THE EFFECT OF DIFFERENT STEPPING LEVELS AND COMPUTATIONAL METHODS UPON THE APPRAISAL OF CARDIOVASCULAR EFFICIENCY AMONG FEMALES OF SELECTED HEIGHTS

by

Kathryn L. Doughty

Approved by:

Vaughn K. Christian
Chairman, Thesis Committee

Judy R. Clarke
Associate Professor of Health and Physical Education

Jay T. Kearney
Assistant Professor of Health and Physical Education

Edward T. Turner
Chairman, Department of Health and Physical Education or Coordinator of Graduate Studies Department of Health and Physical Education

B. F. Strickland
Dean of the Graduate School

THE EFFECT OF DIFFERENT STEPPING LEVELS AND COMPUTATIONAL METHODS UPON THE APPRAISAL OF CARDIOVASCULAR EFFICIENCY AMONG FEMALES OF SELECTED HEIGHTS

A Thesis

Submitted to the Graduate Faculty of Appalachian
State University in Partial Fulfillment of the
Requirement for the Degree Master
of Art
in
The Department of Health, Physical Education, and Recreation

by

Kathryn L. Doughty
B. A., Roanoke College, 1972

July, 1973

ACKNOWLEDGEMENTS

The investigator would like to express her appreciation to Dr. Vaughn K. Christian for his encouragement and professional guidance in the completion of this research project. In addition, the investigator would like to thank Miss Mary Kresge and Miss Lynn Deal for their assistance in the collection of the data.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF CHARTS

Chart | Page

ABSTRACT

The purpose of the study was to analyze differences among four computations of the cardiovascular index scores obtained between two groups of females during three conditions of bench stepping. The subjects consisted of fifty-eight females enrolled at Appalachian State University during spring quarter of 1973. Group I was composed of twenty-nine females with standing heights of 61-63 inches; Group II was composed of twenty-nine females with standing heights of 67-69 inches.

Each subject was required to perform a stepping task at levels of thirteen inches, twenty-one inches, and a height adjusted to the height of the subject's patella at a rate of twenty-four steps per minute for three minutes. Heart rate was monitored throughout the testing session by means of a Schwinn Heart Rate Indicator. Prior to exercise, two consecutive heart rate readings were taken and during exercise, readings were taken at thirty second intervals for the 180 second exercise period. Recovery heart rates were taken at one, two, and three minutes following the cessation of exercise.

Four methods of computing the cardiovascular indices were utilized: the classical computation, the rapid computation, the new classical and the new and rapid (NARSS) computation. Data from each method of computation was analyzed through a two by three, repeated measures, analysis of variance to determine the difference between the height groups, stepping levels, and the interaction of these variables upon the computed cardiovascular indices.

The findings of the study were as follows:

1. The difference between the height groups' cardiovascular indices was not significant for all experimental conditions regardless of the method employed to compute the indices.

2. The classical computation of the cardiovascular indices yielded significantly higher cardiovascular indices at thirteen inches than at twenty-one inches; patella height yielded significantly higher indices than at twenty-one inches.

3. The rapid computation of the cardiovascular indices yielded significantly higher cardiovascular indices at thirteen inches than at twenty-one inches; patella height yielded significantly higher indices than at twenty-one inches.

4. There was a significant difference among the cardiovascular indices as computed by the new classical computation in favor of the thirteen inch stepping level.

5. There was a significant difference among the cardiovascular indices computed by the NARSS computation in favor of the thirteen inch stepping level.

6. The four computational methods yielded non-significant interactions between the effects of height groups and stepping levels on the cardiovascular indices.

The following conclusions were drawn from the study:

1. Differences in individual standing heights do not affect computed cardiovascular indices derived from a stepping task.

2. Lower stepping levels will increase cardiovascular indices, regardless of individual standing height.

3. The four computational methods for the cardiovascular indices: the classical, the rapid, the new classical, and the NARSS are valid computational methods of cardiovascular efficiency.

CHAPTER I

INTRODUCTION

The development of adequate levels of physical fitness and a means of evaluating levels of physical fitness has received notable consideration in recent years. This prominent increase has been the outgrowth of studies which have shown that a physically fit individual has an increased sense of well-being and reduced fatigability. Also, evidence suggests that myocardial infarction was reduced in a physically active person.[1]

"Physical fitness may be defined as the complex of qualities which enables the individual to perform physical activity."[2] Often, the aspect of cardiovascular efficiency has been measured to determine the degree of physical fitness. A variety of step tests, treadmill tests, and the bicycle ergometer tests have emerged as means of assessing cardiovascular efficiency. Quite often the Harvard Step Test or a variation of the step test has been employed.

Physical activity elicits adaptations that allow the body to perform additional activity. Physiological adaptations occur locally and are accompanied by total body adjustments which are often striking, especially

---

[1] J. L. Patterson, A. Graybiel, H. F. Lenhcrdt, and M. J. Madson, "The Evaluation and Prediction of Physical Fitness, Utilizing Modified Apparatus of the Harvard Step Test," American Journal of Cardiology, XIV (1964), p. 811.

[2] Ibid.

in the cardiovascular system.[3] Brouha and Radford indicate that oxygen consumption and cardiac output can be maintained at a steady state with submaximal effort. During maximal effort oxygen consumption reaches its upper limits and the muscles rely heavily on anaerobic processes, decreasing the duration of muscular activity. Maximum oxygen consumption depends on the limitations of total cardiac output. The circulatory responses of the individual play an important part in determining that individual's ability to continue to exercise because of the importance of cardiovascular adaptation during exercise.[4] If the continuance in exercise depends upon cardiac output, then cardiac efficiency can be described as the body's ability to adjust to and recover from strenuous muscular activity over an extended period. The Harvard Step Test is a very appropriate test of cardiovascular efficiency. The test is strenuous, relatively lengthy, and can be administered to a number of subjects without sophisticated apparatus.

In addition to the evaluation of fitness, the stepping task has been used by researchers to develop cardiovascular fitness. Weber and Knowlton conducted research concerning a comparison of physique and performance measures resulting from short-term fitness courses. Using male college freshmen as subjects, the researchers employed the Harvard Step Test as one of the training methods in the short-term physical fitness courses. The results of the research indicated desirable circulorespiratory changes in the subjects.

---

[3]Elwood Davis and Gene Logan, Biophysical Values of Muscular Activity with Implications for Research (Dubuque, Iowa: William C. Brown Company, 1961), pp. 58-59.

[4]Lucien Brouha and Edward P. Radford, Jr., "The Cardiovascular System in Muscular Activity," Science and Medicine of Exercise and Sports, ed. Warren R. Johnson (New York: Harper and Brothers, 1960), p. 178.

The Harvard Step Test scores decreased from 187.19 to 172.71, or 14.48 mean pulse beats per minute.[5]

Since its development during World War II, the reliability of the step test has become an important factor. Meyers conducted a study investigating the reliability of the Harvard Step Test. A reliability coefficient of .65 was found and was considered creditable since pulse readings had been taken by inexperienced subjects.[6]

However, when the Harvard Step Test was performed or the physical fitness indices were computed, no adjustment factor was considered for individual differences in height. The investigator has observed in previous research involving a step test that individuals of shorter stature subjectively appeared to exert more effort when performing the task than did individuals with greater standing height.[7] Since the subjects of shorter stature appeared to exert greater effort during the step test than did individuals of greater standing height, it would seem logical that the heart rate would increase to a greater degree thus prolonging the recovery rates for the shorter subjects.

---

[5]Herbert Weber and Ronald G. Knowlton, "A Comparative Study of Physique and Performance Measures Resulting from a Short-Term Physical Fitness Course," The Research Quarterly, XXXIX (December, 1968), p. 1113.

[6]Carlton R. Meyers, "A Study of the Reliability of the Harvard Step Test," The Research Quarterly, XL (May, 1969), p. 423.

[7]Kathy Doughty, "The Effect of Variant Temperature on Heart Rate in Female Athletes," An Independent Study (Roanoke College, 1972).

The amount of force exerted when an individual steps upon a stepping platform depends upon the angle of pull of the muscle. Mechanically, the most efficient angle of pull which would produce the most efficient force is the pull at a right angle to the lever.[8] The force arm is longest at this position creating the greatest moment of force and securing the greatest mechanical advantage.[9] The greater the deviation from the right angle, the less efficient is the angle of pull.[10]

Such is the case when persons of shorter stature are required to bench step at the identical levels as those of taller stature. For those of shorter stature, the angle of pull of the muscle at the hip and knee joints is less than a right angle which decreases the efficiency of force. One must assume that the decrease in efficiency results in an increase in the workload. An additional load could result in earlier fatigue due to the increased production of lactic acid which introduces a corresponding increase in heart rate to assist in the removal of metabolic waste products. One must also assume that individuals of greater standing height bench step with the angle of pull of the muscle at the hip and knee joints approaching a right angle. Hence, the more efficient force is produced and the physical exertion is reduced. Heart rate is reduced and recovery occurs more quickly as indicated by a higher cardiovascular fitness index. Therefore,

---

[8] Laurence E. Morehouse and Augustus T. Miller, Jr., Physiology of Exercise (St. Louis: C. V. Mosby Co., 1963), p. 82.

[9] John W. Bunn, Scientific Principles of Coaching (New York: Prentice-Hall, 1955), p. 51.

[10] Morehouse and Miller, loc. cit.

can the results of the step test be considered valid measures of cardiovascular efficiency?

Frequently the long or short form computation for the Harvard Step Test is employed in computing the index score. However, neither formula considers individual differences in total stepping time. It is possible for one who steps for a shorter period of time to have a higher index score than one who completed the required stepping bout. A reduction in stepping time results in rapid heart recovery and a higher index score.

There appears to be a dearth of information dealing with the Harvard Step Test in the areas of differences in standing heights and various methods of computing the Harvard Step Test cardiovascular index score. This study will investigate these areas to determine any differences.

STATEMENT OF THE PROBLEM

What are the discrepancies in the cardiovascular indices resulting from different stepping levels among individuals of selected heights and the different methods of computing the cardiovascular indices?

PURPOSE OF THE STUDY

The purpose of the study was to analyze differences among four computations of the cardiovascular index scores obtained between one group of females having a standing height of 61-63 inches and a second group having a standing height of 67-69 inches, during three conditions of bench stepping.

DEFINITION OF TERMS

Cardiovascular Efficiency - The ability of the circulatory and respiratory systems to adjust to and recover from prolonged, strenuous exercise.

Adjustable Stepping Platform - A platform that can be adjusted from levels of ten inches through thirty inches, depending on the desired level of the experimental condition.

Schwinn Heart Rate Indicator - A battery operated Schwinn Heart Rate Indicator, Model X-21, utilizing electrodes attached to the subject's chest which reflected the subject's heart rate on a visual indicator.

Inning - One inning of bench stepping consisted of the subject stepping upon the platform with the foot of their choice and bringing the remaining foot beside the foot already on the platform; then, stepping down with one foot, followed by the other.

DELIMITATIONS OF THE STUDY

Fifty-eight female college students of selected standing heights were utilized in the study. Each subject's performance task consisted of three conditions of bench stepping at heights of thirteen inches, twenty-one inches and a height adjusted to the subject's patella. Heart rate response was measured before exercise, during exercise, and following the cessation of exercise.

LIMITATIONS OF THE STUDY

An initial limitation developed with the heart rate indicator. During the exercise phase, the heart rate of some individuals surpassed

180 beats per minute which could not be monitored by the indicator. A second limitation occurred when individuals had a great deal of adipose tissue at the site of electrode placement, resulting in erratic readings.

A third limitation developed with the subjects' motivation to continue the stepping task for three minutes at each stepping level. Several subjects stopped stepping before completing the exercise bout.

CHAPTER II

REVIEW OF RELATED LITERATURE

INTRODUCTION

In the review of related literature, the examination concentrated upon the various types of step tests which have been used to evaluate cardiovascular efficiency. Also, variations in the procedures of the step tests were examined to determine the affect that these variations had on the measure of cardiovascular efficiency. Variations in the methods of computing the cardiovascular index score were also investigated.

STUDIES RELATED TO THE EVALUATION OF CARDIOVASCULAR EFFICIENCY THROUGH STEP TESTS

The Harvard Step Test was developed during World War II to measure the ability of the body to adapt to and recover from hard work. The test was designed to classify differences in fitness levels among young men as to the measures of least fit, fit, and most fit.

When performing the Harvard Step Test, the subject exercised on a twenty inch bench for five minutes at a cadence of thirty steps per minute. A long and short form of the test could be utilized. The long form required the pulse count to be taken from one to one and a half minutes, two to two and a half minutes, and three to three and a half minutes following the cessation of exercise. Computing the index of cardiovascular fitness was based on the following formula:

$$\text{Index} = \frac{(\text{Duration of exercise in seconds}) \times 100}{2\ (\text{Sum of pulse counts in recovery})} .$$

The result of this computation indicated the degree of fitness when compared to the following standards: below 55, poor; 55-64, low average; 65-79, average; 80-89, good; above 90, excellent.

The short form necessitated that the recovery pulse count be taken from one to one and a half minutes following the cessation of exercise. The formula utilized in the short form was as follows:

$$\text{Index} = \frac{\text{(Duration of exercise in seconds) X 100}}{\text{5.5 X Recovery Pulse Count}}.$$

The result of this computation was compared to the following standards: below 50, poor; 50-80, average; above 80, good.[1]

A modification of the Harvard Step Test for girls was developed by Skubic and Hodkins. Skubic's and Hodkins' test as reported by Mathews was executed on an eighteen inch bench at a stepping rate of twenty-four steps per minute for three minutes.[2]

The Ohio State University Step Test (also known as the Ohio State University Cardiovascular Fitness Test and the Ohio Step Test) was a submaximal cardiovascular test devised to estimate the fitness of men eighteen years and older. The test was based on the finding that the time in which the heart increased from a resting state to 150 beats per minute was a valid indicator of a subject's cardiovascular capacity for exhaustive work.

A bench with a split level of fifteen and twenty inches in height with an adjustable hand bar was utilized as the testing apparatus. The test consisted of a total of eighteen innings of fifty seconds duration

---

[1]Donald K. Mathews, Measurement in Physical Education (Philadelphia: W. B. Saunders Company, 1968), pp. 217-18.

[2]Ibid., p. 219.

and three workloads. Each workload was comprised of six innings. Every inning was divided into a thirty second work period and a twenty second rest period. During the rest period, the pulse count was taken for ten seconds beginning at the fifth second and ending with the fifteenth second. Testing was terminated when the heart rate reached 150 beats per minute or the subject completed the entire eighteen innings. An individual score was the number of consecutive innings completed.

The three workloads were as follows: six innings of stepping at a cadence of twenty-four steps per minute on the fifteen inch bench; six innings of stepping at a cadence of thirty steps per minute on the fifteen inch bench; and six innings of stepping at a cadence of thirty steps per minute on the twenty inch bench.[3]

The reliability and validity of the Ohio Step Test as a submaximal stress test to predict maximal cardiovascular endurance of college women was investigated by Ford. The test-retest correlation for reliability was .928 $\pm$ .032. Correlations of .546 for time to exhaustion and .158 for oxygen consumption were found when the submaximal Ohio Step Test was correlated with the exhaustive Bruce Multistage Capacity Test. Ford concluded that the Ohio Step Test was not a valid measure of maximal cardiovascular endurance among college women.[4]

After modifying the Harvard Step Test, Skubic and Hodkins analyzed the test to determine its reliability and validity. The reliability and

---

[3]Ibid., pp. 223-24.

[4]April Ford, "The Reliability and Validity of the Ohio State University Cardiovascular Fitness Test for College Women," micro-carded thesis (University of Washington, 1970), p. 50.

validity coefficients were obtained from the following four groups of subjects: trained girls, 11-17 years of age; untrained girls, 12-16 years of age; active women and sedentary women, 17-23 years of age. The researchers tested all subjects on an eighteen inch bench at a stepping rate of twenty-four steps per minute for three minutes. Heart rate was telemetered by a radioelectrocardiograph.

The results of the study indicated that the stepping task was a valid measure of cardiovascular efficiency in girls and women. However, the investigators failed to report a validity coefficient. A reliability coefficient of .820 was reported for the test-retest.

A significant difference was found among the groups. The trained group's heart rate recovered more quickly than the sedentary, t=9.35; the trained group's heart rate recovered more quickly than the active group, t=4.50; and the active group's heart rate recovered more quickly than the sedentary group, t=4.73.

The researchers concluded that the modification of the step test was sufficiently strenuous to be classified as hard work for girls and women. The test discriminated among those in excellent physical condition, those moderately active, and those sedentary.[5]

Bookwalter undertook a study of the Harvard Step Test using 1,269 Army Specialist Training Program Students at Indiana University. The researcher administered the Harvard Step Test with the bench height adjusted to nineteen inches. Non-significant correlations were obtained between

---

[5]Vera Skubic and Jean Hodkins, "Cardiovascular Efficiency Test for Girls and Women," The Research Quarterly, XXXIV (May, 1963), pp. 191-97.

the relationship of the Harvard Step Test and the factors of age, height, weight, the Army Test, 100 yard pick-aback, and 300 yard dash.[6]

Sloan also modified the Harvard Step Test for women utilizing two groups of subjects and two experimental procedures. The first group, fifteen female physiology students ranging in age from 17-21 years, performed the step test three times on three separate days: once on a twenty inch stool, once on an eighteen inch stool, and once on sixteen inches. The fitness indices of these subjects were compared with those of a group of forty-six male medical students who performed the test on a twenty inch stool. The second group consisted of sixteen women medical students ranging in age from 17-21 years. These subjects were tested on stools at heights of eighteen, seventeen, and sixteen inches. The closest agreement of the fitness indices comparisons were between the women at eighteen inches and men at twenty inches. In the second comparison, the closest agreement was between the women at seventeen inches and the men at twenty inches.

Sloan suggested the Harvard Step Test was a useful test of the capacity for strenuous exertion by women. However, the investigator felt the twenty inch step had a particular disadvantage for women in that the limiting factor was often local fatigue of leg muscles and thus the test was not a valid measure of the capacity of the body as a whole. Sloan concluded from the results that seventeen inches would be a suitable height for women to bench step.[7]

---

[6]Karl Bookwalter, "A Study of the Brouha Step Test," The Physical Educator, V (May, 1948), p. 55.

[7]A. W. Sloan, "A Modified Harvard Step Test for Women, Journal of Applied Physiology, XVI (1959), pp. 985-86.

While at Radcliffe College, Clarke resolved to provide the students enrolled in swimming, field hockey, crew, tennis, dance, volleyball, and archery with information which would indicate the degree of physical fitness as it related to the physical education courses. The initial test was administered on a bicycle ergometer, but the test discriminated against those who did not ride bicycles regularly and against lighter and heavier girls.

The investigator modified the testing procedure to include a step test. Skill and practice effects were reduced to a minimum and the differences in weights among subjects was not a penalty to anyone since all had the problem of moving their own body weight up and down stairs daily.

The bench test consisted of stepping up and down on an eighteen inch bench every two seconds to the beat of a drum. Exercise continued up to four minutes. Recovery pulse was taken at the same intervals as the Harvard Step Test and the physical fitness index was computed and evaluated in the same manner as the Harvard Step Test. Although no statistical evidence was presented, the investigator reported the test results indicated that the greatest cardiovascular improvement was attained by those enrolled in swimming classes.[8]

In addition to measuring cardiovascular efficiency, the step test has been utilized to reflect changes in the training of basketball players. Michael and Gallon tested seventeen members of a basketball team every three weeks during the sixteen week basketball season. A one minute step

---

[8]Harriet Clarke, "A Functional Physical Fitness Test for College Women," Journal of Health, Physical Education, and Recreation, XIV (September, 1943), pp. 358-59.

test with a stepping cadence of thirty-six steps per minute on a seventeen inch bench was administered to each subject. At the conclusion of each bout of exercise, a recovery heart rate was taken at one, two, three, four and five minutes.

Following the basketball season, the subjects detrained for ten weeks and the test was re-administered. Summer vacation resulted in an additional twenty week detraining period and the subjects were again administered the test after a total of thirty weeks of detraining. The results of the study indicated significant changes in the recovery pulse after three and six weeks of training. Maximum changes occurred during the sixteen weeks of the basketball season. Recovery to the original resting heart rate during training was accomplished in two to three minutes. However, detraining resulted in failure of the recovery pulse to return to the original resting level even after five minutes of recovery.[9]

STUDIES RELATED TO VARYING BENCH HEIGHTS AND RECOVERY RATES

Cairns studied undiscernable changes in the bench height on Harvard Step Test performance in women. Fifteen college females were utilized as subjects. Each subject performed the Harvard Step Test twice at stepping levels of 45.72 centimeters, 48.26 centimeters, and 50.80 centimeters. Five minutes following the cessation of exercise heart rate was taken at intervals of one to one and one half minutes, two to two and one half

---

[9]Ernest D. Michael and Arthur Gallon, "Periodic Changes in the Circulation During Athletic Training as Reflected by a Step Test," The Research Quarterly, XXX (October, 1959), pp. 303-11.

minutes, and three to three and one half minutes for the purpose of calculating the Harvard Step Test index. Data were analyzed through a repeated measure, one way classification, analysis of variance. Non-significant differences among the mean Harvard Step Test scores were obtained at the different stepping levels.[10]

As previously reported, Sloan conducted research involving a lower stepping height for women. Rather than utilizing the twenty inch step, the investigator's results indicated that a seventeen inch step was more suitable for women. Local fatigue of leg muscles was a particular disadvantage for women at the twenty inch step.[11]

Miller and Ebel reported in the review of literature in their investigation, the results of an unpublished study conducted by Ebel and Green in 1946. The study involved bench stepping at various heights of 12, 14, 16, 18, and 20 inches for exercise periods of thirty and sixty seconds. A standardized cadence of twenty-four steps per minute was employed. Ebel and Green found that the pulse rate in healthy male subjects taken one minute after exercise returned to approximately pre-exercise level regardless of the height of the bench or the duration of the exercise.[12]

---

[10]Marilyn A. Cairns, "The Effects of Undiscernable Changes in Bench Height on the Harvard Step Test Performance of Women," Completed Research in Health, Physical Education, and Recreation, XI (1969), p. 147.

[11]Sloan, loc. cit.

[12]Waldo A. Miller, and Edwin R. Ebel, "The Effect Upon Pulse Rate of Various Cadences in the Step Up Test," The Research Quarterly, XVIII (December, 1946), p. 264.

Sloan's and Keen's investigation dealt with observations on the Harvard Step Test. Interest in such a study was first directed to the influence of stature and leg length on the ease with which the subjects were able to bench step. The authors noted: "when the test [Harvard Step Test] was introduced into a practical physiology course, that the tall, long-legged students seem to have less difficulty than their shorter fellows."

The Harvard Step Test was administered to seventy-five young men, fifty-one medical students and twenty-four physical education students. On each subject the investigators measured stature, weight, leg length (as measured from the iliac crest), bi-iliac diameter and resting pulse rate. The results of the study indicated the mean stature and leg length in the two groups were the same. A non-significant correlation resulted among stature, weight, leg length, and bi-iliac diameter. The authors concluded that the results of this study failed to justify any lowering of the step for shorter men.[13]

STUDIES RELATED TO VARIOUS METHODS OF CALCULATING THE CARDIOVASCULAR INDEX

With the widespread use of the Harvard Step Test as a measure of evaluating physical fitness, there has developed a variety of ways for computing the fitness indices. Chrastek, Stolz, and Samek analyzed three methods of computing the cardiovascular index to determine if a difference

---

[13] E. N. Keen and A. W. Sloan, "Observations on the Harvard Step Test," Journal of Applied Physiology, XIII (1958), pp. 241-43.

resulted in the indices. The investigators analyzed the following formulas:

$$\text{Classical} - \frac{\text{(Duration of exercise in seconds) X 100}}{\text{2 X Sum of the three 1/2 minute pulse counts}}$$

$$\text{Abbreviated} - \frac{\text{(Duration of exercise in seconds) X 100}}{\text{5.5 X Pulse Count for 30 seconds}}$$

$$\text{Prolonged} - \frac{\text{(Duration of exercise in seconds) X 100}}{\text{2 X Sum of the four 1/2 minute pulse counts.}}$$

The authors utilized both trained and untrained subjects. For men, the stepping task was administered according to the original description of the Harvard Step Test; for women, Clarke's modification of the Harvard Step Test was employed. The results indicated a non-significant difference among the abbreviated, the classical, and the prolonged computations when comparing the groups.[14]

Carver and Winsmann indicated the Harvard Step Test scoring formula was inadequate when an individual did not complete the prescribed duration of the test. The investigators utilized a linear function suitable to indicate the relationship between the Harvard Step Test score and the duration of stepping. The investigators developed new scoring formulas which were more sensitive when the individual stopped exercising before the end of the prescribed duration of the test. Three maximum stepping durations were administered to twelve subjects prior to and subsequent to running two miles each day for nine days. The results indicated that both the rapid and classical computations of the indices were insensitive to

---

[14] J. Chrastek, I. Stolz, and L. Samek, "On Determination of Physical Fitness by the Step Up Test," The Journal of Sports Medicine and Physical Fitness, V (1965), pp. 61-66.

those subjects who completed the prescribed exercise and that the following formulas were more appropriately applied to the Harvard Step Test:

New Classical Step Test Score = Classical Harvard Step Test Score + .22 (300 - Duration of stepping in seconds)

New and Rapid Step Test Score = Rapid Harvard Step Test Score + .22 (300 - Duration of stepping in seconds).[15]

SUMMARY OF RELATED LITERATURE

In reviewing the literature, two methods of evaluating cardiovascular fitness were described: the Harvard Step Test and the Ohio Step Test.[16] The subsequent literature dealt with modifications of the Harvard Step Test as applied to men and women. One study suggested a stepping height of nineteen inches for men, another suggested seventeen inches for women and two suggested a stepping height of eighteen inches for women.[17,18,19,20] One study utilized the Harvard Step Test as a method of reflecting changes in the training of basketball players.[21]

---

[15] R. P. Carver and F. R. Winsmann, "Study of Measurement and Experimental Design Problems Associated with the Step Test," The Journal of Sports Medicine and Physical Fitness, X, No. II (June, 1970), pp. 1-10.

[16] Mathews, loc. cit.

[17] Bookwalter, loc. cit.

[18] Sloan, loc. cit.

[19] Skubic and Hodkins, loc. cit.

[20] Clarke, loc. cit.

[21] Michael and Gallon, loc. cit.

Four studies were reviewed in which bench heights were changed to determine subsequent changes in recovery rates. None of the studies indicated a significant change in recovery rates.[22,23,24,25]

Variations in computing the cardiovascular index was reviewed in two studies. One study found no difference among the cardiovascular index scores computed by different methods.[26] The remaining study developed new formulas more representative of the cardiovascular fitness indicated by the index score.[27]

---

[22]Cairns, loc. cit.

[23]Sloan, loc. cit.

[24]Miller and Ebel, loc. cit.

[25]Keen and Sloan, loc. cit.

[26]Chrastek, Stolz, and Samek, loc. cit.

[27]Carver and Winsmann, loc. cit.

CHAPTER III

PROCEDURE OF THE STUDY

OVERVIEW

The study utilized fifty-eight female subjects of selected standing heights enrolled at Appalachian State University during spring quarter of 1973. The subjects were divided into two groups: Group I was composed of subjects with a standing height of 61-63 inches; Group II was composed of subjects with a standing height of 67-69 inches. A familiarity period was conducted immediately prior to the first testing session to explain the purpose and the experimental procedures of the study to the subjects.

The testing sessions involved three experimental conditions of stepping levels of thirteen inches, twenty-one inches, and a level adjusted to the individual subject's patella height. A stepping rate of twenty-four steps per minute was maintained. Heart rate was monitored at intervals of 30, 60, 90, 120, 150, and 180 seconds during exercise. Recovery rates were monitored at one, two and three minutes following the cessation of exercise. The testing sessions required ten minutes to administer and were completed with a period of twenty-four to forty-eight hours elapsing between each session.

SELECTION OF THE SUBJECTS

Subjects were obtained from the required physical education classes and the women's dormitories at Appalachian State University during spring quarter of 1973. Information concerning the experiment, its purpose, the number of testing sessions, and the length of each session was explained to the subjects.

The subjects were placed in one of two groups since the investigator was concerned with the subjects' differences in standing heights. Only those subjects with a standing height of 61 to 63 inches and 67 to 69 inches were utilized in the study. Group I consisted of twenty-nine subjects with a measured standing height of 61 to 63 inches. Group II consisted of twenty-nine subjects with a measured standing height of 67 to 69 inches.

TESTING APPARATUS

Stepping Platform - A custom built, adjustable platform designed to permit various height adjustments was utilized in the study. The platform measured sixteen inches in length, eighteen inches in width with a vertical height variation of ten to thirty inches.[1] Figure I illustrates the stepping platform.

Schwinn Heart Rate Indicator - A Schwinn Heart Rate Indicator, model X-21, was used to measure heart rate responses of the subjects during the three phases of the study. The indicator permitted controlled continuous readings of the cardiac muscle.[2] Figure II shows the heart rate indicator.

General Electric Cassette Tape Recorder - A General Electric cassette tape recorder, model M8500, was utilized to record all directions and

---

[1]Manufactured by Christian's Metals, Bristol, Tenn.

[2]Manufactured by Schwinn Bicycle Co., Chicago, Ill. 60639

FIGURE I

ADJUSTABLE STEPPING PLATFORM

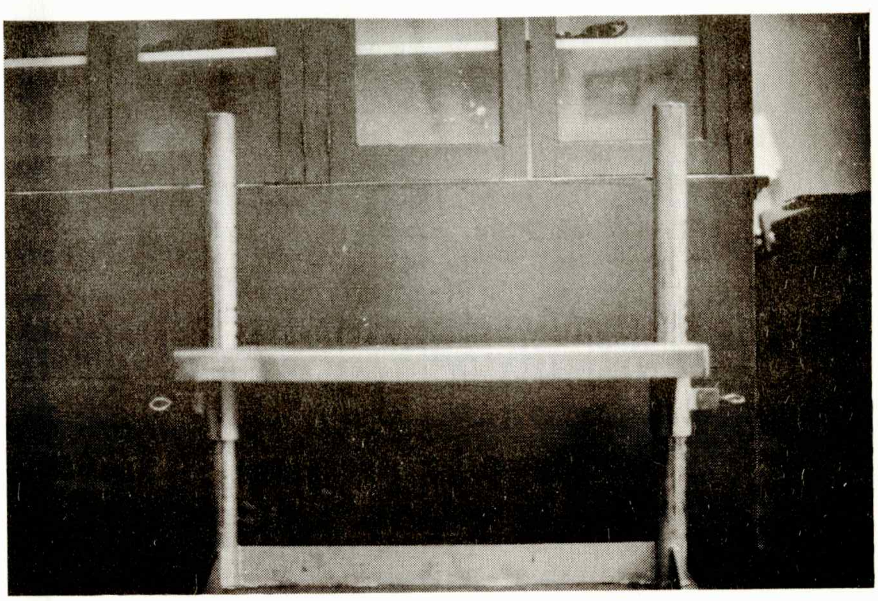
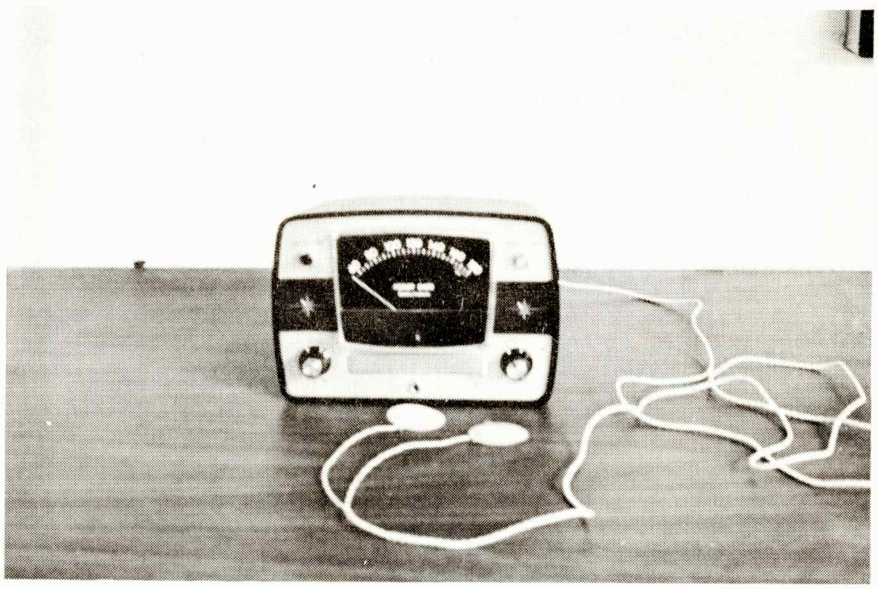


FIGURE II

SCHWINN HEART RATE INDICATOR



the stepping cadence utilized in stepping. This recording permitted uniformity among the directions and cadence given to each subject.[3]

Stop Watch - An Elgin stop watch was utilized to measure the bench stepping bout for each subject. The stop watch insured the interval consistency for the monitoring of the heart rate.

PROCEDURE FOR MONITORING HEART RATE

The Schwinn Heart Rate Indicator was utilized to monitor heart rate during each phase of testing. Prior to electrode placement, the subject's skin was abraded and cleansed with alcohol to insure adequate transmission of the heart rate. The black coded electrode was attached below the right nipple on the bony part of the rib cage. The red coded electrode was attached below the left nipple on the bony part of the rib cage. If an inconsistent reading was obtained at this position, the black coded electrode was attached below and to the left of the sternum; the red coded electrode was attached above the sternum, just to the right of center.[4] Figures III and IV illustrate the former and latter electrode placement.

A continuous heart rate was monitored throughout the three phases of the experiment (pre-exercise, exercise, recovery). The electrodes transmitted the electrical impulses of the heart to the indicator which interpreted the heart rate.

---

[3]Manufactured by the General Electric Co., Utica, New York 13501

[4]Schwinn Heart Rate Indicator Owner's Manual, Schwinn Bicycle Co., Chicago, Illinois 60639, p. 12.

FIGURE III

STANDARD ELECTRODE PLACEMENT

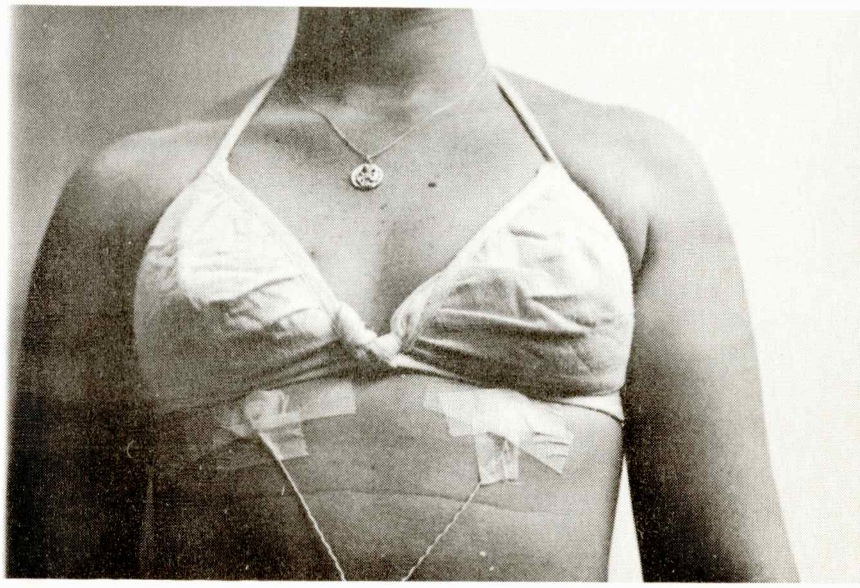
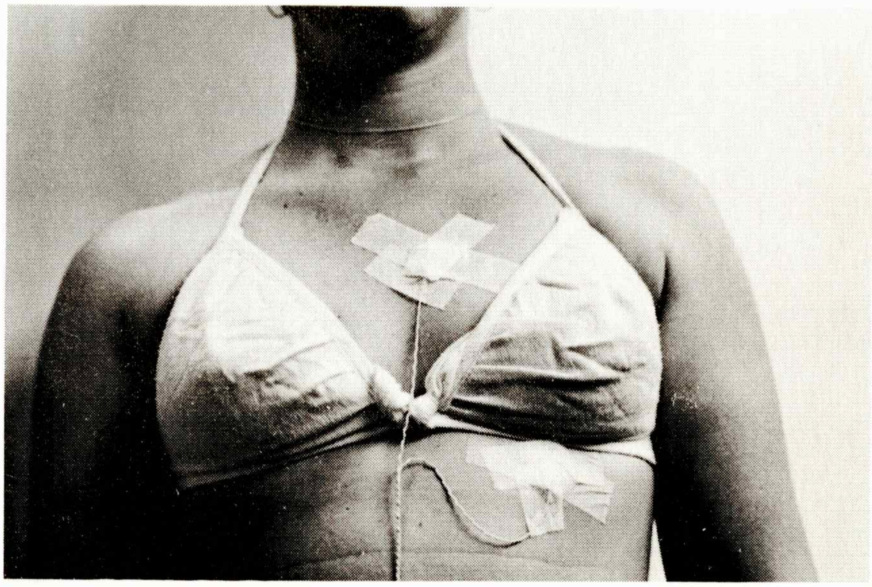


FIGURE IV

ALTERNATE ELECTRODE PLACEMENT



PROCEDURE FOR MONITORING HEART RATE PRIOR TO EXERCISE

After placing the electrodes on the subject, Phase One of the investigation necessitated that the subject assume and maintain a seated position for a period of six minutes while the heart rate was monitored to determine its resting value. If consistent reading for the fifth and sixth minutes, plus or minus three beats, were not obtained, heart rate was monitored until two consistent readings were obtained for two consecutive minutes.

PROCEDURE FOR MONITORING HEART RATE DURING EXERCISE

During the bench stepping exercise, heart rates were monitored and six readings were taken. One reading was taken at each of the following intervals: 30, 60, 90, 120, 150, and 180 seconds.

PROCEDURE FOR MONITORING THE RECOVERY HEART RATE

Following the cessation of exercise, the subject once again assumed the identical position as prescribed prior to exercise. The recovery heart rate was monitored at one, two, and three minutes following the completion of exercise.

BENCH STEPPING PROCEDURE

Each subject performed a bench stepping test following a counterbalanced schedule of three experimental conditions in order to avoid training effects. The experimental conditions were as follows: Experimental Condition One - stepping upon a bench thirteen inches in height at a cadence of twenty-four steps per minute for three minutes; Experimental

Condition Two - stepping upon a bench twenty-one inches in height at a cadence of twenty-four steps per minute for three minutes; Experimental Condition Three - stepping upon a bench adjusted to the mid-point of the subject's patella as measured from the floor, at a cadence of twenty-four steps per minute for three minutes. Hereafter, these conditions will be referred to as Experimental Condition One, Two, and Three.

Every subject was tested on three occasions with twenty-four to forty-eight hours separating each testing session. Subjects were instructed to bench step for a period of three minutes at the prescribed height. The subject was allowed two innings to regain the stepping cadence at which time if the subject was unable to maintain the stepping cadence, the testing session was concluded. The bench stepping time and heart rate were recorded on a standard data sheet (Appendix A).

The following directions for bench stepping were recorded on tape and played to each subject to insure consistency in the directions:

> "You will be participating in an experimental program designed to measure the effect of different levels of bench stepping upon the assessment of cardiovascular efficiency in individuals of different heights. You will be tested on three different occasions with no more than forty-eight hours occurring between each testing session. The testing sessions will consist of one session of bench stepping at thirteen inches, one session of bench stepping at twenty-one inches and one session of bench stepping at a height adjusted to the height of your patella. The order of the stepping heights will be counter-balanced.
>
> Each testing session will consist of three phases. During Phase One, which is prior to exercise, electrodes will be attached to your chest for the purpose of monitoring heart rate during all three phases of the experiment. After the electrodes have been attached, you will assume a seated position for at least six minutes or until consistent heart rates are acquired.
>
> The second phase of the experiment will be the exercise phase. Standing in front of the stepping platform you will be asked to step up with the foot of your choice and bring the other foot

beside the foot already on the platform. You must have the entire foot on the platform and you must be standing erect when both feet are on the platform. You will then step down with one foot, followed by the other. This stepping procedure must be performed in cadence with the experimenter's taped recording of up,up, down,down. You will exercise for a period of three minutes and will be informed of the length of time you have been bench stepping at one and two minute intervals.

When the experimenter tells you to stop, you will immediately sit down in the chair beside the platform. The experimenter will monitor your heart rate for three minutes and then remove the electrodes to complete the testing session.

The experimenter will demonstrate the bench stepping procedure to you before your first testing session. Are there any questions?

The exercise cadence was as follows: Please stand in front of the platform. Prepare to exercise. Exercise, up,up, down, down, ... Stop."

PROCEDURE FOR CALCULATION OF THE CARDIOVASCULAR INDICES

Four cardiovascular indices were calculated for each subject at each experimental condition. The indices considered two factors: the duration of time the subject exercised and the sum of the pulse counts during the recovery phase of the experiment.

The classical index was computed from the following formula:

$$\frac{(\text{Duration of exercise in seconds}) \times 100}{\text{Sum of the pulse counts in recovery}}$$

The rapid index was computed from:

$$\frac{(\text{Duration of exercise in seconds}) \times 100}{5.5 \times \text{One minute recovery pulse count}}$$

The new classical index was computed from the following formula:

Classical Index Score + .22 (180* - duration of stepping in seconds).

The new and rapid index, hereafter referred to as NARSS, was computed from the following formula:

Rapid Index Score + .22 (180* - duration of stepping in seconds).[5]

PILOT STUDY

A pilot study was conducted to determine any areas of difficulty which might be encountered in the experimental procedures. In addition, the reliability of the heart rate indicator was investigated. Six female subjects, three with a standing height of 62 to 64 inches and three with a standing height of 66 to 68 inches, were explained the testing procedures and given the stepping test at two of the three experimental conditions. No difficulties were encountered with the administration of the test to these subjects.

Fifteen males from a general physical education weight lifting class were employed as subjects in the testing of the reliability of the heart rate indicator. The testing session consisted of monitoring each subject's heart rate with the indicator and also manually on the carotid artery during a rest period and two workloads of exercise on a bicycle ergometer. The coefficients of reliability were as follows: resting, .87; exercise one, .96; and exercise two, .97.

---

[5]Carver and Winsmann, op. cit., p. 5.

*A modification was made in these formulas since the subjects stepped for only three minutes rather than five minutes as the original formula intended.

STATISTICAL ANALYSIS

The data used in the statistical analysis in this study were derived from the four computations (classical, rapid, new classical, NARSS) of the cardiovascular indices.

A two by three, repeated measures, factorial analysis of variance was utilized to analyze the difference between the computed cardiovascular indices of the groups, the stepping levels, and the interaction of the groups and the levels for each of the four computations. A Tukey Test was utilized to further analyze any significant differences obtained in the analysis of variance.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

The analysis of data consisted of utilizing the cardiovascular indices computed by the classical, rapid, new classical, and NARSS methods. A two by three analysis of variance with repeated measures on the same subjects was calculated for each method of obtaining a cardiovascular index score. Each calculation was analyzed at three levels: Level A was the difference between the index scores of the tall and short subjects; Level B was the difference among the experimental conditions of bench stepping; and the A X B interaction of these variables.

ANALYSIS OF THE EFFECTS OF THE THREE EXPERIMENTAL CONDITIONS UPON THE CARDIOVASCULAR INDICES COMPUTED BY THE CLASSICAL METHOD

In the analysis of the cardiovascular indices computed by the classical method, differences between the groups at each experimental level were investigated. In addition, differences between the cardiovascular indices computed at each stepping level were determined. Finally, the significance of the interaction of these two variables was determined.

Comparison of the Two Height Groups on the Cardiovascular Indices Computed by the Classical Method

Comparison of the cardiovascular index scores computed by the classical method for the tall and short subjects yielded a non-significant difference between the groups throughout the three experimental conditions. The mean cardiovascular index score for all short subjects and all experimental conditions was 51.99; for tall subjects, the mean value was 48.04. Table I reveals the non-significant F ratio of 2.86.

Comparison of the Stepping Levels of Thirteen Inches, Twenty-One Inches, and Patella Height on the Cardiovascular Indices Computed by the Classical Method

Table I reveals a significant F ratio of 129.31 at the .01 level of confidence for those indices computed by the classical method at the stepping levels of thirteen inches, twenty-one inches, and patella height. The mean cardiovascular indices for all subjects at the three stepping levels were as follows: thirteen inches, 60.83; twenty-one inches, 39.57; and patella height, 49.65.

TABLE I

ANALYSIS OF VARIANCE OF THE CARDIOVASCULAR INDICES COMPUTED BY THE CLASSICAL METHOD FOR FIFTY-EIGHT SUBJECTS COMPOSING TWO HEIGHT GROUPS AND BENCH STEPPING AT THREE EXPERIMENTAL LEVELS

Source of Variation	SS	df	MS	F	P
A	679.70	1	679.70	2.86	N.S.
Between Subject Error	13315.79	56	237.78		
B	13119.75	2	6559.88	129.31*	.01
AB Interaction	175.28	2	87.64	1.73	N.S.
Within Subject Error	5681.48	112	50.73		
TOTAL	32972.00	173			

*An F ratio of 7.08 required for significance.

Further analysis utilizing the Tukey Test yielded significant differences among the cardiovascular indices computed by the classical method. Table II reveals the cardiovascular index differences among the stepping levels. The stepping level of thirteen inches yielded significantly higher cardiovascular indices than twenty-one inches and patella height; patella height yielded significantly higher cardiovascular indices than the stepping level of twenty-one inches.

Interaction Effect of the Height Groups During Bench Stepping at Levels of Thirteen inches, Twenty-One Inches, and Patella Height Upon the Classical Computation of the Cardiovascular Indices

A non-significant F ratio of 1.73 was obtained from the interaction of variables at Levels A and B. The result indicates that no difference existed between the tall and short groups' cardiovascular indices during the stepping conditions of thirteen inches, twenty-one inches, and patella height. Table I reveals the non-significant F ratio. Chart I illustrates the means for the interaction of Levels A and B.

ANALYSIS OF THE EFFECTS OF THE THREE EXPERIMENTAL CONDITIONS UPON THE CARDIOVASCULAR INDICES COMPUTED BY THE RAPID METHOD

The cardiovascular indices computed by the rapid method were analyzed to determine differences between the height groups, among the stepping levels, and the interaction of these variables.

Comparison of the Two Height Groups On the Cardiovascular Indices Computed by the Rapid Method

In comparing the indices calculated by the rapid method, a non-significant F ratio of 4.15 was obtained between the two height groups

TABLE II

COMPARISON OF THE MEAN DIFFERENCES FOR CARDIOVASCULAR INDICES COMPUTED BY THE CLASSICAL METHOD

Comparison Means	Comparison Mean - Smallest Mean	Comparison Mean - Second Smallest Mean
62.24	62.94 - 38.43 = 23.81	62.24 - 40.70 = 21.54
59.42	59.42 - 38.43 = 20.99	59.42 - 40.70 = 18.72
53.03	53.03 - 38.43 = 14.66	53.03 - 40.70 = 12.33
46.26	46.26 - 38.43 = 7.83	46.26 - 40.70 = 5.56
40.70	40.70 - 38.43 = 2.27	
38.43		

T-value of 3.85 Necessary for Significance.

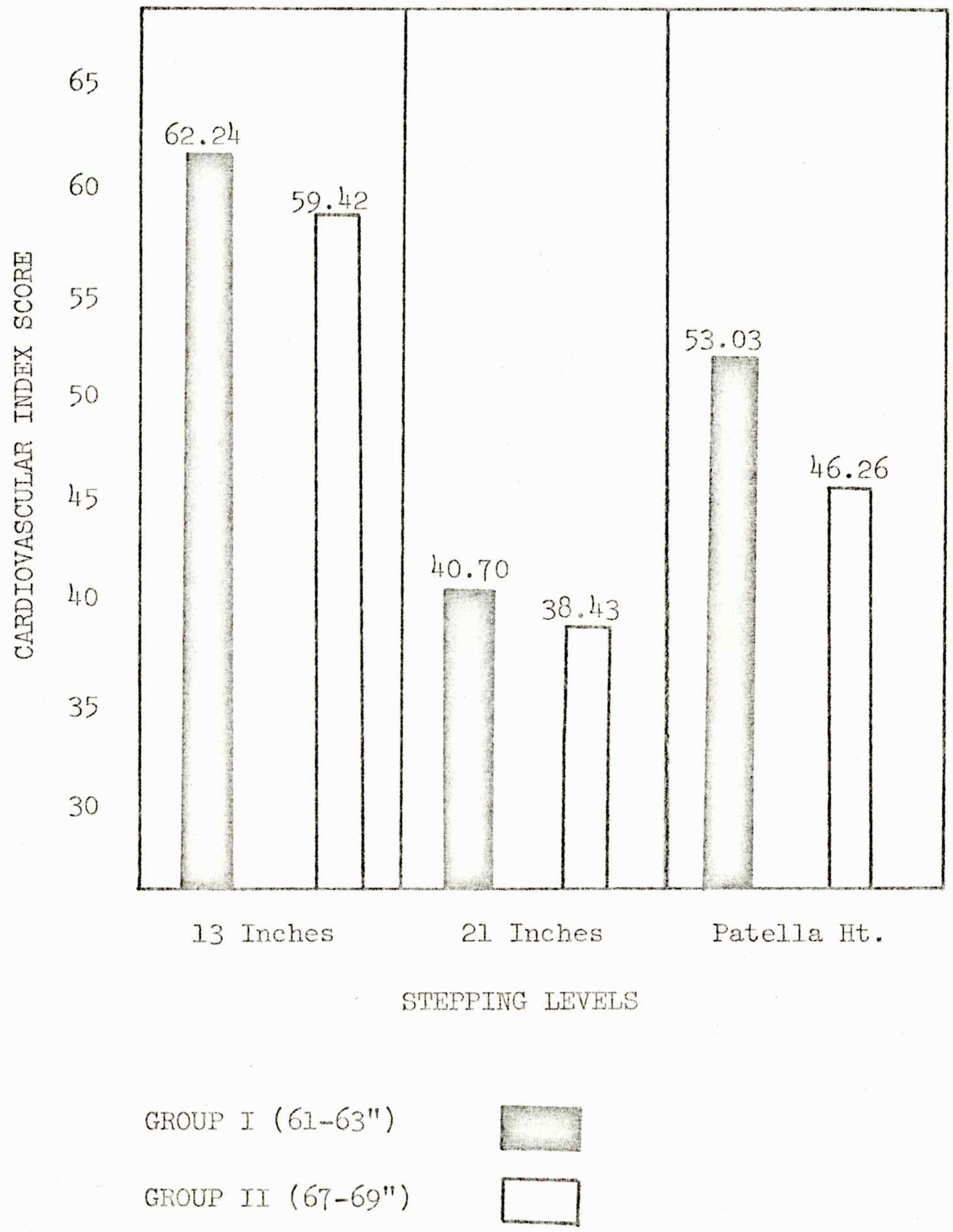
TABLE II (Continued)

Comparison Mean	- Third Smallest Mean	Comparison Mean	- Fourth Smallest Mean	Comparison Mean	- Fifth Smallest Mean
62.24	- 46.26 = 15.98	62.24	- 53.03 = 9.21	62.24	- 59.42 = 2.82
59.42	- 46.26 = 13.16	59.42	- 53.03 = 6.39		
53.03	- 46.26 = 6.77				

T-value of 3.85 Necessary for Significance.

CHART I

MEAN CARDIOVASCULAR INDICES OF THE CLASSICAL COMPUTATION FOR THE INTERACTION OF SUBJECTS' STANDING HEIGHTS AND STEPPING LEVELS



for the three experimental conditions. The mean cardiovascular index score for short subjects was 25.88 while the tall subjects had an index of 23.43. Table III illustrates this non-significant relationship.

TABLE III

ANALYSIS OF VARIANCE OF THE CARDIOVASCULAR INDICES COMPUTED BY THE RAPID METHOD FOR FIFTY-EIGHT SUBJECTS COMPOSING TWO HEIGHT GROUPS AND BENCH STEPPING AT THREE EXPERIMENTAL LEVELS

Source of Variation	SS	df	MS	F	P
A	260.77	1	260.77	4.15	N.S.
Between Subject Error	3517.67	56	62.82		
B	3574.19	2	1787.10	144.82*	.01
AB Interaction	41.01	2	20.51	1.66	N.S.
Within Subject Error	1382.10	112	12.34		
TOTAL	8775.74	173			

*An F ratio of 7.08 required for significance.

Comparison of the Effects of the Stepping Levels of Thirteen Inches, Twenty-One Inches, and Patella Height Upon the Cardiovascular Indices Computed by the Rapid Method

A significant difference existed among the cardiovascular indices computed by the rapid method at the stepping levels of thirteen inches, twenty-one inches, and patella height. Table III reveals that a significant F ratio of 144.82 was obtained. The mean cardiovascular indices computed by the rapid method for all subjects at the three stepping levels were as follows: thirteen inches, 30.39; twenty-one inches, 19.31; and patella height, 24.27.

The Tukey Test was employed to further analyze the data. This analysis yielded significant differences between the cardiovascular indices computed by the rapid method. The cardiovascular indices computed at the stepping level of thirteen inches were significantly higher than those at twenty-one inches or patella height; the cardiovascular indices computed at patella height were significantly higher than those computed at twenty-one inches. Table IV reveals the cardiovascular index differences obtained among the experimental conditions.

Interaction Effect of the Height Groups During Bench Stepping at Levels of Thirteen Inches, Twenty-One Inches, and Patella Height Upon the Cardiovascular Indices Computed by the Rapid Method

The analysis of data yielded a non-significant F ratio of 1.66 for the interaction effects. This indicated that these differences in cardiovascular indices between the height groups was uniform throughout the experimental conditions. Chart II reveals the differences obtained through the interaction.

ANALYSIS OF THE EFFECTS OF THE THREE EXPERIMENTAL CONDITIONS UPON THE CARDIOVASCULAR INDICES COMPUTED BY THE NEW CLASSICAL METHOD

Data were analyzed to determine differences between cardiovascular indices computed by the new classical method between the two height groups, among the stepping levels of thirteen inches, twenty-one inches, and patella height, and the interaction of these variables.

Comparison of the Two Height Groups on the Cardiovascular Indices Computed by the New Classical Method

An F ratio of .50 was obtained for the analysis of the cardiovascular indices computed by the new classical method for the height groups. Table V reveals the non-significant F ratio. The mean cardiovascular index for all short subjects for all experimental conditions was 53.95; for tall subjects the mean value was 52.39.

TABLE IV

COMPARISON OF THE MEAN DIFFERENCES FOR CARDIOVASCULAR INDICES COMPUTED BY THE RAPID METHOD

Comparison Mean	Comparison Mean	-	Smallest Mean	Comparison Mean	-	Second Smallest Mean
31.60	31.60	-	18.67 = 12.93	31.60	-	19.95 = 11.65
29.18	29.18	-	18.67 = 10.51	29.18	-	19.95 = 9.23
26.09	26.09	-	18.67 = 7.42	26.09	-	19.95 = 6.14
22.44	22.44	-	18.67 = 3.77	22.44	-	19.95 = 2.49
19.95	19.95	-	18.67 = 1.28			
18.67						

T-value of 1.895 Necessary for Significance.

TABLE IV (Continued)

Comparison Mean	- Third Smallest Mean	Comparison Mean	- Fourth Smallest Mean	Comparison Mean	- Fifth Smallest Mean
31.60	- 22.44 = 9.16	31.60	- 26.09 = 5.51	31.60	- 29.18 = 2.42
29.18	- 22.44 = 6.74	29.18	- 26.09 = 3.09		
26.09	- 22.44 = 3.65				

T-value of 1.895 Necessary for Significance.

CHART II

MEAN CARDIOVASCULAR INDICES OF THE RAPID COMPUTATION FOR THE INTERACTION OF SUBJECTS' STANDING HEIGHTS AND STEPPING LEVELS

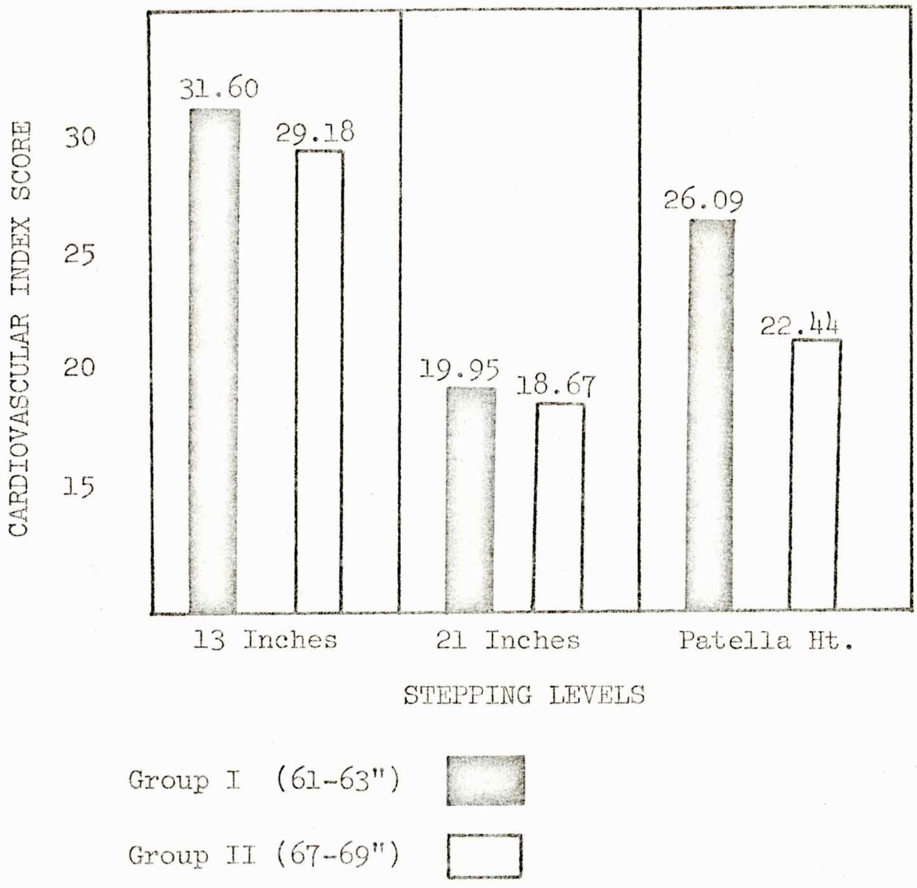


TABLE V

ANALYSIS OF VARIANCE OF THE CARDIOVASCULAR INDICES COMPUTED BY THE NEW CLASSICAL METHOD FOR FIFTY-EIGHT SUBJECTS COMPOSING TWO HEIGHT GROUPS AND BENCH STEPPING AT THREE EXPERIMENTAL LEVELS

Source of Variation	SS	df	MS	F	P
A	106.04	1	106.04	.50	N.S.
Between Subject Error	11859.77	56	211.78		
B	5502.21	2	2751.11	14.82*	<.01
AB Interaction	60.41	2	30.21	.16	N.S.
Within Subject Error	20790.41	112	185.63		
TOTAL	38318.85	173			

*An F ratio of 7.08 required for significance.

Comparison of the Effects of the Stepping Levels of Thirteen Inches, Twenty-One Inches, and Patella Height Upon the Cardiovascular Indices Computed by the New Classical Method

A significant difference was obtained among the cardiovascular indices computed by the new classical method for the stepping levels of thirteen inches, twenty-one inches, and patella height. Table V reveals that the F ratio of 14.82 was significant at the .01 level of confidence.

Additional analysis of the data by the Tukey Test yielded significant differences between the cardiovascular indices computed by the new classical method. The cardiovascular indices obtained at the stepping level of thirteen inches were significantly higher than those obtained at levels of twenty-one inches and patella height. Table VI reveals the cardiovascular index differences obtained among the experimental conditions.

TABLE VI

COMPARISON OF THE MEAN DIFFERENCES FOR CARDIOVASCULAR INDICES COMPUTED BY THE NEW CLASSICAL METHOD

Comparison Mean	Comparison Mean - Smallest Mean	Comparison Mean - Second Smallest Mean
62.21	62.21 - 47.45 = 14.76	62.21 - 47.47 = 14.74
59.42	59.42 - 47.45 = 11.97	59.42 - 47.47 = 11.95
52.20	52.20 - 47.45 = 4.75	52.20 - 47.47 = 4.73
50.27	50.27 - 47.45 = 2.82	50.27 - 47.47 = 2.80
47.47	47.47 - 47.45 = .02	
47.45		

T-value of 7.416 Necessary for Significance.

TABLE VI (Continued)

Comparison Mean	-	Third Smallest Mean	Comparison Mean	-	Fourth Smallest Mean	Comparison Mean	-	Fifth Smallest Mean
62.21	-	50.27 = 11.94	62.21	-	52.20 = 10.01	62.21	-	59.42 = 2.79
59.42	-	50.27 = 9.15	59.42	-	52.20 = 7.22			
52.20	-	50.27 = 1.93						

T-value of 7.416 Necessary for Significance.

Interaction Effect of the Height Groups During Bench Stepping at Levels of Thirteen Inches, Twenty-One Inches, Patella Height Upon the Cardiovascular Indices Computed by the New Classical Method

No difference was obtained between the cardiovascular indices of the two height groups among the three stepping levels. Table V reveals the non-significant F ratio of .16 for the interaction. Chart III illustrates the mean values resulting from the interaction.

ANALYSIS OF THE EFFECTS OF THE THREE EXPERIMENTAL CONDITIONS UPON THE CARDIOVASCULAR INDICES COMPUTED BY THE NARSS METHOD

The cardiovascular indices computed by the NARSS method were analyzed to determine differences in three areas: between the cardiovascular indices of the two height groups; among the cardiovascular indices computed for each stepping level; and the interaction of the above variables.

Comparison of the Two Height Groups Upon the Cardiovascular Indices Computed by the NARSS Method

In the analysis of the cardiovascular indices computed by the NARSS method, a non-significant difference was obtained between the two groups. Table VII reveals the non-significant F ratio of .36. The mean cardiovascular index score for all short subjects for all experimental conditions was 28.32; for all tall subjects the mean value was 27.78.

CHART III

MEAN CARDIOVASCULAR INDICES OF THE NEW CLASSICAL COMPUTATION FOR THE INTERACTION OF SUBJECTS' STANDING HEIGHTS AND STEPPING LEVELS

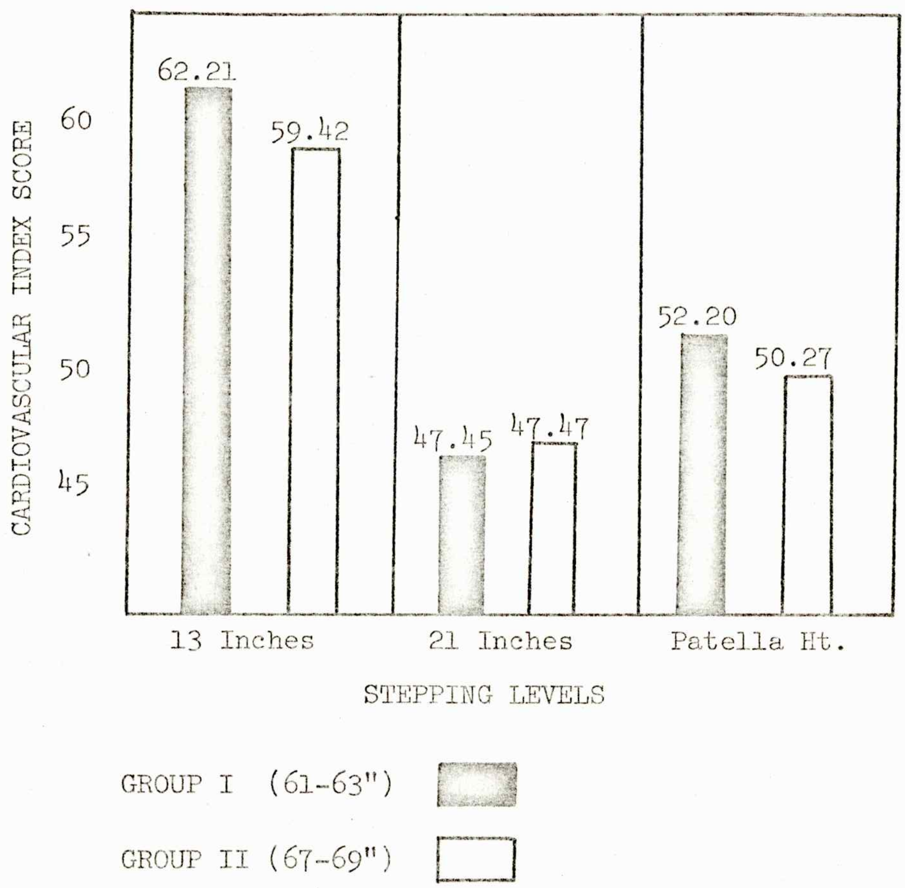


TABLE VII

ANALYSIS OF VARIANCE OF THE CARDIOVASCULAR INDICES COMPUTED BY THE NARSS METHOD FOR FIFTY-EIGHT SUBJECTS COMPOSING TWO HEIGHT GROUPS AND BENCH STEPPING AT THREE EXPERIMENTAL LEVELS

Source of Variation	SS	df	MS	F	P
A	12.55	1	12.55	.36	N.S.
Between Subject Error	1977.98	56	35.32		
B	511.97	2	255.99	14.15*	.01
AB Interaction	78.23	2	39.12	2.16	N.S.
Within Subject Error	2026.01	112	18.09		
TOTAL	4606.74	173			

*An F ratio of 7.08 required for significance.

Comparison of the Effects of the Stepping Levels of Thirteen Inches, Twenty-One Inches, and Patella Height Upon the Cardiovascular Indices Computed by the NARSS Method

In the analysis of data, a significant F ratio of 14.15 was obtained at Level B which is illustrated in Table VII. The mean cardiovascular indices for all subjects at the three stepping levels were as follows: thirteen inches, 30.39; twenty-one inches, 27.44; and patella height, 26.32.

Utilizing the Tukey Test, data were further analyzed and significant differences were obtained between the indices. The cardiovascular indices computed at the stepping level of thirteen inches were significantly higher than those computed at twenty-one inches or patella height.

Table VIII reveals the cardiovascular index differences obtained among the experimental conditions.

Interaction Effect of the Height Groups During Bench Stepping at Levels of Thirteen Inches, Twenty-One Inches, and Patella Height Upon the NARSS Computation of the Cardiovascular Indices

The analysis of data yielded a non-significant F ratio of 2.16 in the interaction of Levels A and B. Table VII illustrates this non-significant difference. Chart IV illustrates the mean values resulting from the interaction.

TABLE VIII

COMPARISON OF THE MEAN DIFFERENCES FOR CARDIOVASCULAR INDICES COMPUTED BY THE NARSS METHOD

Comparison Mean	Comparison Mean - Smallest Mean	Comparison Mean - Second Smallest Mean
31.60	31.60 - 26.19 = 5.41	31.60 - 26.45 = 5.15
29.17	29.17 - 26.19 = 2.98	29.17 - 26.45 = 2.72
27.71	27.71 - 26.19 = 1.52	27.71 - 26.45 = 1.26
27.16	27.16 - 26.19 = .97	27.16 - 26.45 = .71
26.45	26.45 - 26.19 = .26	
26.19		

T-value of 2.286 Necessary for Significance.

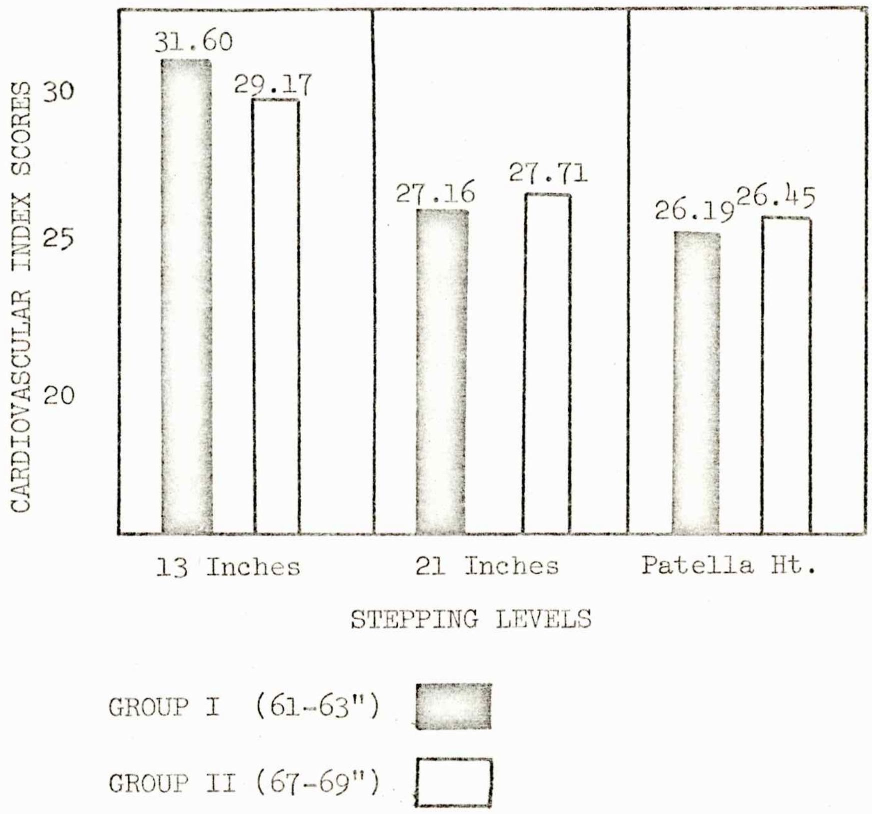
TABLE VIII (Continued)

Comparison Mean	- Third Smallest Mean	Comparison Mean	- Fourth Smallest Mean	Comparison Mean	- Fifth Smallest Mean
31.60	- 27.16 = 4.44	31.60	- 27.71 = 3.89	31.60	- 29.17 = 2.43
29.17	- 27.16 = 2.01	29.17	- 27.71 = 1.46		
27.71	- 27.16 = .55				

T-value of 2.286 Necessary for Significance.

CHART IV

MEAN CARDIOVASCULAR INDICES OF THE NARSS
COMPUTATION FOR THE INTERACTION OF
SUBJECTS' STANDING HEIGHTS AND
STEPPING LEVELS



CHAPTER V

SUMMARY, FINDINGS, DISCUSSION OF THE FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

The primary purpose of the study was to analyze differences between the cardiovascular efficiency as computed by different methods for two height groups during three different stepping levels. The subjects performed three stepping tasks at heights of thirteen inches, twenty-one inches, and a height adjusted to the height of the subject's patella. Each experimental condition consisted of the subject stepping upon the required height for three minutes at a rate of twenty-four steps per minute. Heart rate was monitored throughout the testing session.

The subjects consisted of fifty-eight females enrolled at Appalachian State University during spring quarter of 1973. Group I was composed of twenty-nine females with a standing height of 61-63 inches; Group II was composed of twenty-nine females with a standing height of 67-69 inches.

The cardiovascular indices were computed by four different methods: the classical computation, the rapid computation, the new classical computation, and the new and rapid computation. Each method of computation was analyzed through a two by three, repeated measures, factorial analysis of variance design to determine the difference between the height groups, stepping levels, and the interaction of these variables upon the computed cardiovascular indices.

FINDINGS

The findings of this study were as follows:

1. The difference between the height groups' cardiovascular indices was not significant for all experimental conditions regardless of the method employed to compute the indices.

2. The classical computation of the cardiovascular indices yielded significantly higher cardiovascular indices at thirteen inches than at twenty-one inches; patella height yielded significantly higher indices than at twenty-one inches.

3. The rapid computation of the cardiovascular indices yielded significantly higher cardiovascular indices at thirteen inches than at twenty-one inches; patella height yielded significantly higher indices than at twenty-one inches.

4. There was a significant difference among the cardiovascular indices as computed by the new classical computation in favor of the thirteen inch stepping level.

5. There was a significant difference among the cardiovascular indices as computed by the NARSS computation in favor of the thirteen inch stepping level.

6. The four computational methods yielded non-significant interactions between the effects of height groups and stepping levels on cardiovascular indices.

DISCUSSION OF THE FINDINGS

It was the assumption of the study that differences in standing height would result in differences in computed cardiovascular indices selected stepping levels. However, the results of this study indicate that a significant difference did not exist between the height groups at each of the three experimental stepping levels.

As stated in the introduction, the optimum angle of pull to execute the most efficient mechanical force approximates a right angle. The investigator assumed that the angle of pull of a person of taller stature would closely approximate a right angle at the hip and knee joints when performing a stepping task. Since the force arm is longest at this position, the greatest and most efficient moment of force is produced. Workload decreases and cardiovascular efficiency, reflected by a high cardiovascular index score would increase.

Bunn has cautioned investigators against applying the laws of mechanics to human performance and then making absolute predictions and drawing absolute conclusions. When dealing with the human body, because of the variations in anatomy and physiology, all conditions are not known and cannot be controlled or measured. Problems develop with the accuracy of measurement when the angle at which a force is exerted or the length of the weight arm and power arm are being determined.[1] It appears from the results of this study that the most efficient angle of pull necessary to bench step is not necessarily a right angle as stated in the mechanical law.

In the review of literature, several studies placed emphasis upon the use of various stepping tasks to develop and evaluate

---

[1]John W. Bunn, Scientific Principles of Coaching (New York: Prentice-Hall, 1955), p. 10.

efficiency. The stepping tasks utilized a standard height of bench stepping for each individual, regardless of height. The results of this study support such usage.

Two factors must be considered in the findings of this study. A primary consideration is the fact that many of the subjects did not bench step the required three minutes. The subjects were given no external motivation to continue the stepping task. Often a subject ceased to exercise, only one to two minutes of stepping, before the heart rate had reached a maximum level and thus recovery occurred extremely rapidly. Only one explanation can be offered as to why some subjects ceased the stepping task before the prescribed three minutes. Psychologically, a female will not exert herself without external motivation, unless it is felt that the situation is of tangible benefit. The stepping task could become quite uncomfortable to perform and the subject would cease to perform rather than endure the discomfort since the results of the task would not be a tangible benefit. Higher cardiovascular index scores were obtained because of the fast recovery, but these scores were not an accurate indication of the subject's cardiovascular efficiency since the subject did not complete the exercise bout.

Unlike Cairns and Ebel and Green, the results of the study did indicate a significant difference between the three experimental stepping levels of thirteen inches, twenty-one inches, and patella height. An inverse relationship existed between the stepping levels and the computed cardiovascular index score. At a stepping level of thirteen inches, the highest cardiovascular indices were obtained. Such results indicate that further research is warranted to determine which level provides an accurate indication of cardiovascular efficiency.

In addition to an investigation of the differences obtained between the indices of the two height groups, differences obtained among the four methods of computing the indices were also investigated. Similar cardiovascular indices resulted from the four methods utilized to compute the indices. Chrastek, Stolz, and Samek reported similar results in a study investigating the classical, abbreviated, and prolonged computations. However, Carver and Winsmann developed new formulas which considered the length of time a subject stepped. Supposedly these formulas indicated the most accurate cardiovascular index score. To the contrary, the investigator determined that any of the four methods employed to compute the cardiovascular index will provide a representative score.

CONCLUSIONS

The following conclusions were drawn from the study:

1. Differences in individual standing heights do not affect computed cardiovascular indices derived from a stepping task.

2. Lower stepping levels will increase cardiovascular indices, regardless of individual standing height.

3. The four computational methods for the cardiovascular indices: the classical, the rapid, the new classical, and the NARSS are valid computational methods of cardiovascular efficiency.

RECOMMENDATIONS

The following recommendations have been proposed:

1. To conduct further research in the area of stepping tasks to determine the most appropriate height to bench step when measuring cardiovascular efficiency.

2. To conduct a study modifying the various methods of computing the cardiovascular index scores and the standard scores for cardiovascular indices of the Harvard Step Test to determine if differences obtained warrant modifications in procedures.

SELECTED BIBLIOGRAPHY

SELECTED BIBLIOGRAPHY

A. BOOKS

Brouha, Lucien and Edward P. Radford, Jr. "The Cardiovascular System in Muscular Activity," Science and Medicine of Exercise and Sports, ed. Warren R. Johnson (New York: Harper and Brothers, 1960).

Bunn, John W. Scientific Principles of Coaching. New York: Prentice-Hall, 1955.

Davis, Elwood and Gene Logan. Biophysical Values of Muscular Activity with Implications for Research. Dubuque, Iowa: William C. Brown Company, 1961.

Mathews, Donald K. Measurement in Physical Education. Philadelphia: W. B. Saunders Company, 1968.

Morehouse, Laurence E. and Augustus T. Miller, Jr. Physiology of Exercise. St. Louis: C. V. Mosby Company, 1963.

B. PERIODICALS

Bookwalter, Karl. "A Study of the Brouha Step Test," The Physical Educator, V (May, 1948), 55.

Cairns, Marilyn A. "The Effects of Undiscernable Changes in Bench Height on the Harvard Step Test Performance in Women," Completed Research in Health, Physical Education and Recreation, XI (1969), 147.

Carver, R. P. and F. R. Winsmann. "Study of Measurement and Experimental Design Problems Associated with the Step Test," Journal of Sports Medicine and Physical Fitness, X, No. II (June, 1970), 1-10.

Chrastek, J., I. Stolz, and L. Samek. "On Determination of Physical Fitness by the Step Up Test," Journal of Sports Medicine and Physical Fitness, V (1965), 61-66.

Clarke, Harriet. "A Functional Physical Fitness Test for College Women," Journal of Health, Physical Education and Recreation, XIV (September, 1943), 358-359, 394-395.

Keen, E. N. and A. W. Sloan. "Observations on the Harvard Step Test," Journal of Applied Physiology, XIII (1958), 241-243.

Meyers, Carlton R. "A Study of the Reliability of the Harvard Step Test," The Research Quarterly, XL (May, 1969), 423.

Michael, Ernest D. and Arthur Gallon. "Periodic Changes in the Circulation During Athletic Training as Reflected by a Step Up Test," The Research Quarterly, XXX (October, 1959), 303-311.

Miller, Waldo A. and Edwin R. Ebel. "The Effect Upon Pulse Rate of Various Cadences in the Step Up Test," The Research Quarterly, XVII (December, 1964), 263-269.

Patterson, J. L., A. Graybiel, H. F. Lenherdt, and M. J. Madsen. "The Evaluation and Prediction of Physical Fitness, Utilizing Modified Apparatus of the Harvard Step Test," American Journal of Cardiology, XIV (1964), 811-827.

Skubic, Vera and Jean Hodkins, "Cardiovascular Efficiency Test for Girls and Women," The Research Quarterly, XXXIV (May, 1963), 191-197.

Sloan, A. W. "A Modified Harvard Step Test for Women," Journal of Applied Physiology, XVI (1959), 985-986.

Weber, Herbert and Ronald G. Knowlton. "A Comparative Study of Physique and Performance Measures Resulting from a Short-Term Physical Fitness Course," The Research Quarterly, XXXIX (December, 1968), 1107-1113.

C. UNPUBLISHED MATERIAL

Doughty, Kathy. "The Effect of Variant Temperature on Heart Rate in Female Athletes." An Independent Study, Roanoke College, Salem, Virginia, 1972.

Ford, April. "The Reliability and Validity of the Ohio State University Cardiovascular Fitness Test for College Women." Microcarded Master of Science Thesis, University of Washington, 1970.

APPENDICES

APPENDIX A

MODEL DATA SHEET

NAME ____________________ HEIGHT ____________

DORM ____________________ WEIGHT ____________

P.O. BOX ________________ PATELLA HEIGHT ____________

PHONE ___________________ CLASS ________ AGE ________

		13"	21"	Patella
PRE-EXER. RATE	1.			
	2.			
EXERCISE (SEC)	30			
	60			
	90			
	120			
	150			
	180			
RECOVERY (MIN)	1			
	2			
	3			

COMPUTATION OF CARDIOVASCULAR INDICES

	13"	21"	Patella
1. Classical			
2. Rapid			
3. New Classical			
4. New Rapid			

APPENDIX B

STANDING HEIGHTS AND PATELLA HEIGHTS FOR ALL SUBJECTS

S - Short Group

T - Tall Group

SUBJECT	STANDING HEIGHT (in inches)	PATELLA HEIGHT (in inches)
S_1	62	18
S_2	63	19
S_3	61	17
S_4	61	18
S_5	62	18
S_6	62	18
S_7	61	17
S_8	63	19
S_9	63	18
S_{10}	63	18
S_{11}	62	17
S_{12}	63	19
S_{13}	63	18
S_{14}	61	18
S_{15}	62	16
S_{16}	62	18
S_{17}	62	17
S_{18}	63	17
S_{19}	61	17

APPENDIX B (Continued)

S_{20}	61	18
S_{21}	63	17
S_{22}	62	18
S_{23}	63	19
S_{24}	62	19
S_{25}	61	17
S_{26}	63	18
S_{27}	62	18
S_{28}	61	17
S_{29}	62	17
T_{1}	67	19
T_{2}	68	20
T_{3}	67 1/2	19
T_{4}	67	18
T_{5}	68	20
T_{6}	68	19
T_{7}	67	18
T_{8}	68	20
T_{9}	67	20
T_{10}	67 1/2	21
T_{11}	68	19
T_{12}	68	20
T_{13}	68	20
T_{14}	67	19

APPENDIX B (Continued)

T_{15}	67	18
T_{16}	67	18
T_{17}	67 1/2	20
T_{18}	67 1/2	20
T_{19}	67	20
T_{20}	69	19
T_{21}	67	18
T_{22}	67	18
T_{23}	68 1/2	21
T_{24}	68	20
T_{25}	67	18
T_{26}	67 1/2	20
T_{27}	67	19
T_{28}	67 1/2	19
T_{29}	67	20

APPENDIX C

CARDIOVASCULAR INDICES COMPUTED BY THE CLASSICAL, RAPID, NEW CLASSICAL AND NARSS METHODS FOR ALL THREE EXPERIMENTAL CONDITIONS

1. Classical Computation
2. Rapid Computation
3. New Classical Computation
4. NARSS Computation

SUBJECT		13"	21"	Patella
S_1	1.	69.23	55.21	54.22
	2.	35.96	27.27	25.57
	3.	69.23	55.21	54.22
	4.	35.96	27.27	25.57
S_2	1.	88.24	47.49	50.70
	2.	46.75	22.73	25.37
	3.	88.24	47.49	50.70
	4.	46.75	22.73	25.37
S_3	1.	65.45	51.14	60.20
	2.	35.93	24.24	28.46
	3.	65.45	51.14	60.20
	4.	35.93	24.24	28.46
S_4	1.	68.18	48.65	55.90
	2.	35.96	24.24	26.61
	3.	68.18	48.65	55.90
	4.	35.96	24.24	26.61
S_5	1.	59.41	48.78	51.72
	2.	32.17	24.24	25.17
	3.	59.41	48.78	51.72
	4.	32.17	24.24	25.17
S_6	1.	71.71	47.49	55.56
	2.	37.62	22.26	27.50
	3.	71.71	47.49	55.56
	4.	37.62	22.26	27.50
S_7	1.	75.31	65.69	100.00
	2.	38.96	32.09	51.14
	3.	75.31	65.69	100.00
	4.	38.96	32.09	51.14

APPENDIX C (Continued)

S_8	1.	49.18	42.15	44.67
	2.	25.37	21.82	22.42
	3.	49.18	42.15	44.67
	4.	25.37	21.82	22.42
S_9	1.	58.82	50.28	58.44
	2.	30.03	25.97	29.48
	3.	58.82	50.28	58.44
	4.	30.03	25.97	29.48
S_{10}	1.	58.82	46.04	53.41
	2.	30.30	23.38	27.27
	3.	58.82	46.04	53.41
	4.	30.30	23.38	27.27
S_{11}	1.	76.92	51.72	50.13
	2.	36.77	25.17	26.18
	3.	76.92	51.72	50.13
	4.	36.77	25.17	26.18
S_{12}	1.	79.29	51.57	59.21
	2.	41.33	25.17	30.03
	3.	79.29	51.57	59.21
	4.	41.33	25.17	30.03
S_{13}	1.	65.69	50.13	52.02
	2.	34.82	23.89	25.37
	3.	65.69	50.13	52.02
	4.	34.82	23.89	52.02
S_{14}	1.	49.86	43.54	49.18
	2.	25.97	20.83	24.42
	3.	49.86	46.84	49.18
	4.	25.97	20.83	24.42
S_{15}	1.	52.63	36.41	47.00
	2.	26.61	17.26	22.73
	3.	52.63	43.01	47.00
	4.	26.61	23.86	22.73
S_{16}	1.	69.50	46.76	62.28
	2.	38.05	23.89	31.47
	3.	69.50	51.38	62.28
	4.	38.05	30.27	31.47

APPENDIX C (Continued)

S_{17}	1.	61.22	44.48	55.38
	2.	27.73	21.30	25.97
	3.	61.22	49.54	55.38
	4.	27.73	26.36	25.97
S_{18}	1.	52.63	33.93	42.15
	2.	26.61	16.94	20.98
	3.	52.63	40.53	42.15
	4.	26.61	23.54	20.98
S_{19}	1.	56.25	36.32	47.49
	2.	25.97	17.81	23.83
	3.	56.25	44.68	47.49
	4.	25.97	26.17	23.83
S_{20}	1.	55.73	41.40	47.75
	2.	28.46	20.65	23.54
	3.	55.73	49.76	47.75
	4.	28.46	29.01	23.54
S_{21}	1.	49.45	29.77	46.63
	2.	24.24	15.58	21.96
	3.	49.45	42.97	46.63
	4.	24.24	28.78	21.96
S_{22}	1.	54.05	28.35	45.11
	2.	25.37	13.53	20.98
	3.	54.05	39.13	45.11
	4.	25.37	24.31	20.98
S_{23}	1.	67.92	29.03	55.73
	2.	32.73	13.52	27.50
	3.	67.92	48.83	55.73
	4.	32.73	33.32	27.50
S_{24}	1.	79.30	29.61	53.57
	2.	38.05	14.23	26.39
	3.	79.30	49.41	53.57
	4.	38.05	34.03	26.39
S_{25}	1.	61.02	28.45	55.38
	2.	30.59	14.17	27.27
	3.	61.02	46.27	55.38
	4.	30.59	31.99	27.27
S_{26}	1.	55.55	22.67	45.45
	2.	27.50	11.36	21.67
	3.	55.55	42.47	45.45
	4.	27.50	31.16	21.67

APPENDIX C (Continued)

S_{27}	1.	47.00	26.25	40.45
	2.	23.21	12.32	19.96
	3.	47.00	42.75	40.45
	4.	23.21	28.82	19.96
S_{28}	1.	46.27	24.79	45.56
	2.	23.54	12.21	21.82
	3.	46.27	44.59	45.56
	4.	23.54	32.01	21.82
S_{29}	1.	60.20	22.26	52.68
	2.	29.75	10.36	25.52
	3.	60.20	49.32	55.54
	4.	29.75	37.42	28.38
T_1	1.	78.26	43.89	44.55
	2.	40.40	19.50	22.17
	3.	78.26	54.23	53.57
	4.	40.40	29.84	31.19
T_2	1.	56.96	49.58	49.31
	2.	28.71	23.54	23.54
	3.	56.96	49.58	49.31
	4.	28.71	23.54	23.54
T_3	1.	45.91	50.84	57.14
	2.	23.38	24.42	26.61
	3.	45.91	50.84	57.14
	4.	23.38	24.42	26.61
T_4	1.	77.58	52.47	75.94
	2.	40.91	25.17	36.36
	3.	77.58	52.47	75.94
	4.	40.91	25.17	36.36
T_5	1.	56.42	49.31	49.86
	2.	29.48	24.98	25.17
	3.	56.42	49.31	49.86
	4.	29.48	24.98	25.17
T_6	1.	76.92	45.45	55.90
	2.	38.05	22.57	25.97
	3.	76.92	45.45	55.90
	4.	38.05	22.57	25.97

APPENDIX C (Continued)

T_7	1.	75.00	57.50	69.49
	2.	36.77	27.50	32.73
	3.	75.00	57.50	69.49
	4.	36.77	27.50	32.73
T_8	1.	60.81	40.54	45.92
	2.	30.03	19.96	22.42
	3.	60.81	40.54	45.92
	4.	30.03	19.96	22.42
T_9	1.	56.96	44.12	52.48
	2.	27.27	22.42	24.61
	3.	56.96	44.12	52.48
	4.	27.27	22.42	24.61
T_{10}	1.	53.41	46.04	46.04
	2.	27.05	22.73	22.57
	3.	53.41	46.04	46.04
	4.	27.05	22.73	22.57
T_{11}	1.	52.94	43.97	44.18
	2.	27.05	22.59	22.33
	3.	52.94	47.49	47.04
	4.	27.05	26.11	25.19
T_{12}	1.	62.28	45.64	47.83
	2.	32.40	20.69	23.08
	3.	62.28	50.70	51.13
	4.	32.40	25.75	26.38
T_{13}	1.	73.17	43.49	42.85
	2.	21.25	19.82	19.62
	3.	73.17	48.55	49.45
	4.	21.25	24.88	26.22
T_{14}	1.	56.96	38.96	50.84
	2.	29.75	19.34	24.98
	3.	56.96	45.56	50.84
	4.	29.75	25.94	24.98
T_{15}	1.	44.88	37.22	44.66
	2.	22.73	18.18	21.82
	3.	44.88	43.82	44.66
	4.	22.73	24.78	21.82

APPENDIX C (Continued)

T_{16}	1.	59.21	49.70	56.25
	2.	29.75	23.20	26.61
	3.	59.21	51.68	56.25
	4.	29.75	25.18	26.61
T_{17}	1.	61.85	34.74	47.25
	2.	32.09	17.91	24.29
	3.	61.85	45.52	52.75
	4.	32.09	28.69	29.79
T_{18}	1.	61.43	31.90	45.68
	2.	26.39	15.92	22.26
	3.	61.43	43.56	45.68
	4.	26.39	27.58	22.26
T_{19}	1.	50.42	36.47	41.44
	2.	25.57	17.88	21.19
	3.	50.42	49.67	46.94
	4.	25.57	31.08	26.69
T_{20}	1.	68.70	38.48	37.74
	2.	33.06	18.62	18.05
	3.	68.70	50.14	47.86
	4.	33.06	30.28	28.17
T_{21}	1.	54.05	35.52	45.11
	2.	26.39	17.29	21.67
	3.	54.05	45.42	45.11
	4.	26.39	27.19	21.67
T_{22}	1.	52.02	23.31	29.55
	2.	25.57	11.44	14.64
	3.	52.02	43.11	42.75
	4.	25.57	31.24	27.84
T_{23}	1.	55.90	28.41	38.36
	2.	29.75	14.27	19.34
	3.	55.90	45.57	44.96
	4.	29.75	31.43	25.94
T_{24}	1.	54.54	36.21	45.88
	2.	27.05	17.41	22.47
	3.	54.54	50.95	47.42
	4.	27.05	32.15	24.01

APPENDIX C (Continued)

T_{25}	1.	52.94	21.12	43.68
	2.	26.18	10.84	21.96
	3.	52.94	40.92	43.68
	4.	26.18	30.64	21.96
T_{26}	1.	61.43	30.82	45.65
	2.	29.75	14.48	21.21
	3.	61.43	50.62	52.91
	4.	29.75	34.28	28.47
T_{27}	1.	53.73	19.80	23.75
	2.	25.57	9.65	11.74
	3.	53.73	46.20	47.73
	4.	25.57	36.05	35.72
T_{28}	1.	54.54	18.80	42.95
	2.	27.50	9.60	20.58
	3.	54.54	43.88	42.95
	4.	27.50	34.68	20.58
T_{29}	1.	53.89	20.21	21.25
	2.	26.39	9.54	10.66
	3.	53.89	43.31	42.15
	4.	26.39	32.64	31.56

APPENDIX D

MEAN VALUES OF THE CLASSICAL COMPUTATION OF THE CARDIOVASCULAR INDICES

ANOVA Comparison	Experimental Condition	Mean Cardiovascular Index
A	Average cardiovascular index of all short subjects for all experimental conditions	51.99
	Average cardiovascular index of all tall subjects for all experimental conditions	48.04
	Mean Difference	3.95
B	Average cardiovascular index of short and tall subjects at a stepping height of 13 inches	60.83
	Average cardiovascular index of short and tall subjects at a stepping height of 21 inches	39.57
	Average cardiovascular index of short and tall subjects at a stepping height adjusted to the subject's patella height	49.65
	Mean Difference between the cardiovascular indices of 13 and 21 inches	21.26
	Mean Difference between the cardiovascular indices at 13 inches and patella height	11.18
	Mean Difference between the cardiovascular indices at 21 inches and patella height	-10.08

APPENDIX D (Continued)

AB Interaction	Average cardiovascular index of short subjects at 13 inches	62.24
	Average cardiovascular index of tall subjects at 13 inches	59.42
	Mean Difference	2.82
	Average cardiovascular index of short subjects at 21 inches	40.70
	Average cardiovascular index of tall subjects at 21 inches	38.43
	Mean Difference	2.27
	Average cardiovascular index of short subjects at patella height	53.03
	Average cardiovascular index of tall subjects at patella height	46.26
	Mean Difference	6.77

APPENDIX E

MEAN VALUES FOR THE CARDIOVASCULAR INDICES OF THE RAPID COMPUTATION

ANOVA Comparison	Experimental Condition	Mean Cardio-vascular Index
A	Average cardiovascular index of all short subjects for all experimental conditions	25.88
	Average cardiovascular index of all tall subjects for all experimental conditions	23.43
	Mean Difference	2.45
B	Average cardiovascular index of short and tall subjects at a stepping height of 13 inches	30.39
	Average cardiovascular index of short and tall subjects at a stepping height of 21 inches	19.31
	Average cardiovascular index of short and tall subjects at a stepping height adjusted to the subject's patella height	24.27
	Mean Difference between the cardiovascular indices at 13 and 21 inches	11.08
	Mean Difference between the cardiovascular indices at 13 inches and patella height	6.12
	Mean Difference between the cardiovascular indices at 21 inches and patella height	-5.96

APPENDIX E (Continued)

AB Interaction	Average cardiovascular index of short subjects at 13 inches	31.60
	Average cardiovascular index of tall subjects at 13 inches	29.18
	Mean Difference	2.42
	Average cardiovascular index of short subjects at 21 inches	19.95
	Average cardiovascular index of tall subjects at 21 inches	18.67
	Mean Difference	1.28
	Average cardiovascular index of short subjects at patella height	26.09
	Average cardiovascular index of tall subjects at patella height	22.44
	Mean Difference	3.65

APPENDIX F

MEAN VALUES FOR THE CARDIOVASCULAR INDICES
OF THE NEW CLASSICAL COMPUTATION

ANOVA Comparison	Experimental Condition	Mean Cardio-vascular Index
A	Average cardiovascular index of all short subjects for all experimental conditions	53.95
	Average cardiovascular index of all tall subjects for all experimental conditions	52.39
	Mean Difference	1.56
B	Average cardiovascular index of short and tall subjects at a stepping height of 13 inches	60.81
	Average cardiovascular index of short and tall subjects at a stepping height of 21 inches	47.46
	Average cardiovascular index of short and tall subjects at a stepping height adjusted to the subject's patella height	51.23
	Mean Difference between the cardiovascular indices at 13 and 21 inches	13.35
	Mean Difference between the cardiovascular indices at 13 inches and patella height	9.58
	Mean Difference between the cardiovascular indices at 21 inches and patella height	-3.77

APPENDIX F (Continued)

AB Interaction	Average cardiovascular index of short subjects at 13 inches	62.21
	Average cardiovascular index of tall subjects at 13 inches	59.42
	Mean Difference	2.79
	Average cardiovascular index of short subjects at 21 inches	47.45
	Average cardiovascular index of tall subjects at 21 inches	47.47
	Mean Difference	-.02
	Average cardiovascular index of short subjects at patella height	52.20
	Average cardiovascular index of tall subjects at patella height	50.27
	Mean Difference	1.93

APPENDIX G

MEAN VALUES FOR THE CARDIOVASCULAR INDICES
OF THE NARSS COMPUTATION

ANOVA Comparison	Experimental Condition	Mean Cardio-vascular Index
A	Average cardiovascular index of all short subjects for all experimental conditions	28.32
	Average cardiovascular index of all tall subjects for all experimental conditions	27.78
	Mean Difference	.54
B	Average cardiovascular index of short and tall subjects at a stepping height of 13 inches	30.39
	Average cardiovascular index of short and tall subjects at a stepping height of 21 inches	27.44
	Average cardiovascular index of short and tall subjects at a stepping height adjusted to the subject's patella height	26.32
	Mean Difference between the cardiovascular indices at 13 and 21 inches	2.95
	Mean Difference between the cardiovascular indices at 13 inches and patella height	4.07
	Mean Difference between the cardiovascular indices at 21 inches and patella height	1.12

APPENDIX G (Continued)

AB Interaction	Average cardiovascular index of short subjects at 13 inches	31.60
	Average cardiovascular index of tall subjects at 13 inches	29.17
	Mean Difference	2.43
	Average cardiovascular index of short subjects at 21 inches	27.16
	Average cardiovascular index of tall subjects at 21 inches	27.71
	Mean Difference	-.55
	Average cardiovascular index of short subjects at patella height	26.19
	Average cardiovascular index of tall subjects at patella height	26.45
	Mean Difference	-.26

VITA

The investigator, Kathryn L. Doughty, was born in St. Paul, Minnesota on October 29, 1950. Miss Doughty took her undergraduate work at Roanoke College and received a B.A. degree in Psychology in May of 1972. In December of 1972, Miss Doughty presented a research paper entitled "The Effect of Variant Temperatures on Heart Rate in Female Athletes" at the Virginia Association for Health, Physical Education, and Recreation Convention.