./min. = $\frac{\quad}{10}$(Kymo.mm.)=____ x 1.332 = ____L/min.
6. Corr. vent. = $\frac{\quad}{\text{vent}}$ x $\frac{\quad}{\text{corr fact}}$ = ____L./min.
7. O_2 Intake - True O_2 x corr. vent. = $\frac{x}{100}$ = L./min.

RECOMMENDED FIELD TEST PROCEDURE

The equipment necessary for the field version of this test would be a recording of the metronome beats of the ten stepping cadences, a watch or wall clock with a sweep second hand, an elastic bandage, a stethoscope fitted with a three and one-half foot length of surgical tubing leading to the diaphragm and a bench 15 inches in height.

Prior to beginning the test the subject would be asked to sit in front of the bench for one minute. During this rest period the diaphragm of the stethoscope would be strapped to the left chest of the subject with the elastic wrap so his heart rate could be monitored by the test administrator during the exercise.

When properly prepared the subject would be recorded by the test administrator during the last thirty seconds of each workload, and the test would be terminated after completing the workload of 33 steps per minute. The cardiorespiratory fitness of the subject could then be determined from the norm table according to his heart rate at that workload. Since this is a submaximal test it would also be terminated for any subject whose heart rate reached 180 beats per minute prior to this workload. In this instance his predicted maximum oxygen intake would have to be figured for a heart rate of 180 by the appropriate regression equation for that workload. It would then be necessary to refer to either Balke's or Cooper's maximum oxygen intake norm table to determine the cardiorespiratory fitness level of this individual

	Heart Rates at Various Workloads										Max O_2 Intakes						
Subject	12	15	18	21	24	27	30	33	36	39	L/min.	Ml/kg/ min.	O_2%	R.Q.	True O_2	CO_2%	Corr. Vent.
Brannan	102	114	120	126	138	150	168	174	180		2.56	46	16.14	.85	4.95	4.26	51.7882
Brown	132	138	150	162	174	180					2.79	39	16.40	1.05	4.52	4.58	61.6440
Campbell	114	126	138	138	144	162	174	180			2.48	33	15.90	1.00	5.05	5.05	49.0780
Cox	108	114	126	138	156	168	174	180			2.18	45	16.80	1.01	3.69	5.90	59.0760
Coyle	126	138	138	150	156	162	168	174	180		3.31	38	16.96	.97	4.00	3.92	82.7172
Doughty	102	108	120	126	138	168	168	174	186		3.66	53	17.00	1.21	4.83	4.60	75.8700
Finefrock	108	114	120	138	150	168	174	180			2.92	39	17.08	1.11	3.71	4.22	78.7878
Fujita	96	108	114	120	126	138	150	156	162	176	2.87	47	16.43	.96	4.53	4.37	63.3046
Gibson	102	114	114	126	138	156	168	180			2.57	34	16.70	.88	4.33	3.86	59.2740
Gladden	126	126	132	150	168	180					2.33	38	16.51	1.00	4.42	4.45	52.6060
Hall	126	138	144	150	162	174	186				3.30	48	15.60	.80	6.30	5.05	52.2783
Holding	132	144	150	162	168	174	186				3.01	42	16.64	.86	4.41	3.85	64.9377
Howard	120	131	132	144	156	168	180				2.59	38	16.80	.88	4.23	3.77	61.1708
Jaeb	108	120	138	144	150	168	174	186			2.28	27	16.20	1.42	4.36	6.20	52.2780
Keene	114	126	132	144	162	174	180				3.10	41	16.80	1.73	4.38	3.21	70.7985
Keller	120	120	120	132	138	144	150	162	174	180	3.57	59	16.50	.91	4.51	5.15	79.1901
Lee	120	120	132	138	138	156	168	174	180		3.01	52	17.00	1.04	3.90	4.10	77.0560
Manley	120	126	138	144	156	168	180				2.88	43	16.41	.85	4.66	4.00	61.8581
Mason	102	102	108	120	126	144	162	174	186		5.53	44	17.18	1.13	3.65	4.15	96.6233
Nelson	138	144	150	156	168	174	180				2.53	30	14.00	.92	6.35	5.85	39.[illegible]530
Orr	108	114	120	126	139	150	162	174	186		3.36	45	16.67	1.04	4.22	4.45	79.6643
Patrick	108	108	114	120	126	144	162	168	180		3.76	48	16.71	1.13	4.12	4.68	91.1514
Pellissier	108	126	132	138	150	156	162	168	180		3.31	43	16.43	.96	4.54	4.37	72.7885
Phelan	108	114	126	126	144	156	162	174	180		3.11	44	16.83	.98	4.11	4.07	75.6336
Phillips	114	114	126	138	150	162	180				2.71	36	15.87	.88	5.20	4.60	52.1611
Propes	108	120	126	144	150	162	174	180			3.05	41	17.24	.99	3.68	3.70	82.9836
Quisenberry	102	108	114	120	138	150	162	168	186		3.45	49	16.03	.94	4.97	4.68	69.4691
Robbins	108	108	114	132	132	156	168	174	186		3.38	52	16.52	1.02	2.40	4.52	76.8191
Sears	102	108	120	132	150	162	174	186			2.44	30	17.70	1.11	2.83	4.80	86.2710
Shields	114	120	120	120	144	150	168	174	180		2.50	36	17.70	1.29	3.05	3.95	82.0352
Simpson	114	120	132	144	156	168	174	186			2.84	41	16.34	.99	4.60	4.60	61.6450
Smith	120	138	150	156	162	168	174	180			2.11	32	17.43	1.01	3.49	3.55	60.4195
Sonnenberg	114	120	132	144	162	174	180				3.42	40	16.60	1.00	4.33	4.35	78.9520
Staiger	138	138	144	150	150	162	174	180			2.93	41	16.14	.96	4.83	4.68	60.6966
Stites	90	102	108	114	126	162	174	186			2.86	42	16.65	.93	4.35	4.07	63.0675
Stravlo	114	120	126	132	138	138	156	162	174	186	3.35	53	16.89	1.02	4.01	4.15	83.4365
Thrasher	102	102	108	114	114	126	138	156	168	180	3.16	52	16.08	.94	4.92	4.68	61.6450
Acken	114	126	132	144	156	168	174	186			2.59	38	17.60	1.28	3.15	4.05	82.2377
Furrow	102	114	126	138	150	168	180				2.41	33	17.14	.94	3.82	3.62	63.0675
Rosson	114	120	132	138	144	150	156	174	180		4.72	63	15.69	.92	5.97	5.51	79.1315
Rouse	114	114	126	132	144	168	180				3.39	47	16.86	.94	4.11	3.92	78.2417
Cravens	108	126	126	144	156	162	174	180			2.90	39	16.57	1.01	4.35	4.44	66.6533
Chaloupecky	90	90	96	102	108	108	120	132	146	160	3.60	51	16.72	1.04	4.18	4.37	68.3316
Barnard	126	138	144	150	156	168	180				2.45	40	16.98	.93	4.00	3.77	61.1708
Christian	102	108	120	126	138	162	174	180			3.37	43	16.82	1.02	4.10	4.22	82.2723
Finley	120	126	138	150	162	174	186				3.70	40	17.21	.97	3.74	3.66	98.8690
Glenn	126	126	138	150	162	168	180				3.17	36	16.43	.95	4.55	4.37	69.7062
Kasti	120	120	132	138	144	156	168	180			2.95	42	16.06	.94	4.95	4.68	59.5111
Rehl	102	108	114	126	138	150	162	168	180		2.92	45	16.50	.99	4.43	4.41	65.9127
Shaw	96	96	108	114	120	132	144	156	174	180	3.04	45	17.55	1.08	3.32	3.62	91.5191
Chappel	120	126	132	138	144	162	162	174	180		4.97	54	16.49	.83	4.61	3.85	1[illegible].8920
Nine	108	120	126	132	138	150	162	168	180		3.85	53	16.40	.91	4.62	4.22	83.2207
Werling	120	138	144	156	162	168	180	186			3.90	48	17.01	1.00	3.92	3.96	99.5803
Cummings	114	120	132	138	150	168	180	192			2.04	24	17.40	1.14	2.96	5.75	68.7570

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