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Leg Strength and Height - Weight Factors in Relation to Cardiovascular Efficiency of College Women.

Samia Hanem ahmed Abdo

Louisiana State University and Agricultural & Mechanical College

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LEG STRENGTH AND HEIGHT-WEIGHT FACTORS IN RELATION TO CARDIOVASCULAR EFFICIENCY OF COLLEGE WOMEN

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The Department of Health, Physical and Recreation Education

by

Samia Hanem Ahmed Abdo
B.S., Physical Education Institute, Cairo, Egypt, 1957
M.S., Louisiana State University, 1962
May, 1965
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ABSTRACT

During recent years the widespread concern with physical fitness has resulted in physical educators' renewed attempts to define, measure, and establish standards for various aspects of physical fitness. Very little data, however, have been reported that are devoted to studying women's adjustment to the stress of activity.

The major purposes of this investigation were to determine the influence of leg strength on the performance of a three-minute cardiovascular efficiency test and to study the relationship between the weight of women when classified into three weight groups and their cardiovascular efficiency. A secondary purpose was to investigate the relationship between girls' ponderal indices and their cardiovascular efficiency scores.

The total number of subjects used was one hundred and ninety-eight women students enrolled in physical education classes at Louisiana State University, Baton Rouge, Louisiana. Twenty-two of the students who volunteered to participate in the study were physical education majors. The remainder of students who volunteered were enrolled in the basic physical education program for women. All subjects were classified as qualified for regular physical education classes by the Louisiana State University Student Health Service.

A leg strength test and a three-minute cardiovascular efficiency test were administered to the subjects on two separate days. Height, weight, chest width, and pelvic width of the subjects were measured.
The coefficient of correlation was used to determine the relationship between cardiovascular efficiency and leg strength and ponderal index for the total group of subjects. Coefficient of correlation was also used to determine the relationship between cardiovascular efficiency and leg strength for each of the three weight groups and also to determine the relationship between cardiovascular efficiency and weight as well as height for each of the three weight groups. Analysis of variance was utilized to determine the difference in leg strength between subjects who completed the three-minute step test and those who did not. Analysis of variance was also utilized to determine the difference in cardiovascular efficiency among the three weight groups. Analysis of variance was also used to determine the difference in leg strength among the three weight groups. Regression was used to analyze the relationship of cardiovascular efficiency classifications to ponderal index classifications.

As a result of the analysis of the data, the following conclusions were drawn:

1. Body build and other factors are more important, from a cardiovascular efficiency point of view, than the strength of the legs. Cardiovascular efficiency, however, is related positively to leg strength for normal weight women.

2. Cardiovascular efficiency is inversely related to excess weight. The more the person approximates normal weight or underweight to a certain point, the better cardiovascular efficiency will be. Being overweight has a negative
effect on cardiovascular efficiency.
3. The strength of the legs influences the performance on the Cardiovascular Efficiency Test for Girls and Women.
4. Cardiovascular efficiency is related significantly to ponderal index. This relationship is not as significant with women who possess a high degree of cardiovascular efficiency as it is with those who react to exercise less efficiently. Other factors apparently operate to produce a high degree of cardiovascular efficiency.
5. Cardiovascular efficiency is not related to height.
CHAPTER I

INTRODUCTION

I. CURRENT INTEREST IN CARDIOVASCULAR EFFICIENCY

Physical fitness in its many aspects has long interested physical educators. The recent widespread concern with physical fitness has resulted in physical educators' renewed attempts to define, measure, and establish standards for various aspects of physical fitness. Gallagher and Brouha have described the three primary aspects of physical fitness as follows:

1. Medical or static fitness, having to do with the soundness of organs of the body.

2. Functional or dynamic fitness, which has to do with functional status, the ability to do strenuous work, and physiological efficiency.

3. The type of fitness which has to do with specific skills, muscle coordinations, and strength.

A good deal of research in the area of "functional or dynamic fitness" has been completed, the bulk of which deals with male subjects. Not until Skubic and Hodgkins developed their cardiovascular efficiency test has there been a tool for studying women's adjustment to the stress.

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of activity. These women have developed a valid and reliable three-minute step test of cardiovascular efficiency in women. HAVING tested 2,360 women with the three-minute step test, the authors have provided cardiovascular efficiency standards for women.

In summarizing their findings, Skubic and Hodgkins have stated that "13% of the subjects could not complete the three-minute test" and "heavy women tend to score less well than lighter women." This study proposes to investigate further two of the factors which may have had a bearing upon the inability of the subjects to complete the three-minute step test: namely, leg strength and excess weight. A better understanding of the variability of females in reacting to activity stress may provide us with important information for the development of programs where this aspect of fitness is an objective.

II. PURPOSES OF THE STUDY

The major purposes of this investigation were to determine the influence of leg strength on the performance of a three-minute cardiovascular efficiency test and to study the relationship between the weight of women when classified into three weight groups and their cardiovascular efficiency. A secondary purpose was to investigate the relationship between girls' ponderal indices and their cardiovascular efficiency.


\(^3\)Ibid., p. 461.
efficiency scores. Specifically, this study proposed to provide further understanding of the variability of female cardiovascular efficiency by seeking the answers to these three questions:

1. Is there a correlation between leg strength scores and cardiovascular efficiency scores?
2. Is there a significant difference in leg strength between women who complete the three-minute step test and those who cannot?
3. What specific weight factors other than "heavy" influence women's cardiovascular efficiency scores?

III. DEFINITION OF TERMS

For this study the following definitions of terms were used.

Cardiovascular efficiency is the ability of the heart and circulatory system to adjust to the stress of activity.  

Ponderal index is a ratio of height and weight—a measure of the person's achieved mass over his surface area. According to Sheldon, the subject's ponderal index is determined by the formula:

\[ \frac{\text{Height}}{3 \sqrt{\text{Weight}}} \]

Leg Strength is the degree to which leg and hip extensors can exert force through isometric contraction.

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4 Hodgkins and Skubic, op. cit., p. 191.
**Normal weight.** Normal weight subjects were classified according to Pryor Width-Weight Tables. Subjects who were from five per cent underweight to five per cent overweight were included in the normal weight classification.

**Underweight.** Subjects were classified as underweight according to Pryor Width-Weight Tables. Those who were more than five per cent underweight were included in the underweight classification.

**Overweight.** Overweight subjects were classified according to Pryor Width-Weight Tables. Those who were more than five per cent overweight were included in the overweight classification.

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6 Helen B. Pryor, *Width-Weight Tables* (second revised edition; Stanford University, California, 1940).
CHAPTER II

REVIEW OF RELATED LITERATURE

Relatively little has been reported in the research literature dealing specifically with the problem involved in this study. A substantial amount has been reported, however, pertaining to ways and means of measuring the factors to be dealt with in the study: namely, leg strength, height, weight, and cardiovascular efficiency of women. Since the validity and reliability of the study are dependent to quite a degree upon the tools used in the study, it seemed important to review briefly some of the most significant work which has been done in perfecting tools and devices used in gathering data related to the factors involved in this study; such a review follows.

I. MEASUREMENT OF LEG STRENGTH

Logan¹ presented a description of a Modified Quadrant Assembly, a device for the measurement of knee extensor strength at varying angles in the range of motion. The instrument, modified from a similar device reported by Brewster of England, was described and illustrated. Instructions for construction and use were included.

Smith measured the leg strength of seventy college men with a conventional leg strength dynamometer in a position designed to involve the power thrust of the major muscle groups used in the vertical jump. The subjects then performed a modified Sargent Jump that involved no arm snap. Although the reliability of all measures was high, individual differences in the ratio of tested strength to body mass showed only a low and non-significant correlation with jumping performance.

The current interest in isometric exercise has brought about a need for an accurate measuring device for determining strength of specific muscle groups. Coach's Sporting Goods Corporation has developed a strength-measuring device called the Iso-Scale. This particular instrument can be used in several ways to measure the strength of various muscle groups, including those involved in "step" testing.

The Iso-Scale can be used to measure forces from zero to five hundred tensile pounds with a high degree of accuracy. The adaptability of this instrument for laboratory use in the measurement of leg strength was well-suited for the purpose of this research.

II. RELATING HEIGHT, WEIGHT AND BODY BUILD

In reviewing this type of research, an attempt was made to find

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3Coach's Sporting Goods Corporation, P. O. Box 835, Marion, Indiana.
an instrument or procedure that would provide the investigator with a means of classifying students as overweight, normal weight, or underweight and further provide the investigator with an index of the height-weight ratio that would give a measure of body surface. Concern with the nutritional status of students has given rise to the development of tables for classifying students into overweight, normal, and underweight groups.

The earliest methods of appraising physical status were tables from which weight could be predicted on the basis of sex, age, and height. In establishing these tables, a large number of people of the same sex, age, and height were weighed. The average weight was computed and recorded as the normal weight for all persons of the same sex, age, and height. The best known tables of this type are the Wood-Baldwin Age-Height-Weight Tables. One cannot expect a given person to weigh exactly the same as a norm computed on the basis of several thousand people. Hence, the usual interpretation of such norms is that the person should be within ten to fifteen per cent of his own norm.

It is at times an error to accept the average as being normal. The averaging of a large number of weights results in one number. What this average means in terms of health could be anyone's guess. It simply is the best single score for representing the group.

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5 Ibid., p. 213.
Cureton\(^6\) devised an equation for predicting proper individual weight on the basis of the skeletal measurements of bone, muscle, and fat. Here a skeletal index, a muscle girth index, and an adipose tissue index were combined. This was later improved and the results were the following formula:

\[
\text{Weight (lb.)} = 9.09 \text{ (ankle girth, in.)} + 5.01 \text{ (minimum chest girth, in.)} + 4.12 \text{ (hip width, in.)} - 249.55
\]

In studying methods of weight prediction for college women, Ludlum and Powell\(^7\) found that height, chest depth, and chest width were the most effective of the items studied. The following regression equation was obtained between these tests and the weights of 1,580 women from nineteen colleges throughout the United States:

\[
\text{Weight} = 2.6 \text{ (Sum of Measurements)} - 154.3.
\]

The coefficient of correlation between actual and the predicted weights was .71, with a predictive index of .30. Height correlated with actual weight, .57, with a predictive index of .17. Thus, the new formula was found to be approximately twice as effective in predicting weight as was height alone.

After an intensive research project in which the factor analysis

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\(^7\) F. E. Ludlum and Elizabeth Powell, "Chest-Height-Weight Tables for College Women," Research Quarterly, XI (October, 1940), 55.
approach was used, McCloy\textsuperscript{8} recommended that schools use anthropometric measurements of height, weight, hip width, chest circumference, leg girth, width of elbow and knee, and girths of upper arm, forearm, and thigh in predicting normal weight. He found that these elements were highly correlated with normal weight. It was necessary to make corrections in the measurement of chest girth and hip width in relation to deficiency or excess of fat. The correction was based upon measurements of skin and subcutaneous tissue taken with fat calipers.

Lowman and Young,\textsuperscript{9} as well as Blesh and others,\textsuperscript{10} recommend the use of the Pryor Width-Weight Tables for evaluating nutritional status.

Pryor,\textsuperscript{11} maintaining that determination of appropriate body weight as an index of nutrition should take into account not only the factors of sex, height, and age, but also the nature of the bony framework and body structure, has devised a test of nutritional status for persons between the ages of one and forty-one.

Following a study of various body measurements that might be used as an index of body build, the bi-iliac diameter or width of the pelvic crest was selected as the most important and least variable


\textsuperscript{10}T. Erwin Blesh and others, "The Body Mechanics Program at Yale University," (unpublished study, Yale University).

\textsuperscript{11}Helen B. Pryor, Width-Weight Tables (second revised edition; Stanford University, California, 1940).
measurement of body width. In addition to this measurement, the thoracic width and the height and age of the subject were recorded. With these data, specially prepared tables were used to determine the proper weight of the subject.\textsuperscript{12}

The Ponderal Index, a ratio of height and weight, has been used to provide an indication of body surface. After many years of investigation, Sheldon\textsuperscript{13} has classified human physiques into three major body types: endomorphic, mesomorphic, and ectomorphic. The first step in the somatotyping procedure is that of determining the subject's ponderal index by the formula:

\[
\frac{\text{Height}}{3 \sqrt[3]{\text{Weight}}}
\]

Sheldon described the ponderal index as a measure of the person's achieved mass over his surface area. This index gives us another point of reference in the study of the relation of weight to cardiovascular efficiency.

III. MEASUREMENT OF CARDIOVASCULAR EFFICIENCY

Since 1884, researchers have been seeking to find tests to measure muscular and circulatory efficiency.\textsuperscript{14} Such tests are, for the most part, attempts at measuring certain variables which reflect the condition of the circulatory system in adjusting to work conditions.

\textsuperscript{12} Ibid.

\textsuperscript{13} William H. Sheldon, S. S. Stevens and W. B. Tucker, \textit{loc. cit.}

\textsuperscript{14} Mathews, \textit{op. cit.}, p. 187.
The involvement of the United States in the recent wars has promoted much research and test development in this area. The bulk of this research deals with male subjects. According to Mathews, the following tests related to cardiovascular function have been developed:

1. Balke Treadmill Test
2. Barach Index
3. Burger Test
4. Carlson Fatigue Curve Test
5. Crampton Blood Potosis Test
6. Foster's Test
7. Gallagher and Brouha Test for Girls
8. Gallagher and Brouha Test for High School Boys
9. Harvard Step Test
10. Pack Test
11. Schneider Test
12. Sloan Test

Three tests reported in the literature were chosen for review here primarily because they were designed for women and apparently have been successfully used in measuring cardiovascular efficiency. Pertinent statements about these tests follow.

The Gallagher and Brouha Test for Girls was devised for

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15 Ibid., pp. 190-207.

estimating the dynamic physical fitness of high school girls. The test was based upon the principle that the more fit a girl is, the more rapidly will her heart rate return to normal after exercise. In the test, the subject stepped up and down on a sixteen-inch platform thirty times a minute. The subject continued stepping as long as she could up to a maximum of four minutes. The pulse was counted from 1 to 1½, 2 to 2½, and 3 to 3½ minutes after the subject finished the test. The score was computed by the formula:

\[
\text{Physical Fitness Score} = \frac{(\text{Duration of exercise in sec.}) \times 100}{2 \times (\text{Sum of pulse counts})}
\]

Clarke\(^{17}\) used the Brouha modification of the Harvard Step Test as a Functional Physical Fitness Test for College Women. In this test an eighteen-inch bench was used and the exercise was continued for four minutes. The remainder of the administration of the test was the same as the Gallagher and Brouha Test for Girls.

The Sloan Test\(^{18}\) is a modification of the Harvard Step Test, suitable for use with women. In an effort to equate fitness index scores between men and women, this experiment was conducted to establish a step height for women that would produce scores equivalent to those obtained with a twenty-inch step for men. The subjects stepped up and down on an eighteen-inch bench at the rate of thirty steps per minute, for a total exercise period of five minutes or until unable to continue.

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the exercise. The remainder of the administration of the test was the same as the Gallagher and Brouha Test for Girls. The Fitness Index was computed using the same formula as that employed by these authors in their original study.

The limitation the three tests discussed above are clearly identified. They are quite lengthy and difficult to administer. The only other test for girls and women is the recently developed three-minute step test by Skubic and Hodgkins. These authors first made a study to determine whether or not a three-minute step test with one recovery pulse count is a valid and reliable instrument for measuring the cardiovascular efficiency of women. Ninety-six females between the ages of twelve and twenty-five volunteered to take both the five-minute and three-minute tests. The rate of stepping in both tests was set at twenty-four steps per minute on a bench eighteen inches high. The stepping rhythm was regulated by an electric metronome. After one minute of rest following exercise, the pulse was taken for thirty seconds. As far as possible, all conditions were the same for both administrations of the test, the only variable being the length of the test. In order to minimize the effects of practice and learning, some subjects were given the five-minute test first, while others started with the three-minute test. The result obtained, a correlation of .790, was accepted as sufficiently high to justify further study of the three-minute test.

The modified three-minute test was then used to test four groups of subjects:

1. Trained girls, between eleven and seventeen years of age.
2. Untrained girls, twelve to sixteen years of age.
3. Active women, aged seventeen to twenty-three.
4. Sedentary women, seventeen to twenty-three years of age.

From this study, Skubic and Hodgkins concluded that:

1. The three-minute step test is sufficiently strenuous to be classified as hard work for girls and women.
2. The test, as described in the study, discriminates to a high degree among subjects in an excellent state of physical condition, subjects who are moderately active, and those who are sedentary.
3. Trained swimmers have lower heart rates during the second and third minutes of exercise and during recovery than girls and women who are not in a trained condition.
4. Physical education major students appear to be highly reliable in checking pulse rates of subjects after exercise.
5. Age is not a factor in the step test among females of junior high, high school, and college age.
6. The test is valid and reliable as an instrument for determining the cardiovascular efficiency of girls and women.

Pursuant to the above-mentioned research, Hodgkins and Skubic further investigated the three-minute step test, establishing national cardiovascular efficiency standards for college women. A total of

\[ \text{20 Ibid., p. 197.} \]

\[ \text{21 Hodgkins and Skubic, "Cardiovascular Efficiency Test Scores for College Women in the United States," pp. 454-461.} \]
2,360 college women, representing all United States geographical locations, participated in the follow-up study. From this second study, Hodgkins and Skubic concluded that:

1. When rated on a national scale for cardiovascular efficiency, the majority of the 2,360 college women in the study were rated "fair."

2. Thirteen per cent of all subjects could not complete the three-minute step test, and the overwhelming majority of these were in the "poor" and "very poor" categories.

3. Subjects in the Eastern District had better cardiovascular efficiency scores than subjects in the other five districts. The subjects in the Southern District made poorer scores than subjects in any other district.

4. The height of subjects does not affect scores on the step test, but there is clear indication that heavy women tend to score less well than lighter women.

5. Physical education majors are more fit from a cardiovascular standpoint than any other group of majors studied. The education majors are less fit than most other major groups.22

Skubic and Hodgkins23 also used the three-minute step test in a third study designed (1) to gather test scores from junior and senior high school subjects in order to provide standards for girls of secondary school age, (2) to compare these results with those of college women, (3) to determine whether or not air temperature or diurnal variations affected the scores, and (4) to compare the scores obtained from the six districts of the American Association for Health, Physical Education and Recreation. A total of 686 junior high school

22 Ibid., pp. 460-461.

students, aged nine through fourteen, and 1,332 high school students, aged fifteen through nineteen, participated in the study. The junior high school subjects were enrolled in twenty-five different schools distributed throughout the six districts of the American Association for Health, Physical Education and Recreation. Thirty high schools were represented and these were also distributed throughout the six districts.

From this third study, Skubic and Hodgkins concluded that:

1. A comparison of 686 junior high school students with 1,332 high school students indicated that the younger girls made significantly better scores than the older girls on the cardiovascular efficiency test.

2. When compared with scores of college women obtained in a previous study, junior high school subjects scored significantly better than college women, but there was no difference between high school and college scores.

3. Subjects tested in cool temperatures (between 54°F and 65°F) did not score differently from those subjects tested in the warm temperatures (between 80°F to 91°F). A very low, insignificant relationship was found between temperature and scores on the three-minute step test.

4. Tests given at four different times during the day revealed that the time of testing does not affect test scores.

5. Senior high school students in the Central district made better scores than students in any of the other five districts of the American Association for Health, Physical Education and Recreation. In the junior high school group, students in the Central and Southern districts made the best scores. At the college level, subjects in the Eastern district scored higher than all others.\textsuperscript{24}

\textsuperscript{24}ibid., p. 191.
CHAPTER III

PROCEDURE USED IN THE STUDY

The data for this study were gathered during the spring semester of the school year 1963-1964 at Louisiana State University, Baton Rouge, Louisiana.

1. SUBJECTS USED

The investigator explained the nature of the study to women students enrolled in conditioning exercises, badminton, tennis, and swimming classes, which are a part of the basic physical education program at Louisiana State University, and also to a limited number of women students majoring in physical education. This was done in order to have a broad sample of subjects. Students were asked to volunteer for participation in this study.

One hundred ninety-eight students volunteered as subjects. All subjects were classified "qualified for regular physical education" by the L.S.U. Student Health Service. Ages ranged from eighteen to twenty-five years. Sixty-nine of the subjects were enrolled in conditioning exercise classes, seventy-three were registered for badminton classes; twenty-two were enrolled in tennis classes; twelve students were enrolled in swimming classes; twenty-two of the subjects were majoring in physical education and were participating in a variety of activities in relation to their major courses.
II. TESTING THE SUBJECTS

The tests used in this study were the leg strength test, using the Iso-Scale, and the Cardiovascular Efficiency Test for Girls and Women. Measurements taken were height, weight, and chest and pelvic width.

The investigator undertook a pre-research one-week testing period to perfect her own technique for measurements as well as to determine the reliability of her measuring and testing procedures. During this week the investigator used twenty-four subjects for this purpose. Anthropometric measures were taken twice for each subject and figures were compared until the obtained figures were the same. The leg strength test was administered twice for each subject and when the scores were compared, it was found that they were essentially the same. The cardiovascular efficiency test was administered to each subject individually, having one other person with the investigator counting the recovery pulse and recording same. Practice in this pre-research experience was continued until the investigator's techniques were judged to be perfected to a satisfactory degree.

Subjects were tested on two separate days due to the demands of the two tests. On the first day, the subjects were instructed to record personal information on the research cards; anthropometric

---

1 Coach's Sporting Goods Corporation, P. O. Box 835, Marion, Indiana.

measurements were taken and recorded; the leg strength test was adminis-
tered to each subject and scores were recorded. On the second day, the
cardiocvascular efficiency test was administered to each subject. The
number of seconds duration of exercise, and thirty-second recovery pulse
following one-minute rest were recorded for each subject.

Procedure for First Day

After the subject's personal information was recorded, height,
weight, chest, and pelvic width measurements of each were taken. Then
the leg strength test was administered to each subject.

Height. A stadiometer and a wall chart were used to obtain the
height of the subjects. Each subject was measured without shoes,
having the subject stand as tall as she could with her feet together,
heels on the floor, and with her back against the wall chart. A
stadiometer was placed on the subject's head and the exact height of
the subject was read from the wall chart. The record was made to the
nearest quarter of an inch.

Weight. The weight of each subject was obtained by use of medical
scales. The subject wore regulation gymnasium clothes and stood without
shoes. Weight of the subject was recorded to the nearest half-pound.

Ponderal Index. The height-weight data were used to determine
each subject's ponderal index by the formula:

\[
\text{Ponderal Index} = \frac{\text{Height}^3}{\sqrt[3]{\text{Weight}}}
\]

Chest Width. The subject was instructed to stand relaxed, to
breathe normally, with arms at the side of the body. The investigator
faced the subject with wooden sliding calipers held horizontally at nipple level and with the arms of the caliper resting, without pressure, on the sides of the thoracic cage. The measurement was taken at the end of a normal expiration and recorded to the nearest tenth of a centimeter. A deduction of one-tenth of a centimeter was made later for clothes.

**Pelvic Width.** The investigator stood facing the subject, who was standing with feet together, and measured with firm pressure of the two arms of the caliper, the greatest width at the crest of the ilium. The arms of the caliper were tilted slightly upward. The record was made to the nearest tenth of a centimeter. A deduction of two-tenths of a centimeter was made later for clothes.

**Weight Classifications.** The age, height, weight, chest, and pelvic width were used to determine whether or not each subject was normal weight, underweight, or overweight according to the Pryor Width-Weight Charts. Weights from five per cent underweight to five per cent overweight were considered to be within the range of normal variation.

**Leg Strength Test.** The leg strength test with the Iso-Scale, a strength-measuring device which can be used to measure forces from zero to five hundred tensile pounds, was used to obtain leg strength scores of the subjects. The investigator explained and demonstrated the test to the subjects, then the test was administered to each subject individually. The subject was instructed to stand, with the feet apart, on the flat parts of the metal bar and with the knees and hips flexed at $30^\circ$ angles with the vertical line. A goniometer with
two angles, $30^\circ$ each, representing the knees and hips in a flexed position, was used to be sure that all subjects were tested with their bodies at the same angle. The belt was fixed to one end of the metal bar, crossed over the lower back of the subject, adjusted to the height of the subject and then fixed to the other end of the metal bar. A towel was placed on the back of the subject not only to prevent the belt from sliding while the subject performed the test but also to prevent the pressure of the belt from causing unnecessary pain. The subject was urged to push upward against the belt by contracting the leg and hip extensors as hard as she could. The number of pounds the subject was able to push was read from the Iso-Scale and recorded. This number was multiplied by two, since the subject pushed against two belts, one from each side, and this was recorded as the leg strength score.

Procedure for Second Day

The Cardiovascular Efficiency Test for Girls and Women, developed by Skubic and Hodgkins,\(^3\) was administered to the subjects to obtain their cardiovascular efficiency scores.

**Cardiovascular Efficiency Test.** This test consisted of continuous stepping up and down on a bench eighteen inches high at the rate of twenty-four steps per minute for three minutes. Students who completed the three-minute duration of exercise rested for one minute in a sitting position. Following the completion of the one-minute rest, recovery pulse was counted for thirty seconds. For subjects who

\(^3\)Ibid.
stopped prior to the three-minute period, the total time of stepping was noted, and they were allowed to rest one minute. Recovery pulse was then counted for thirty seconds. The actual number of seconds the subject was able to step up and down and recovery pulse counts were recorded on the subject's research card. They were converted later to a cardiovascular efficiency score as described by Hodgkins and Skubic.4

The investigator administered this test to each subject individually. A metronome was used to set the time of the cadence. The cadence was set at ninety-six beats per minute to regulate the time of stepping. Two stop watches were used. One was started simultaneously with the signal for the subject to start performing the test and stopped exactly after three minutes or when the subject could no longer continue stepping up and down at that cadence. The second watch was started simultaneously when the first watch was stopped, to time the one-minute rest and the thirty-second pulse-counting interval. Recovery pulse counts were taken by the investigator at the carotid artery by the palpation method. The author gave verbal signals to start and stop the test and to help the subject maintain the cadence.

Scores for subjects who failed to finish the three-minute test were computed by the formula:5

\[
\text{Score} = \frac{\text{No. of seconds of stepping} \times 100}{30 \text{-second recovery pulse} \times 5.6}
\]

For subjects who completed the three-minute test, a conversion

5Ibid., p. 456.
table was used to determine the scores. Standards set in the table were as follows: Excellent, 71 and above; Very Good, 60-70; Good, 49-59; Fair, 39-48; Poor, 28-38; and Very Poor, 0-27.

III. STATISTICAL ANALYSIS

The Louisiana State University Computer Research Center was utilized to analyze statistically the data gathered for this study. The raw scores were entered on I.B.M. score sheets which were used to provide information for the punching of I.B.M. cards. These cards were then used to compute the final results for this study.

The product-moment coefficient of correlation was employed to determine the relationship between cardiovascular efficiency and leg strength, and ponderal index. Coefficient of correlation was also used to determine the relationship between cardiovascular efficiency and leg strength for each of the groups--normal weight, underweight, and overweight; it was also used to determine the relationship between cardiovascular efficiency and weight, and height for the three weight groups.

In order to determine if there were significant differences in leg strength between those who completed the three-minute step test and those who could not, analysis of variance was used. Analysis of variance was also used to determine if there were significant differences in cardiovascular efficiency among the three weight groups, and

6 Ibid., p. 461.
to determine whether or not there were significant differences in leg strength among the three weight groups.

Regression was used to analyze the relationship between cardiovascular efficiency classifications of the subjects to their ponderal index classifications.
CHAPTER IV

ANALYSIS AND PRESENTATION OF THE DATA

In analyzing the data, coefficients of correlation were computed between cardiovascular efficiency and leg strength, and ponderal index. The group was then divided into three groups—normal weight, underweight, and overweight groups. The subjects were assigned to these groups according to Pryor Width-Weight Tables, using the age, height, weight, chest, and pelvic width data. Weights from five per cent underweight to five per cent overweight were considered to be within the range of normal variations. Coefficients of correlation were computed between cardiovascular efficiency and leg strength for each of the three weight groups. Coefficients of correlation were also obtained between cardiovascular efficiency and weight and height for the three weight groups.

Analysis of variance was used to determine whether or not there were significant differences in leg strength between those who completed the three-minute step test and those who did not complete the test. Analysis of variance was also used to determine whether or not there were significant differences in cardiovascular efficiency among the three weight groups. Analysis of variance was also utilized to determine whether or not there were significant differences in leg strength among the three weight groups.

An additional phase of the study involved rating and classifying the groups into very good, good, fair, poor, and very poor categories based on their cardiovascular efficiency scores. These ratings and
classifications were based on the national standards for college women
developed by Hodgkins and Skubic. For these classifications, five
ponderal index classifications of the subjects were computed. Regression
was used to analyze the extent of the relationship of the cardiovascular
efficiency classifications of the subjects to their ponderal index
classifications.

I. TOTAL GROUP ANALYSIS

Using the total group data, coefficients of correlation were
computed between the scores of cardiovascular efficiency and leg strength
and ponderal index. The correlations were tested against the null
hypothesis to determine their significance. Results of these correla­
tions are shown in Tables I and II.

TABLE I

COEFFICIENT OF CORRELATION OF CARDIOVASCULAR EFFICIENCY
SCORES AND LEG STRENGTH SCORES FOR ONE HUNDRED
NINETY-EIGHT COLLEGE WOMEN

<table>
<thead>
<tr>
<th>Mean of Cardiovascular Efficiency Scores</th>
<th>Mean of Leg Strength Scores</th>
<th>D.F.</th>
<th>r</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>47.2</td>
<td>326.8</td>
<td>196</td>
<td>.193</td>
<td>.01</td>
</tr>
</tbody>
</table>

r needed for .05 level was .138 and for the .01 level, .181

Relationship of Cardiovascular Efficiency to Leg Strength

The coefficient of correlation shown in Table I between

1Ibid., p. 461.
cardiovascular efficiency and leg strength was .193. For 196 degrees of freedom, correlations of .138 and .181 were needed to reject the null hypothesis at the .05 and .01 levels of confidence, respectively. The r of .193 was therefore found to be significant at the .01 level of confidence, and the null hypothesis was rejected accordingly. This indicated a positive relationship between cardiovascular efficiency scores and leg strength scores.

Relationship of Cardiovascular Efficiency to Ponderal Index

As shown in Table II, a coefficient of correlation of .364 was obtained between cardiovascular efficiency scores and ponderal index scores. The obtained correlation of .364 was highly significant beyond the .01 level of confidence, and the null hypothesis was rejected. This revealed that the cardiovascular efficiency ratings were highly related to the ponderal index of the subjects in this study.

<table>
<thead>
<tr>
<th>Mean of Cardiovascular Efficiency Scores</th>
<th>Mean of Ponderal Index</th>
<th>D.F.</th>
<th>r</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>47.2</td>
<td>13.06</td>
<td>196</td>
<td>.364</td>
<td>.01</td>
</tr>
</tbody>
</table>

r needed for .05 level was .137 and for the .01 level, .181

II. ANALYSIS OF DATA BY WEIGHT GROUPS

The subjects were divided into normal weight, underweight, and
overweight groups according to the Pryor Width-Weight Tables. The number of subjects in each group was seventy-one, one hundred ten, and seventeen, respectively. It was surprising to find the greatest number of subjects in the underweight group. The investigator has no explanation for this finding.

The data were analyzed to determine the relationship between cardiovascular efficiency and leg strength for each of the three weight groups. Coefficient of correlation was also used to determine the relationship between cardiovascular efficiency and weight and height for each of the three weight groups. These correlations were tested against the null hypothesis to determine their significance.

Using the data for the three weight groups, analysis of variance was employed to determine whether or not there were significant differences in cardiovascular efficiency scores among the three groups. Analysis of variance was also employed to determine if there were significant differences in leg strength among the three groups.

Coefficients of Correlation of Cardiovascular Efficiency and Leg Strength for the Three Weight Groups

Relationship of cardiovascular efficiency and leg strength for the normal weight group. The obtained coefficient of correlation shown in Table III between cardiovascular efficiency and leg strength for the normal weight group was .484. For the sixty-nine degrees of freedom for this group, coefficients of correlation of .234 and .304 were needed to indicate significant relationships at the .05 and .01 levels of confidence, respectively. The r of .484 was, therefore, found to be significant at
the .01 level of confidence, and the null hypothesis was rejected accordingly. This indicated existing positive relationship between cardiovascular efficiency scores and leg strength scores for the normal weight group.

TABLE III

COEFFICIENTS OF CORRELATION OF CARDIOVASCULAR EFFICIENCY SCORES AND LEG STRENGTH SCORES FOR THREE GROUPS OF COLLEGE WOMEN CLASSIFIED AS NORMAL WEIGHT, UNDERWEIGHT, AND OVERWEIGHT

<table>
<thead>
<tr>
<th>Group or Classification</th>
<th>Mean of C.V.E. Scores</th>
<th>Mean of Leg Strength</th>
<th>D.F.</th>
<th>r</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal weight</td>
<td>47.1</td>
<td>335.1</td>
<td>69</td>
<td>.484</td>
<td>.01</td>
</tr>
<tr>
<td>Underweight</td>
<td>48.6</td>
<td>315.5</td>
<td>108</td>
<td>.057</td>
<td>--</td>
</tr>
<tr>
<td>Overweight</td>
<td>39.1</td>
<td>365.9</td>
<td>15</td>
<td>.223</td>
<td>--</td>
</tr>
</tbody>
</table>

For 69 df, r .05 = .234; r .01 = .304
For 108 df, r .05 = .188; r .01 = .246
For 15 df, r .05 = .482; r .01 = .606

Relationship of cardiovascular efficiency and leg strength for the underweight group. As shown in Table III, the obtained coefficient of correlation between cardiovascular efficiency and leg strength for the underweight group was .057, indicating that cardiovascular efficiency scores for the underweight group of college women were not related to their leg strength scores.

Relationship of cardiovascular efficiency and leg strength for the overweight group. The obtained coefficient of correlation between cardiovascular efficiency and leg strength for the overweight group was .223 as shown in Table III. This coefficient of correlation was
considerably less than the r of .482 that is needed for significance at the .05 level of confidence. Consequently, although the correlation was positive, it can be seen that the cardiovascular efficiency scores of the subjects in the overweight group were not significantly proportional to their leg strength scores.

Earlier in this chapter, it was shown that there was found a significant relationship between cardiovascular efficiency and leg strength for the total group of subjects (see Table I, page 27). Apparently, the subjects in the normal weight group accounted for most of this coefficient of correlation between the two variables. From the foregoing analysis of the relationship of cardiovascular efficiency and leg strength within each weight group, the evidence suggests that as the individual's body build deviates from the normal, leg strength becomes less important in predicting cardiovascular efficiency performance and other factors that are associated with body build become increasingly more prominent. In regard to this study, it is obvious that excess weight is the principal determining factor and probably overshadows the beneficial effect of leg strength.

**Coefficients of Correlation of Cardiovascular Efficiency and Weight for Three Weight Groups.**

**Relationship of cardiovascular efficiency and weight for the normal weight group.** The coefficient of correlation obtained between cardiovascular efficiency and weight was -.403, as shown in Table IV. In order to be significant, an r of .234 was needed at the .05 level of confidence and an r of .304 was needed at the .01 level of confidence.
The obtained correlation of -.403 was significant at the .01 level of confidence, therefore the null hypothesis was rejected. Since the obtained correlation was negative, this indicated that the heavier the subject, the lower the cardiovascular efficiency score obtained by that subject.

TABLE IV
COEFFICIENTS OF CORRELATION OF CARDIOVASCULAR EFFICIENCY AND WEIGHT FOR THREE GROUPS OF COLLEGE WOMEN CLASSIFIED AS NORMAL WEIGHT, UNDERWEIGHT, AND OVERWEIGHT

<table>
<thead>
<tr>
<th>Group or Classification</th>
<th>Mean of C.V.E. Scores</th>
<th>Mean Weight</th>
<th>D.F.</th>
<th>r</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Weight</td>
<td>47.1</td>
<td>129.58</td>
<td>69</td>
<td>-.403</td>
<td>.01</td>
</tr>
<tr>
<td>Underweight</td>
<td>48.6</td>
<td>113.87</td>
<td>108</td>
<td>-.018</td>
<td>--</td>
</tr>
<tr>
<td>Overweight</td>
<td>39.1</td>
<td>152.85</td>
<td>15</td>
<td>-.478</td>
<td>--</td>
</tr>
</tbody>
</table>

For 69 df, r .05 = .234; r .01 = .304
For 108 df, r .05 = .188; r .01 = .246
For 15 df, r .05 = .482; r .01 = .606

Relationship of cardiovascular efficiency and weight for the underweight group. The obtained coefficient of correlation between cardiovascular efficiency and weight for the underweight group was -.018. As shown in Table IV, this correlation was not significant and the null hypothesis was not rejected, indicating that in the underweight group, weight did not have any relationship with the cardiovascular efficiency scores obtained by these individuals.

Relationship of cardiovascular efficiency and weight for the overweight group. The coefficient of correlation between cardiovascular efficiency and weight for the overweight group was -.478. For the
fifteen degrees of freedom for this group, shown in Table IV, coefficients of correlation of .482 and .606 were needed to indicate significant relationships at the .05 and .01 levels of confidence, respectively. The obtained correlation of -.478 did not quite reach significance at the .05 level of confidence. As shown in Table IV, the obtained correlation for the overweight group was higher than the obtained correlation for the normal weight group, but because of the small number of subjects in the overweight group and the larger number of subjects in the normal weight group, the coefficients of correlation were significant at the .01 level of confidence for the normal weight group and not significant at the .05 level of confidence for the overweight group. The obtained correlation was negative which reaffirmed the indication that persons with excess weight tend to be in poorer cardiovascular condition than those whose weight is either normal or slightly under normal. The mean score for cardiovascular efficiency for the overweight group was the poorest of all the three weight groups. It was felt that use of a larger number of subjects in this group might have resulted in a significant negative correlation between weight and cardiovascular efficiency scores.

Coefficients of Correlation of Cardiovascular Efficiency and Height for the Three Weight Groups

Relationship of cardiovascular efficiency and height for the normal weight group. The obtained coefficient of correlation between cardiovascular efficiency and height was -.087. As shown in Table V, this correlation was not found to be significant and the null hypothesis
was not rejected, indicating that height was not related to the scores of cardiovascular efficiency for the normal weight group.

TABLE V

COEFFICIENTS OF CORRELATION OF CARDIOVASCULAR EFFICIENCY SCORES AND HEIGHT FOR THREE GROUPS OF COLLEGE WOMEN CLASSIFIED AS NORMAL WEIGHT, UNDERWEIGHT, AND OVERWEIGHT

<table>
<thead>
<tr>
<th>Group or Classification</th>
<th>Mean of C.V.E. Scores</th>
<th>Mean Height</th>
<th>D.F.</th>
<th>r</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Weight</td>
<td>47.1</td>
<td>65.01</td>
<td>69</td>
<td>-.087</td>
<td>--</td>
</tr>
<tr>
<td>Underweight</td>
<td>48.6</td>
<td>64.51</td>
<td>108</td>
<td>-.085</td>
<td>--</td>
</tr>
<tr>
<td>Overweight</td>
<td>39.1</td>
<td>64.88</td>
<td>15</td>
<td>-.026</td>
<td>--</td>
</tr>
</tbody>
</table>

For 69 df, \( r .05 = .234; r .01 = .304 \)

For 108 df, \( r .05 = .188; r .01 = .246 \)

For 15 df, \( r .05 = .482; r .01 = .606 \)

**Relationship of cardiovascular efficiency and height for the underweight group.** As shown in Table V, a coefficient of .085 was obtained between cardiovascular efficiency scores and height, showing no relationship between height and the scores made in cardiovascular efficiency by the underweight group.

**Relationship of cardiovascular efficiency scores and height for the overweight group.** The obtained coefficient of correlation between cardiovascular efficiency scores and height was .026, as shown in Table V. Height, therefore, was not found to be a factor affecting the scores of cardiovascular efficiency for any of the three groups tested.
Analysis of Variance of Cardiovascular Efficiency Scores Among the Three Weight Groups

As shown in Table VI, the analysis of variance of cardiovascular efficiency scores among the three weight groups resulted in an F-ratio of 11.33. This ratio was found to be highly significant beyond the .01 level of confidence. This meant that a true difference existed among the three groups in cardiovascular efficiency scores.

TABLE VI

ANALYSIS OF VARIANCE OF CARDIOVASCULAR EFFICIENCY SCORES FOR THREE GROUPS OF COLLEGE WOMEN CLASSIFIED AS NORMAL WEIGHT, UNDERWEIGHT, AND OVERWEIGHT

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>D.F.</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>197</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Among Groups</td>
<td>02</td>
<td>657.5</td>
<td>11.33</td>
<td>.01</td>
</tr>
<tr>
<td>Error</td>
<td>195</td>
<td>58.03</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F .05 = 3.09; F .01 = 4.84

Further study of the data was made to determine specifically, which group significantly differed from the others in cardiovascular efficiency scores. With three groups only two degrees of freedom for comparisons is allowed. Therefore, analysis of variance was used to compare the underweight group with the normal weight group to determine if there was a significant difference in cardiovascular efficiency scores. Then the scores of cardiovascular efficiency for the underweight and normal weight groups were combined and compared with cardiovascular efficiency scores of the overweight group.
These particular comparisons were made because of the negative correlations obtained between weight and cardiovascular efficiency scores. Thus, analysis of variance was employed to determine whether or not the underweight and normal weight groups significantly differed from the overweight group in cardiovascular efficiency scores. Results of these analyses are shown in Table VII.

**TABLE VII**

**ANALYSIS OF VARIANCE OF CARDIOVASCULAR EFFICIENCY SCORES FOR THE UNDERWEIGHT GROUP VERSUS THE NORMAL WEIGHT GROUP, AND THE COMBINATION OF UNDERWEIGHT AND NORMAL WEIGHT VERSUS THE OVERWEIGHT GROUP OF COLLEGE WOMEN**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Sources of Variance</th>
<th>D.F.</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Weight Group vs.</td>
<td>Total</td>
<td>180</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight Group</td>
<td>Among Groups</td>
<td>01</td>
<td>93</td>
<td>1.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>179</td>
<td>53.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal and Underweight Group</td>
<td>Total</td>
<td>197</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group vs. Overweight Group</td>
<td>Among Groups</td>
<td>01</td>
<td>1222</td>
<td>20.99</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>196</td>
<td>58.21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For 1 and 179 df, $F_{.05} = 3.90; F_{.01} = 6.79$

For 1 and 196 df, $F_{.05} = 3.89; F_{.01} = 6.76$

*F-ratio of cardiovascular efficiency scores between underweight and normal weight groups.* Analysis of variance of cardiovascular efficiency scores between underweight and normal weight groups resulted in an F-ratio of 1.74, as indicated in Table VII. For the 1 and 179
degrees of freedom, F-ratios of 3.90 and 6.79 were needed for significance at the .05 and .01 levels of confidence, respectively. The F-ratio of 1.74 was therefore not significant, indicating no difference between the underweight group and normal weight group on cardiovascular efficiency.

F-ratio of cardiovascular efficiency scores between the normal and underweight groups versus the overweight group. As shown in Table VII, page 36, the analysis of variance of cardiovascular efficiency scores between the combined normal and underweight groups versus the overweight group resulted in an F-ratio of 20.99 in favor of the normal and underweight groups. For 1 and 196 degrees of freedom, F-ratios of 3.89 and 6.76 were needed for significance at the .05 and .01 levels of confidence, respectively. The obtained F-ratio of 20.99 was therefore highly significant beyond the .01 level of confidence. Since no significant difference was found between the normal weight and underweight groups in cardiovascular efficiency, and the obtained F-ratio between the combined normal and underweight groups versus the overweight group was highly significant, it can be concluded that being overweight has a significantly detrimental effect on cardiovascular efficiency, as measured by this test.

Analysis of Variance of Leg Strength Scores Among the Three Weight Groups

The means of leg strength scores for the three weight groups were 335.1 for the normal weight group, 315.5 for the underweight group, and 365.9 for the overweight group. Analysis of variance of leg strength scores among the three weight groups resulted in obtaining an F-ratio of 1.65, as shown in Table VIII. For 2 and 196 degrees of freedom, an F-ratio of 3.09 was needed for significance at the .05 level of confidence.
The obtained F-ratio of 1.65, therefore, was not significant which means that no true difference existed among the three groups in leg strength scores. No further analysis was needed.

**TABLE VIII**

**ANALYSIS OF VARIANCE OF LEG STRENGTH SCORES FOR THREE GROUPS OF COLLEGE WOMEN CLASSIFIED AS NORMAL WEIGHT, UNDERWEIGHT, AND OVERWEIGHT**

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>D.F.</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>197</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Among Groups</td>
<td>02</td>
<td>22490.5</td>
<td>1.65</td>
<td>--</td>
</tr>
<tr>
<td>Error</td>
<td>195</td>
<td>13628.28</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*F* .05 = 3.09; *F* .01 = 4.84

It was beyond the realm of this study to speculate as to whether significant differences might have been found among the groups had the numbers of subjects in the groups been comparable. It would seem logical that, generally speaking, the larger the person, the more leg strength that individual would possess. It was found that the overweight group had the largest mean in leg strength, which was 365.9. The normal weight group had the next largest mean of leg strength, which was 335.1, and the underweight group had the lowest mean of leg strength, which was 315.5. It would seem reasonable to assume that significant differences in leg strength among the three weight groups would have been found if the number of subjects in each group had been equal.
III. COMPARISON OF LEG STRENGTH OF SUBJECTS COMPLETING AND NOT COMPLETING STEP TEST

The data were analyzed to determine whether or not there was a significant difference in leg strength between the group that completed the three-minute step test and the group that did not. Analysis of variance was used to determine if there was significant difference between the leg strength means of the two groups. Results of this analysis of variance are shown in Table IX.

**TABLE IX**

**ANALYSIS OF VARIANCE OF LEG STRENGTH SCORES FOR COLLEGE WOMEN SUBJECTS WHO COMPLETED THE THREE-MINUTE STEP TEST AND THOSE WHO DID NOT**

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>D.F.</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>197</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Among Groups</td>
<td>01</td>
<td>167280</td>
<td>12.93</td>
<td>.01</td>
</tr>
<tr>
<td>Error</td>
<td>196</td>
<td>12935</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F \_{.05} = 3.89; F \_{.01} = 6.76

F-ratio of leg strength between the group that completed the three-minute step test and the group that did not. The number of subjects in the group that completed the three-minute step test was one hundred sixty-seven. The mean of leg strength for this group was 339.3. The number of subjects in the group that did not complete the three-minute step test was thirty-one, and the mean of leg strength for this group was 259.4.
As shown in Table IX, page 38, the F-ratio of leg strength for the group that completed the three-minute step test and the group that did not was 12.93 in favor of the subjects completing the test. For the degrees of freedom shown, F-ratios of 3.89 and 6.76 were needed for significance at the .05 and .01 levels of confidence, respectively. Therefore, the F-ratio of 12.93 was found to be highly significant beyond the .01 level of confidence. Thus, the subjects who completed the three-minute step test were significantly stronger in leg strength than the subjects who could not complete the test.

IV. ANALYSIS OF DATA BY CARDIOVASCULAR EFFICIENCY RATINGS

The subjects were divided into five classifications according to their cardiovascular efficiency scores. These classifications were: Very Good, Good, Fair, Poor, and Very Poor, as determined by the national standards for college women developed by Hodgkins and Skubic. For these classifications, five ponderal index classifications of the subjects were also computed. It was decided to use regression to analyze the relationship of the cardiovascular efficiency classifications of the subjects to their ponderal index classifications in order to provide a more graphic illustration. Orthogonal polynomials from Fisher and Yates were utilized to determine the nature of the regression line. The orthogonal polynomials that were used are as follows:

---


<table>
<thead>
<tr>
<th>Comparison 1</th>
<th>Very Poor</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Very Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>+1</td>
<td>+2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comparison 2</th>
<th>Very Poor</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Very Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadratic</td>
<td>+2</td>
<td>-1</td>
<td>-2</td>
<td>-1</td>
<td>+2</td>
</tr>
</tbody>
</table>

The regression was first tested for linearity and was found to be significantly linear at the .05 level of confidence. The sum of squares of this comparison was then subtracted from the treatment sum of squares in order to find whether the regression curve had other characteristics or whether it was wholly linear. The next step was to see whether the line was quadratic and an F test revealed that it was significantly of this nature, at the .01 level of confidence. By subtracting the combined sum of squares of the linear and quadratic computations, it was found that these two treatments had accounted for nearly all of the treatment sum of squares and therefore no further tests were made. The resultant plotting of the regression line of the relationship of a subject's ponderal index with her cardiovascular efficiency index is shown in Chart I.

It can be seen that there is a rather rapid corresponding increase in cardiovascular efficiency scores with an increase in the ponderal index of the subjects. This rise continues up to the "good" category in cardiovascular efficiency rating. Then it can be observed that there is a slight drop in the regression line from the "good" to the "very good" ratings of step test performance with the highest ponderal index.

Generally speaking, the higher the ponderal index, the more ectomorphic is the person, or stated another way, the more the person's
CHART I

RELATIONSHIP OF CARDIOVASCULAR EFFICIENCY CLASSIFICATIONS OF ONE HUNDRED NINETY-EIGHT COLLEGE WOMEN TO THEIR PONDERAL INDEX CLASSIFICATIONS

Ponderal Index

V.P.  P.  F.  G.  V.G.

Cardiovascular Rating
physique tends away from endomorphy. Therefore, again it can be observed that the more excess weight the person carries, the more detrimental this weight is to her cardiovascular efficiency.

The noted drop in the regression line of the highest ponderal indices with highest cardiovascular efficiency ratings might be explained in one of several ways. It might be that the number of subjects in the extreme ranges of the two scales was too small to be considered true representation of the population. Perhaps other factors such as strength, muscular endurance, general physical fitness, and exercise are more important in the "very good" step test performances than mere body build characteristics represented by the ponderal index. Or, it may also be that there is a point of diminishing returns, or optimum ponderal index, beyond which subjects approaching extreme ectomorphy lack strength and general physical fitness which results in poorer step test scores.
CHAPTER V

SUMMARY

1. PURPOSES AND PROCEDURE

The major purposes of this investigation were to determine the influence of leg strength on the performance of a three-minute cardiovascular efficiency test and to study the relationship between the weight of women when classified into three weight groups and their cardiovascular efficiency. A secondary purpose was to investigate the relationship between girls' ponderal indices and their cardiovascular efficiency scores. Specifically, this study proposed to provide further understanding of the variability of female cardiovascular efficiency by seeking the answers to these three questions:

1. Is there a correlation between leg strength scores and cardiovascular efficiency scores?

2. Is there a significant difference in leg strength between women who complete the three-minute step test and those who cannot?

3. What specific weight factors other than "heavy" influence women's cardiovascular efficiency scores?

One hundred and seventy-six college women enrolled in conditioning exercises, badminton, tennis, and swimming classes which are a part of the basic physical education program at Louisiana State University, and twenty-two women students majoring in physical education served as subjects for this study. The latter group participated in a variety of physical education activities related to the major courses in which they
were enrolled during the period of testing. All subjects were volunteers ranging in age from eighteen to twenty-five years, and were classified "qualified for regular physical education" by Louisiana State University's Student Health Service.

Height, weight, chest width, and pelvic width of each subject were measured. These were utilized to compute ponderal indices of the subjects, and to classify them into normal weight, underweight, and overweight groups. The strength of the legs was measured with an Iso-Scale to obtain leg strength scores of the subjects. A cardiovascular efficiency test for girls and women was utilized. The number of seconds the subjects could perform the stool-stepping involved in the test and their recovery pulse were converted by formula to cardiovascular efficiency scores of the subjects. Subjects were tested on two separate days due to the time required to take the tests. The data were gathered during the spring semester of the school year 1963-1964 at Louisiana State University.

Statistical computations were calculated in the laboratory of the Louisiana State University Computer Research Center. The data were analyzed to determine the relationship between cardiovascular efficiency and leg strength, and ponderal index for the total group of subjects. Coefficients of correlation were also computed between cardiovascular efficiency and weight as well as height for each of the normal weight, underweight, and overweight groups. Coefficients of correlation were also computed between cardiovascular efficiency and leg strength for each of the three weight groups. Analysis of variance was utilized in treating the data to determine if there were significant
differences in leg strength between subjects who completed the three-minute step test and those who did not. Analysis of variance was also utilized to determine if there were significant differences in cardiovascular efficiency among the three weight groups. Analysis of variance was also utilized to determine if there were significant differences in leg strength among the three weight groups. Regression was used to demonstrate the relationship of cardiovascular efficiency classifications to their ponderal index classifications.

II. FINDINGS

The following findings were obtained in this study:

1. A positive correlation was found between leg strength and cardiovascular efficiency for the total group of subjects as measured in this study. When the subjects were divided into normal weight, underweight, and overweight groups, however, the correlation between cardiovascular efficiency and leg strength was found to be significant for the normal weight group only.

2. The correlation between cardiovascular efficiency, as measured in this study, and ponderal index was found to be significant.

3. The correlation between cardiovascular efficiency and weight for the normal weight group was -.403, and for the overweight group was -.478. A significant negative correlation was found between cardiovascular efficiency and weight for the normal weight group. The negative correlation for the
overweight group obviously would have been more significant had the number of subjects in the group been larger. No relationship was found between cardiovascular efficiency and weight for the underweight group; the correlation was -.018.

4. No relationship was found between cardiovascular efficiency and height for any of the three weight groups.

5. No significant differences in cardiovascular efficiency were found between the normal weight and underweight groups. Significant differences were found in cardiovascular efficiency between the overweight group and the combination of normal weight and underweight groups.

6. No significant differences were found in leg strength among the three weight groups.

7. Significant differences were found in leg strength between subjects who completed the three-minute step test and those who did not.

8. The relationship of cardiovascular efficiency classifications to ponderal index classifications was found to be both linear and quadratic. The increase in ponderal index resulted in better cardiovascular efficiency ratings. A slight drop in ponderal index was found in the group with the highest cardiovascular efficiency classification.

III. CONCLUSIONS

Based on the findings of this study, the following conclusions
were drawn:

1. Body build and other factors are more important, from a cardiovascular efficiency point of view, than the strength of the legs. Cardiovascular efficiency, however, is related positively to leg strength for normal weight women.

2. Cardiovascular efficiency is inversely related to excess weight. The more the person approximates normal weight or underweight to a certain point, the better cardiovascular efficiency will be. Being overweight has a negative effect on cardiovascular efficiency.

3. The strength of the legs influences the performance on the Cardiovascular Efficiency Test for Girls and Women.

4. Cardiovascular efficiency is related significantly to ponderal index. This relationship is not as significant with women who possess a high degree of cardiovascular efficiency as it is with those who react to exercise less efficiently. Other factors apparently operate to produce a high degree of cardiovascular efficiency.

5. Cardiovascular efficiency is not related to height.
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SELECTED BIBLIOGRAPHY

A. BOOKS


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Pryor, Helen B. Width-Weight Tables, Stanford University, California, Second revised edition, 1940.


C. UNPUBLISHED MATERIAL

A GRAPH SHOWING THE DISTRIBUTION OF SUBJECTS IN THE VARIOUS WEIGHT CLASSIFICATIONS
VITA

The author was born in Elmahala El-Kobra, Egypt on November 28, 1934. She obtained her elementary and junior high school education at Helmia School in Cairo. Her high school education was obtained at Intermediate Institute of Physical Education in Cairo from which she graduated in 1953.

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EXAMINATION AND THESIS REPORT

Candidate: Samia Hanem Ahmed Abdo

Major Field: Physical Education

Title of Thesis: Leg Strength and Height-Weight Factors in Relation to Cardiovascular Efficiency of College Women

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

May 6, 1965