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CHANGES IN CARDIOVASCULAR CONDITION RESULTING
FROM AN EIGHT WEEK WEIGHT TRAINING PROGRAM
AS SHOWN BY THE CAMERON HEARTOMETER

BY

MERLE L. FOSS

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Department of Physical
Education, South Dakota State College
of Agriculture and
Mechanic Arts

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CHANGES IN CARDIOVASCULAR CONDITION RESULTING
FROM AN EIGHT WEEK WEIGHT TRAINING PROGRAM
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This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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The author wishes to express his sincere appreciation to Dr. Reuben B. Frost who gave so graciously of his time while advising this thesis and to the members of the two weight training classes for serving as subjects.

M.L.F.

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CHAPTER I

INTRODUCTION

Preliminary Statement

The effect of different activities and conditioning exercises on the cardiovascular system has been the basis for many recent studies by physical educators and physiologists. No doubt much of this research has been prompted by statements such as that by Reidman, "An athlete is only as good as his heart."¹

Reidman reasoned that the ability of the athlete to perform work was dependent in large measure on the ability of the heart to supply oxygen to the muscles. This, in turn, was dependent upon two factors: (1) the capacity of the heart to furnish enough blood to meet the demands of exertion, and (2) the ability of the heart to return to its resting pulse rate.²

Other students of physiology have indicated that there is a great need for methods by which people may be motivated to maintain sound cardiovascular fitness. The number of deaths attributed to diseases of the heart and

¹Sarah R. Reidman, The Physiology of Work and Play, p. 277, Henry Holt and Company, Incorporated: New York, 1956.

²Ibid., p. 277.

cardiovascular system have certainly emphasized the truth and importance of such statements.

It should be the obligation of physical educators and physiologists to determine which activities best serve to condition the heart and circulatory system and to develop within their students a feeling of "need" for cardiovascular fitness. It was with these thoughts in mind that the author decided to pursue further the problem of cardiovascular condition resulting from certain types of exercise.

Need for the Study

Weight training has recently been widely accepted by coaches and physical educators as a means to improve the strength and physiological condition of their athletes and students. Since cardiovascular fitness is an important part of total physiological fitness and has a direct bearing on individual motor performance there seemed to be a need for a study of relationships between weight training and cardiovascular condition.

Statement of the Problem

The purpose of this study was to identify and analyze changes in cardiovascular condition resulting from an eight week progressive weight training program. Subjects

were 37 South Dakota State College freshmen male students who were enrolled in weight training classes.

Steps in the solution of this problem were:

1. To graphically record, both before and after the period of training, the heart action at rest and after a brief exertive exercise.

2. To determine, both before and after the period of training, (1) the pulse rate, (2) the systolic pulse wave amplitude, (3) the diastolic pulse wave amplitude, (4) the aortic notch amplitude and (5) the diastolic surge of each subject at rest and following a brief exertive exercise.

3. To measure the body weight of each subject before and after the training period.

4. To compute the fatigue ratio, recovery indices, and weight indices of the subjects before and after the training period.

5. To calculate the differences and the significance of the differences between the means of the subjects' test data before they began weight training and the means of their data after the training.

6. To determine by correlative techniques any significant relationships between several of the test variables in this study.

Delimitations

1. This experimental study was limited to 37 freshmen at South Dakota State College who were enrolled in the authors weight training classes.
2. This study was limited to changes in the cardiovascular condition of the subjects.
3. Eight weeks of weight training were administered to the subjects between the initial and the final tests.
4. The reliability of the testing instrument was a limiting factor in the study.
5. Lack of control over the diet, activities and emotional states of the subjects was also a limitation.

Definition of Terms

1. weight training - a program of exercises in which the participants employ dumbbells and barbells to increase progressively the resistance against which these exercises are performed.
2. cardiovascular system - the entire circulatory system including the heart and blood vessels.
3. initial testing period - the 3 day period from October 5 to 7 during which the initial measurements were taken and initial heartometer tests administered.
4. final testing period - the 3 day period from December 7 to 9 during which the final measurements were

taken and the final heartometer tests administered.

5. eight week weight training period - the period (October 13 to December 3) during which the subjects participated in lifting weights twice weekly.

6. body weight - the weight of each subject to the nearest pound. The subjects were dressed in a T-shirt, supporter, shorts and stockings.

7. brief exertive exercise - the performance of an exercise which requires the use of a large percentage of total strength for a short duration.

8. weight indices - amount of weight lifted during the brief exertive exercise divided by the body weight of the individual (weight lifted/body weight).

9. resting tests - those tests administered while the subject was in a state of rest.

10. post exercise tests - those tests administered exactly 30 seconds after the subject had performed the brief exertive exercise.

11. recovery indices - resting heart rate divided by post exercise heart rate (resting rate/post exercise rate).

12. apprehension relief test - a preliminary test administered to each subject to familiarize him with the testing procedures and thereby reduce any existing apprehension.

13. apprehension relief indices - the heart rate

during the apprehension relief test minus the resting heart rate.

14. heart rate - the number of heart beats per minute. Determined by counting the number of cycles found in the first two complete 15 second intervals of the heartograph and multiplying this value by two. The fractional part of a beat was estimated to the nearest tenth of a beat by inspection before multiplication.

15. systolic pulse wave amplitude - (AB - Figure 3) the magnitude, as measured on the heartograph, resulting from the myocardial action due to the contraction of the ventricles. It is the first and greatest deflection of the needle in the heartograph cycle.³

16. dirotic notch amplitude - (ED - Figure 3) the measurement indicating the level of cardiovascular tone; is proportional to the diastolic blood pressure which acts as back pressure to close the semilunar valves. If the elastic rebound of the aorta and other principal vessels is relatively strong, the pressure is transmitted mechanically through the blood to close the semilunar valves quickly.⁴

³Cameron Heartometer Company, The Heartometer in the Field of Physical Education, p. 15, Cameron Heartometer Company, Chicago, 1954.

⁴Ibid.

17. fatigue ratio - (E/AB - Figure 3) the ratio of the dirotic notch amplitude to the systolic amplitude. The slower the valve closes, the greater the fatigue, which is indicated by lower diastolic blood pressure acting to snap the valves shut and consequently, the amplitude of the dirotic notch is lower which in turn results in a lower fatigue ratio.⁵

18. diastolic pulse wave amplitude - (PH - Figure 3) the portion of the single cardiac cycle which occurs after the semilunar valves close as represented by the diastolic pulse wave. It is measured from the peak of the diastolic wave to the base line of the cycle selected, parallel to the blue line radiating from the center.⁶

19. diastolic surge - (QH - Figure 3) the amplitude of the "hump" or dirotic wave which appears as a second upward stroke similar to the original systolic stroke and coming just after the lowest point of the dirotic notch. It seems to be caused by a reflected pressure wave after the semilunar valves close and possibly by active contraction of the aorta due to its elasticity.⁷

⁵Ibid., p. 17.

⁶Ibid.

⁷Ibid.

CHAPTER II

REVIEW OF RELATED LITERATURE

An examination of the literature related to cardiovascular condition reveals a vast amount of research material in this area. Physiologists have from early times been interested in the effect of exercise on the heart rate and the respiratory rate which accounts for a large portion of the previous studies. An effort has therefore been made to critically evaluate the literature and to select only those studies which seem clearly relevant and beneficial to the understanding of this study.

Studies of Cardiovascular Condition

In 1927 Klyver, Huang and Shafer studied the first secondary change in the pulse rate of 12 college men following a brief violent exercise. They found an immediate rise in the heart rate after the exercise which consisted of running in place at full speed. The first secondary rise in pulse rate following a brief period of violent exercise occurred, on the average, 3.2 seconds after the exercise, immediately upon the return to normal following the primary rise.⁸

⁸Fred Klyver Jr., J. Huang and George D. Shafer,

The metabolic, respiratory and circulatory responses to light muscular work of three subjects during a course of training were studied by Gemmill, Booth and Pacock. The subjects rode a stationary bicycle at a definite speed and load over a period of several weeks. Following the repetition of the work each day for 24 days there was a marked change in the reaction of the heart to a given amount of work. The recovery period was shortened and the total increase in heart and respiratory rate during work was lessened. The authors stated, "It is evident that training to light muscular work brings about an increase in the efficiency of the cardiac and respiratory mechanism rather than a change in the efficiency of the muscle." They reasoned that this increased efficiency allowed one to do the same amount of work with fewer subjective symptoms of distress and fatigue.⁹

Gemmill, Booth, Detrick and Schiebel conducted an investigation in 1931 which was similar to the 1930 study mentioned above. They studied the effect of a training

"The First Secondary Change in Pulse Rate Following a Very Brief Violent Exercise", American Journal of Physiology, vol. 81, 765-773, American Physiological Society: Baltimore, 1927.

⁹C. Gemmill, W. Booth, and E. Pacock, "The Physiological Effect of Daily Repetition of the Same Amount of Light Muscular Work", American Journal of Physiology, vol. 92, 253-270, American Physiological Society: Baltimore, 1930.

period consisting of running on the metabolism, ventilation, respiratory and pulse rates and the blood pressure during the recovery period following severe exercise on a treadmill. The two subjects were tested before, during, and after the training periods and the results obtained indicated that after training the pulse rate returned to near normal much faster.¹⁰

To determine the nature of the heart response to exercise of graded intensity, Nelson tested 10 male subjects. Each subject performed five bouts of weight lifting and four bouts of weight sustaining. In this study weight lifting involved pressing to the rhythmic cadence of a metronome a 25 pound barbell in bouts of 5, 10, 15, 20 and 25 repetitions per minute. Weight sustaining involved holding an 85 pound barbell at arms length for 1/2, 1, 1 1/2, and 2-minute intervals. The findings indicated that the heart rate immediately following weight lifting varied directly with the intensity of the exercise. There was no direct correlation between the sustaining of weight and the heart rate immediately following exercise. The recovery speed remained nearly constant following both the weight lifting

¹⁰C. Gemmill, W. Booth, J. Detrick and H. Schiebel, "The Effect of Training on the Recovery Period Following Severe Muscular Exercise", American Journal of Physiology, vol. 96, 265-277, American Physiological Society: Baltimore, 1931.

and weight sustaining and no mathematical relationship existed between the heart rate at rest and the speed of recovery. Recovery time was lengthened as the intensity of the weight lifting exercise was increased in contrast to being irregular and unpredictable as the intensity of weight sustaining was increased. No direct relationship existed between the recovery time after weight lifting and either the rate of the heart directly following exercise or the resting rate. There occurred a point (15 lifts per minute) during a series of graded intensities of weight lifting at which the recovery time for the next exercise (20 lifts per minute) was markedly increased.¹¹

In a study of 14 high school track athletes, Tuttle and Walker found that a season of training and competition produced no significant change in the resting heart rate, pulse rate immediately following exercise, rate above the resting rate after exercise and primary recovery time, and recovery time. The recovery pulse rate, however, was less at the close of the season which indicated that there was an improvement in physical condition. The authors mentioned also that although many of the cardiovascular changes were not statistically significant, they were always in favor

¹¹Norman Nelson, The Nature of the Response of the Heart to Weight Lifting and Weight Sustaining, Unpublished Master of Science Thesis, University of Iowa, Iowa City, Iowa, 1939.

of more efficient heart action.¹²

Morehouse, in his study of the response of the heart to various types of exercise, stated that "The time between each of the first thirty beats after exercise is constant following a strenuous exercise, but variable following mild exercises".¹³

Morehouse also worked with Tuttle on a study of post-exercise heart rate wherein a cardiometer was used to accurately count the pulse rate. The 10 adult male subjects lifted a 25 pound barbell 5, 10, 15, 20 and 25 times per minute. The heart rate returned to the resting level within three minutes after 5 to 15 lifts per minute in a majority of cases. After 20 to 25 lifts per minute, however, most of the subjects needed nine or more minutes to recover. The rate of the first few heart beats immediately after exercise was directly related to the intensity of the exercise and the heart rate at rest. The post exercise pulse rate was inversely related to resting pulse rate after mild exercise. The deceleration rate

¹²W. W. Tuttle and Frank Walker, "The Effect of a Season of Training and Competition on the Response of the Heart of High School Boys", Research Quarterly, vol. 11, 78-81, American Association for Health, Physical Education and Recreation: Washington, D. C., December, 1940.

¹³Laurence E. Morehouse, A Study of the Response of the Heart to Various Types of Exercise, Ph.D. Thesis, University of Iowa, Iowa City, Iowa, 1941.

of the pulse after exercise was directly related to the intensity of the lifting exercise. A general conclusion was that in order to get reliable results, the exercises must be strenuous.¹⁴

Michael and Gallon, in a recent study, administered a one-minute step test to 17 varsity basketball players in an attempt to determine periodic changes in circulation during athletic training. The subjects were tested each three weeks during 16 weeks of training and after 10 and 20 weeks of detraining. The authors reported that significant changes in the recovery pulse rate occurred during the training for basketball. The changes were significant at the five percent level after three weeks and significant at the one percent level after six weeks, with maximum changes occurring after 16 weeks. During the training period the pulse rate recovered to the resting level by the second or third minute after exercise in contrast to a five minute recovery period when the training program was not followed. In 10 weeks of detraining the circulatory changes had reversed significantly so that conditioning was

¹⁴L. E. Morehouse and W. W. Tuttle, "A Study of the Post-Exercise Heart Rate", Research Quarterly, vol. 13, 3-9, American Association for Health, Physical Education and Recreation: Washington, D. C., 1942.

not maintained when daily workouts ceased.¹⁵

Heartometer Testing

One of the earliest studies in which the heartometer was used was the one by Meeland at the University of Illinois in 1946. Fluctuations of the heartometer were investigated and special instructions for the standardized operation of the instrument determined. The reliability and objectivity of the heartometer pulse wave tracing was found to be significantly high to warrant its use in health and physical education. Other findings were that the objectivity coefficient in measuring the diastolic blood pressure was low and varied considerably with different machines. As one of his recommendations, Meeland stated, "This preliminary work on the accuracy of the heartometer opens up a wide area for investigation of the validity of the instrument in measuring those aspects of physical fitness relative to health and physical education."¹⁶

Reuter, in 1949, made a comparison of auscultatory and heartometer blood pressure after exercise. He outlined

¹⁵Ernest D. Michael and Arthur Gallon, "Periodic Changes in Circulation During Athletic Training as Reflected by Step Test", Research Quarterly, vol. 30, 303-311, American Association for Health, Physical Education and Recreation: Washington, D. C., October, 1959.

¹⁶Tor Meeland, Technical Accuracy of the Heartometer, Unpublished Master of Science Thesis, University of Illinois, Urbana, Illinois, 1946.

some of the principal errors of the heartometer. The first error mentioned was an occasional malfunctioning of the instrument usually accompanied by the lights blinking at improper pressures. Blinking of the lights at the improper pressures was also caused by any movement of the subject. The tester also had to be certain that the light was blinking in rhythm with the pulse rate before ascertaining the blood pressure. The conclusions drawn from the study were that systolic pressure determined through the use of the Cameron Heartometer was acceptable and was "probably" more accurate than that obtained by the auscultation method. The diastolic pressure of the Heartometer averaged approximately 23 millimeters below auscultatory measurements. The auscultatory readings, particularly systolic pressure, were not as correct as the Heartometer readings immediately following vigorous exercise since heart sounds were evident before blood was actually flowing through the artery.¹⁷

A study by Massey, Husman and Kehoe of 70 young male subjects to determine the effects of posture on the brachial sphygmogram as an indicator of cardiovascular condition was conducted in 1953. Results indicated that the amplitude of both the systolic and diastolic waves, measured from

¹⁷Edward R. Reuter, A Comparison of Auscultatory and Heartometer Blood Pressure Measurements After Exercise, Unpublished Master of Science Thesis, University of Illinois, Urbana, Illinois, 1949.

recordings taken with the subjects lying, sitting or standing were significantly larger for a group of individuals who proved to be in good cardiovascular condition than they were for a group in poor condition. Changes in posture from lying to sitting to standing caused the systolic amplitude to progressively decrease and the heart rate to progressively increase. The amplitude of the diastolic waves were found to be lower for the standing posture than the lying and sitting postures. The authors recommended that brachial sphygmograms used to indicate cardiovascular fitness should be compared with other tests which are more generally accepted.¹⁸

Forsyth tested eight members of a college basketball team with the Cameron Heartometer to determine the effect of a basketball training program on cardiovascular condition. The fatigue ratio of the group was increased which was an indication that they did not tire as easily and showed an improvement in cardiovascular condition during the basketball season. There was an increase in the stroke volume of the heart which was indicated by an increase in systolic amplitude. The resting pulse rate decreased during the

¹⁸ Benjamin H. Massey, Burris F. Husman, and Charles L. Kehoe, "The Effect of Posture on the Brachial Sphygmogram as an Indicator of Cardiovascular Condition", Research Quarterly, vol. 24, 194-204, American Association for Health, Physical Education and Recreation: Washington, D. C., May, 1953.

training period. This decrease was evident both before and after vigorous exercise. The author concluded that the cardiovascular condition of the subjects was improved during the basketball season.¹⁹

The heartometer was used by Riley to test 40 male students before and after an eight-week developmental physical education program. The subjects were divided into two groups. Group I consisted of students with a physical fitness index of 86 and above while the students in Group II all had indices of 85 or lower. The developmental program was made up of conditioning exercises, weight lifting, rope climbing, gymnastics, apparatus work, combatives, relays and team games. The program "appeared to have" decreased the pulse rates of both groups but had questionable effect on the systolic blood pressure, diastolic blood pressure and fatigue ratio. The subjects with the low physical fitness indices generally showed a more significant decrease of pulse rate than did the individuals with higher indices. Although the increases in systolic and diastolic blood pressures and fatigue ratio were questionable and inconsistent they were in the direction commonly associated with

¹⁹Harry L. Forsyth, The Effect of a Basketball Training Program on Cardiovascular Condition as Shown by the Cameron Heartometer, Unpublished Master of Science Thesis, South Dakota State College, Brookings, South Dakota, August, 1956.

good cardiovascular condition. The persons with the higher physical fitness indices in general had lower pulse rates, slightly higher systolic and diastolic blood pressures and higher fatigue ratios than those with lower indices.²⁰

Indicators of Cardiovascular Condition

Many physiologists have written pertaining to factors which accompany good and poor cardiovascular condition and to the effects of training on this condition. This material is here reviewed to furnish the reader with information concerning different levels of cardiovascular condition and possible changes which may result from physical training. This knowledge will prove valuable to the understanding of the present study.

McCloy and Young outlined the following factors as those which accompany good condition: slow pulse, small rise in pulse rate upon arising from a reclining position, normal systolic pressure, rise of systolic pressure upon arising from a reclining position, fairly high diastolic pressure, relatively high venous pressure, relatively small increase in pulse rate after exercise, and a rapid pulse

²⁰James Riley, The Effects of an Eight Week Developmental Physical Education Program on Physical Fitness Index and Certain Cardiovascular Factors of Freshmen Male Students, Unpublished Master of Science Thesis, South Dakota State College, Brookings, South Dakota, 1957.

rate recovery after the cessation of exercise. They mentioned the following factors as those which accompany poor condition: fast pulse, relatively great change in pulse rate upon arising from a reclining position, relatively low systolic pressure, a decrease in systolic pressure upon arising from a reclining position, a fairly low diastolic pressure, a fairly low pulse pressure, low venous pressure, large increase in pulse rate after exercise, and a slow recovery of pulse rate after the cessation of exercise.²¹

Morehouse and Miller listed several adjustments in heart function, resulting from training, which increase its efficiency and maximal capacity. The first change mentioned was an increase in the strength and thickness of the ventricular musculature which results in a greater contractile force for a given diastolic volume. The second change is a slowing of the resting heart rate. A greater stroke volume for any given level of venous blood returned was the third change listed. This greater stroke volume allows for an increased heart output with a smaller increase in heart rate. Since the diastolic phase makes up a larger fraction of the total time for each heart cycle,

²¹Charles H. McCloy and Norma D. Young, Tests and Measurements in Health and Physical Education, p. 290, Appleton-Century-Crofts, Incorporated: New York, 1954.

fatigue of the heart is postponed.²²

Some factors which indicate cardiovascular condition and which are more closely related to the present study are those reported by Cureton. They pertain directly to measurements obtained with the heartometer. The following measurements accompany good and poor circulatory conditions:

Good condition:

Relatively high diastolic notch amplitude
Above average systolic pulse wave amplitude
High fatigue ratio
Presence of diastolic surge

Poor condition:

Systolic pulse wave amplitude above the normal range
Systolic pulse wave amplitude below the normal range
Relatively low diastolic notch amplitude
Low fatigue ratio
Lack of diastolic surge²³

The foregoing review of the literature in the area of cardiovascular research indicates the complexity of investigations in this area as well as the need for continuing research. While some investigators have measured immediate physiological changes resulting from weight lifting, none has used weight lifting during training periods and measured the variations in condition which resulted.

²²Laurence E. Morehouse and Augustus T. Miller, Physiology of Exercise, p. 108, C. V. Mosby Company: St. Louis, 1948.

²³T. K. Cureton, Physical Fitness Appraisal and Guidance, p. 235-250, C. V. Mosby Company: St. Louis, 1947.

This factor, plus the fact that many investigators recommended further study with the heartometer prompted the author to conduct this study.

CHAPTER III

PROCEDURES

Source of Data

This investigation dealt with the changes in the circulatory system which were evident following an eight week program of weight training. The subjects selected for the study were 37 freshmen male students at South Dakota State College who were enrolled in either of the two weight training classes taught by the author. During the fall quarter, 1959, weight training was taught as part of the freshmen service program. All freshmen were required to take three quarters of physical education activities but could select those activities in which they desired to participate.

For the purposes of this study the single group method was employed and the two weight training classes were combined to form one group. Three of the subjects dropped out of school midway through the quarter which reduced the number of subjects to 34. Initial tests followed by a program of training and the final tests were administered to members of this group.

Initial Tests

During the first class meeting the body weight to

the nearest pound and the standing height to the nearest half-inch for each subject were determined and recorded. Each student's biceps, calves and chest were also measured, but these measurements served only to motivate the students during the training period and were not employed as data for the study. All of the students wore the required gym trunks, supporter, T-shirt and stockings during the weighing and measuring. Appointments for the initial heartometer tests were also arranged with each student at this time.

The instrument employed to obtain data relative to the circulatory function was the Cameron Heartometer. All of the initial heartometer tests were conducted during the three-day period from October 5 to 7.

The Cameron Heartometer (Fig. 1) consisted of the machine proper and an air pressure cuff and bulb similar to that which is used as part of the sphygmomanometer. The machine operated on the principle that pulsation caused a volume change in the cuff which in turn actuated the aneroid bellows found within the machine. The bellows, through a lever arrangement, moved the pen arm which was attached to springs which returned it after it was moved and held it in contact with the graph paper. The pen arm supported a bulb-like pen that released specially prepared ink and drew a distinct line on the rotating, circular disk. This disk, (Fig. 2) referred to as a heartograph or heartogram, furnished a permanent record of the systolic

and diastolic blood pressures and other functions of the circulatory system. It was calibrated in time units which enabled the tester to determine the time phases of the tracing along with other important measures.

Cureton outlined the following possible applications for the heartograph records in the field of physical fitness workers:

1. Prediction of the relative state of "functional cardiovascular condition" in subjects without heart disease.
2. Detection of the relative state of training of athletes in training and out of training.
3. As a screen test to encourage interest in cardiovascular condition related to endurance in life's activities and in particular athletic events with possible referral of subjects with very abnormal heartographs to a physician.
4. To show the relative effect of specific exercises or tests on the cardiovascular system, such as a particular cross-country run or a chinning test or any event whatsoever which induces cardiovascular fatigue.²⁴

It is important to note that no claim was made that the graphs should be used in health and physical education to diagnose heart disease.

Each subject was given three initial tests with the heartometer. The first test was administered to familiarize the subject with the machine and to reduce any apprehension which might exist within the subject and therefore distort the training (hereafter referred to as the "initial

²⁴Cureton, op. cit., p. 232.

apprehension relief test"). The second test ("initial resting test") was given immediately after the first and the identical procedure was followed. The third graph was recorded after a brief exertial exercise which required the subjects to press (military style) a 46 pound barbell 12 times at a cadence of 72 repetitions per minute. The author practiced counting the cadence and timed each trial until he could "feel" the proper rate. The speed at which the subjects pressed the weight was controlled by issuing the order to lift at the proper time and counting aloud the cessation of each complete press. The third test ("initial post-exercise test") was begun exactly 30 seconds after the barbell was returned to the floor so that the time which elapsed between the cessation of the exercise and the beginning of the test was identical for each subject. A stopwatch was used for all timing.

For all of the foregoing tests the subjects were seated and the cuff was placed over the left brachial artery. The author also maintained constant vigilance to avoid violation of the rules for operating the heartometer as outlined by Cureton.²⁵ These rules and precautions applied to the subjects, examiner and instrument.

²⁵Cureton, op. cit., p. 266-267.

Training

The eight week weight training program was begun on October 13 and lasted until December 3. Both classes convened on Tuesday and Thursday with one beginning at 10 A.M. and the other at 11 A.M. The periods officially lasted 50 minutes but only 35 minutes of this time could be used for actual lifting. Five minutes of each period was used for warm-up exercises and calisthenics.

An 8-10 repetition progressive resistance training program was used where each subject would begin exercising with weights which he could barely lift eight times. Progression charts were kept for each individual and the number of repetitions and the amount of weight lifted for each exercise were recorded. When the student was able to perform 10 repetitions for any exercise, weight was added until only eight repetitions could be completed. The students were always encouraged to progress as rapidly as possible.

The program included the following eight exercises:

1. Curl
2. Military press
3. Forward raise
4. Walking squats
5. Bench lateral raise
6. Bench press
7. Rise-on-toes
8. Lateral raise

The weight training room was divided into stations with one or two activities at each station so that it was

possible for every student to perform all of the exercises during the class period.

Final Tests

The final testing was done during the three day period from December 7 to December 9. The height and weight were once again recorded and the biceps, calves, and chest were measured. The three final heartometer tests were once again given to each subject during a prearranged period. The first final test was termed the "final apprehension relief test", the second test the "final resting test", and the third test the "final post exercise test." Exactly the same methods and procedures were followed during the final measuring and testing as were used to obtain the initial data. In neither case was any of the heartometer testing conducted during the weight training classes or until the subjects had recovered following the exercise period.

Data from Heartographs

With the exception of body weight all other data for the study were obtained through measurements taken from the heartographs. The items which were measured are listed below and were defined earlier in the manuscript. The measurement of all items with the exception of heart rate was made with the vernier calipers, in centimeters

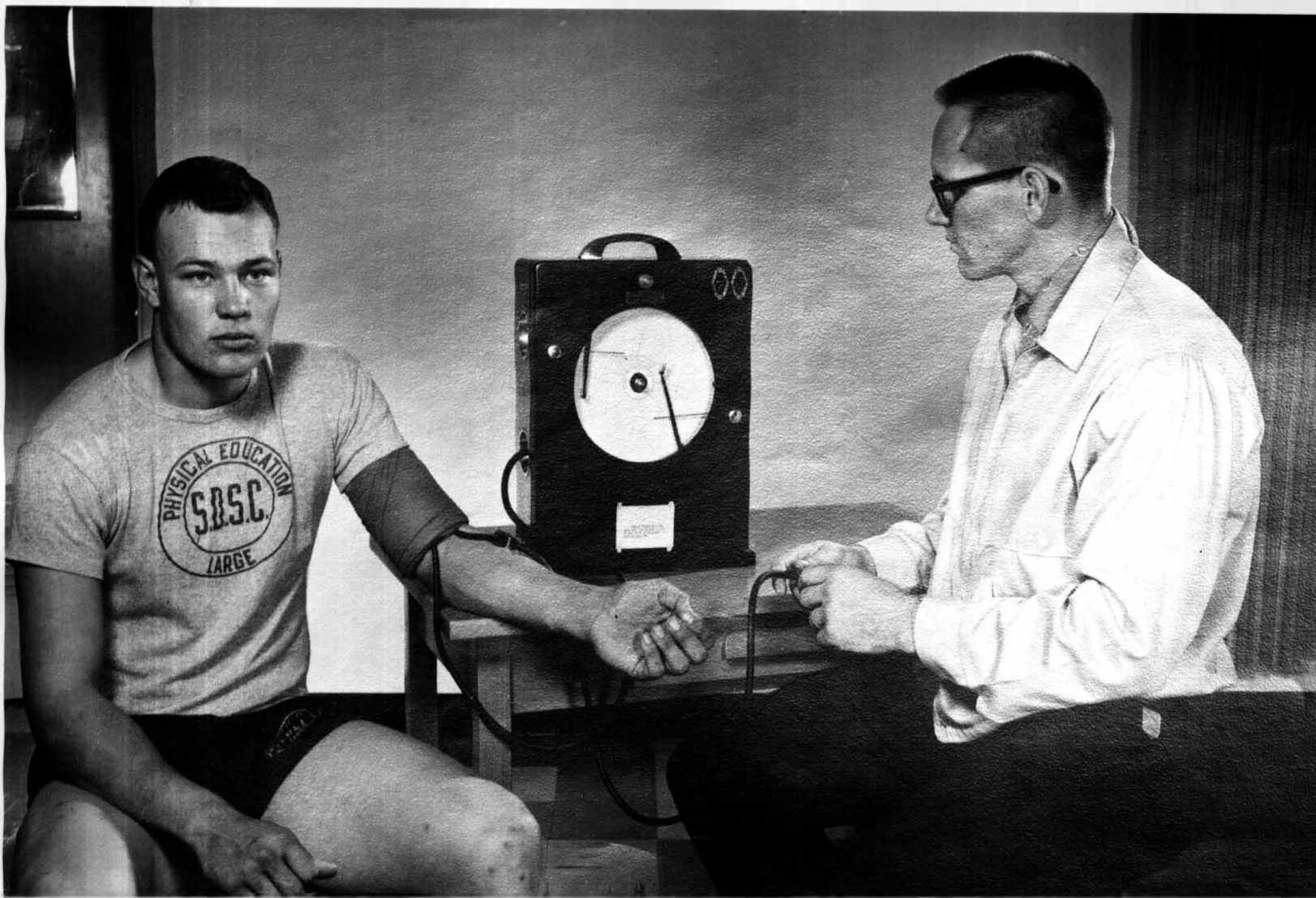


Figure 1. Author Testing Subject with the Cameron Heartometer

and hundredths, nearly vertically and parallel to the blue time lines. The measuring techniques as outlined by Cureton were closely adhered to at all times.²⁶

All of the measurements for each graph were taken from the same pulse wave. Figure 4 illustrates an enlarged pulse wave (cardiac cycle). The wave to be measured was selected from those traced in the first seven and one-half seconds of the first complete 15 second interval. An attempt was made to always select an average good sized cycle, one which would do full justice to the subject.

Listed below are the measurements to be used in the study which were taken from the heartographs:

1. Systolic pulse wave amplitude (AB - Fig. 3)
2. Diastolic notch amplitude (EE - Fig. 3)
3. Fatigue ratio (DE/AB - Fig. 3)
4. Diastolic pulse wave amplitude (FH - Fig. 3)
5. Diastolic surge (GH - Fig. 3)

²⁶Cureton, op. cit., p. 235-250.

TYPICAL HEARTOGRAPH

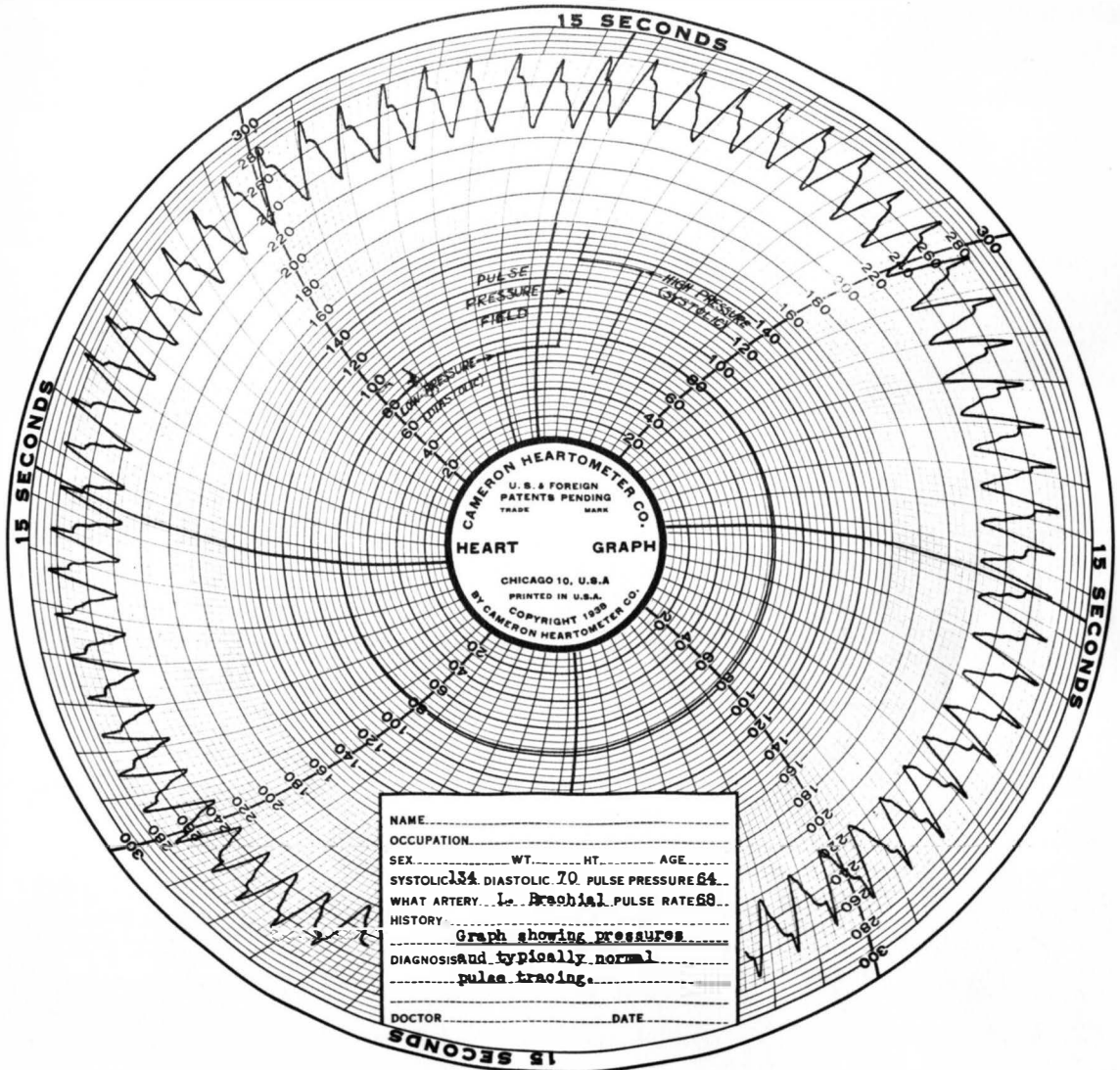


Figure 2

(Courtesy Cameron Heartometer Company)

CARDIAC CYCLE WITH VARIOUS FACTORS

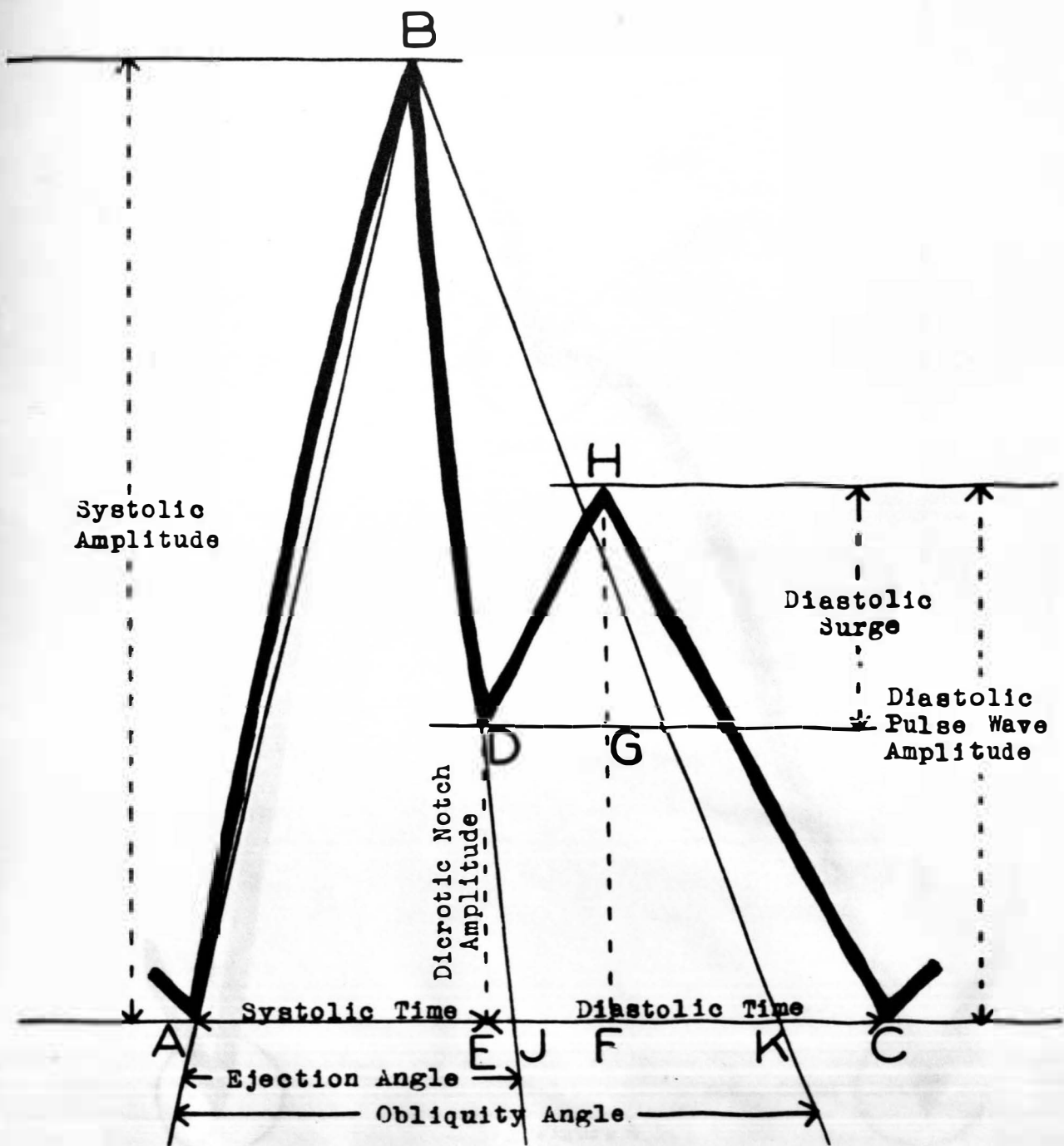


Figure 3

(Courtesy Cameron Heartometer Company)

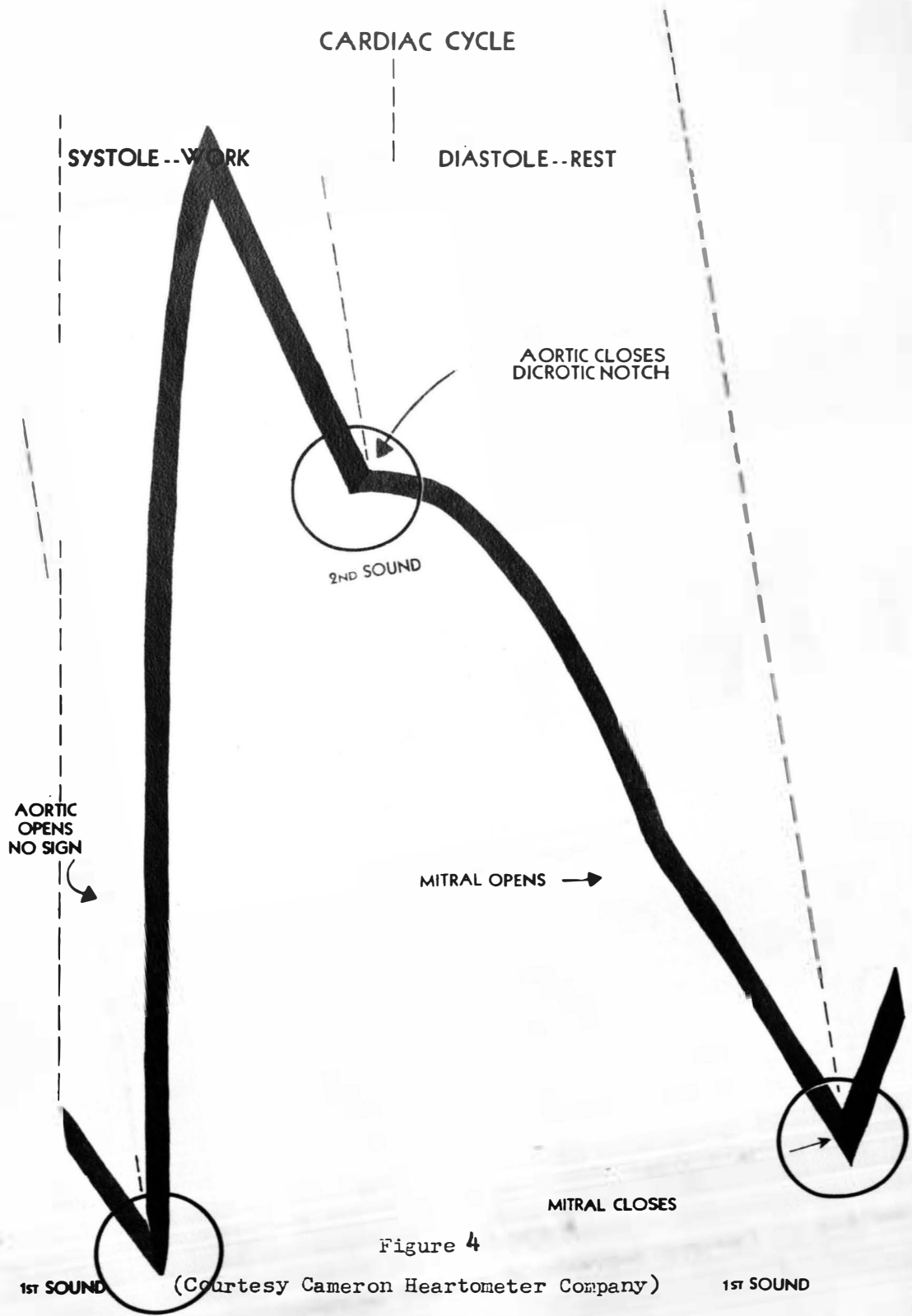


Figure 4

(Courtesy Cameron Heartometer Company) 1ST SOUND 1ST SOUND

CHAPTER IV

TREATMENT AND INTERPRETATION OF DATA

The primary purpose of this study was to determine and analyze changes in the cardiovascular condition resulting from an eight week period of weight training. The experimental design employed was the "single group" method in which the difference between means was computed from the raw scores* of the same tests administered to the same group on different occasions. Because the group was small ($N=34$) the "difference method" described by Garrett was employed to determine the critical ratio (t) for each test. This ratio was used to test the significance of the difference between the means of the scores obtained in successive trials.²⁷

A comparison of the results of the initial and final tests for each item was made. The differences between the means of these items, and the significance of these differences were then computed. The items compared were:

1. Body weight
2. Weight indices

²⁷Henry E. Garrett, Statistics in Psychology and Education, fifth edition, p. 227, Longmans, Green and Company: New York, 1958.

*The raw scores were too cumbersome to be included in the manuscript but are available from the author.

3. Resting heart rate
4. Post exercise heart rate
5. Recovery indices
6. Resting systolic pulse wave amplitude
7. Post exercise systolic pulse wave amplitude
8. Resting diastolic pulse wave amplitude
9. Post exercise diastolic pulse wave amplitude
10. Resting diastolic surge
11. Post exercise diastolic surge
12. Resting fatigue ratio
13. Post exercise fatigue ratio
14. Resting dicrotic notch amplitude
15. Post exercise dicrotic notch amplitude

These differences were then tested for significance at the five percent and one percent level. The null hypothesis was then applied in each case. With 33 degrees of freedom ($N-1$), a t -value of 2.03 was considered as indicating significance at the five percent level and a t -value of 2.73 at the one percent level.²⁸

Table I contains the results obtained from a comparison of the initial and final test scores for several of the test items. There was an average increase in body weight of 3.65 pounds during the eight week weight training period. The t -value of 4.80 indicated significance at the one percent level. The null hypothesis was therefore rejected and this gain assumed to be real.

An average decrease in the weight indices of .09 was also evident. This decrease, with a t -value of 4.50 was significant at the one percent level. This could probably be expected since the weight index was a ratio of

²⁸ Ibid., p. 449.

weight lifted during the brief exertive exercise to body weight. As the body weight increased, therefore, the weight index would decrease, other things being equal.

A difference of .05 accompanied by a t -value of 5.00 was computed for the recovery indices. This indicated an increase in the mean which was significant at the one percent level. The null hypothesis was rejected and the increase assumed to be real. Since the recovery indices were ratios of resting heart rates to post exercise heart rates, the increase in the final ratio was due to a considerably larger decrease in final post exercise heart rate than in final resting heart rate. This would indicate a definite improvement in this aspect of cardiovascular condition.

A study of Table II indicates a significant difference in only one of the resting test items. This item, systolic pulse wave amplitude, increased .14 cms. on the average which was represented by a t -value of 3.50. The null hypothesis was rejected at the one percent level and this difference assumed to be real. While the differences between the initial and final test scores for the resting diastolic pulse wave amplitude and the resting diastolic surge were not significant at either the five or one percent level, they were in the direction generally associated with an improvement in cardiovascular condition.

TABLE 1. DIFFERENCES BETWEEN THE MEANS, STANDARD ERROR OF THE DIFFERENCES, CRITICAL RATIOS, AND SIGNIFICANCE OF THE DIFFERENCES COMPUTED FROM THE INITIAL AND FINAL TEST SCORES

Test Item	M_1	M_2	Diff _m ($M_1 - M_2$)	σ Diff	t	Level of Significance
Body Weight	160.94	164.59	-3.65	.76	4.80	.01
Weight Indices	3.49	3.40	.09	.02	4.50	.01
Recovery Indices	.99	1.04	-.05	.01	5.00	.01
Initial Apprehension Relief Index	77.56	76.82	.74	.67	1.21	NS*
Final Apprehension Relief Index	75.59	76.38	-.79	.67	1.18	NS

*NS - Not significant for purposes of this study.

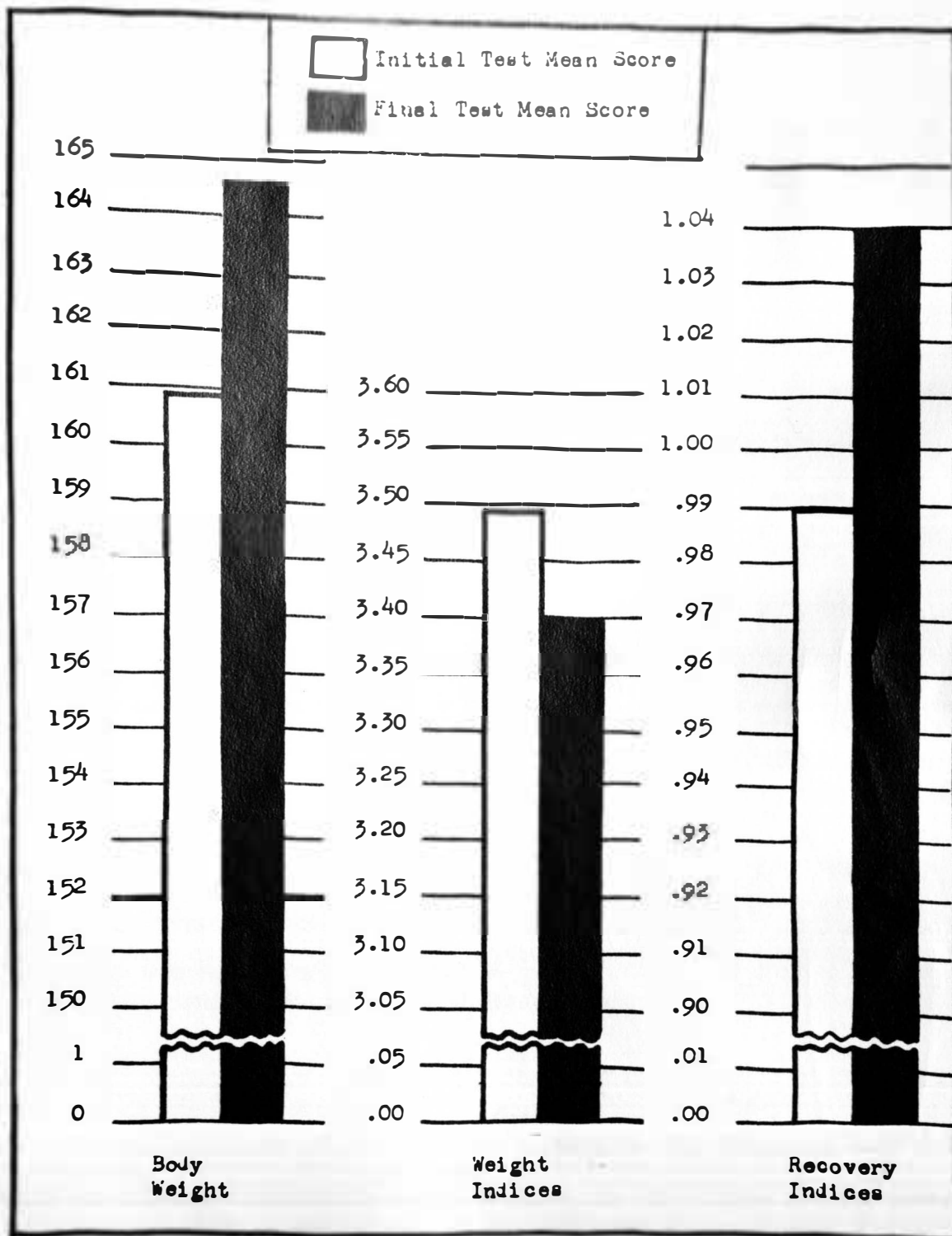


Figure 5. Comparison of Initial Test Mean Scores with Final Test Mean Scores

Table III reflects the results obtained by comparing the initial and final scores of the post exercise tests. The systolic pulse wave amplitude showed a mean increase of .29 cms., the diastolic pulse wave amplitude, a mean increase of .15 cms., and the dicrotic notch amplitude, an average increase of .11 cms. These differences were represented by t -values of 4.83, 3.75, and 3.67, respectively, which indicated a rejection of the null hypothesis at the one percent level in each instance. Although not significant at either the five or one percent level, the differences between the initial and final post exercise heart rate, post exercise diastolic surge and post exercise fatigue ratios were evident and in the direction associated with good cardiovascular condition.

For a more thorough analysis of the data obtained in this study, the product-moment coefficients of correlation²⁹ between the following selected items in the final test were computed and analyzed:

1. Resting heart rate
2. Post exercise heart rate
3. Recovery index
4. Systolic pulse wave amplitude
5. Diastolic pulse wave amplitude
6. Fatigue ratio

The significance of each obtained coefficient of correlation (r) was then tested against the null hypothesis.

²⁹Ibid., p. 135.

TABLE II. DIFFERENCES BETWEEN THE MEANS, STANDARD ERROR OF THE DIFFERENCES, CRITICAL RATIOS, AND SIGNIFICANCE OF THE DIFFERENCES COMPUTED FROM THE INITIAL AND FINAL SCORES OF THE RESTING TESTS

Test Item	M(I)	M(F)	Diff _M (M _I -M _F)	σ Diff	t	Level of Significance
Heart rate	76.82	76.38	.44	1.96	.22	NS*
Systolic Pulse Wave Amplitude	1.20	1.34	-.14	.04	3.50	.01
Diastolic Pulse Wave Amplitude	.61	.66	-.05	.03	1.67	NS
Diastolic Surge	.03	.05	-.02	.01	2.00	NS
Fatigue Ratio	.50	.47	.03	.02	1.50	NS
Dicrotic Notch Amplitude	.60	.62	-.02	.03	.67	NS

*NS - Not significant for purposes of this study.

TABLE III. DIFFERENCES BETWEEN THE MEANS, STANDARD ERROR OF THE DIFFERENCES, CRITICAL RATIOS, AND SIGNIFICANCE OF THE DIFFERENCES COMPUTED FROM THE INITIAL AND FINAL SCORES OF THE POST EXERCISE TESTS

Test Item	M(I)	M(F)	Diff _M (M _I -M _F)	σ Diff	t	Level of Significance
Heart Rate	77.88	73.47	4.41	2.19	2.01	NS*
Systolic Pulse Wave Amplitude	.98	1.27	-.29	.06	4.83	.01
Diastolic Pulse Wave Amplitude	.59	.74	-.15	.04	3.75	.01
Diastolic Surge	.02	.06	-.04	.02	2.00	NS
Fatigue Ratio	.60	.57	.03	.03	1.00	NS
Aortic Notch Amplitude	.59	.70	-.11	.03	3.67	.01

*NS - Not significant for purposes of this study.

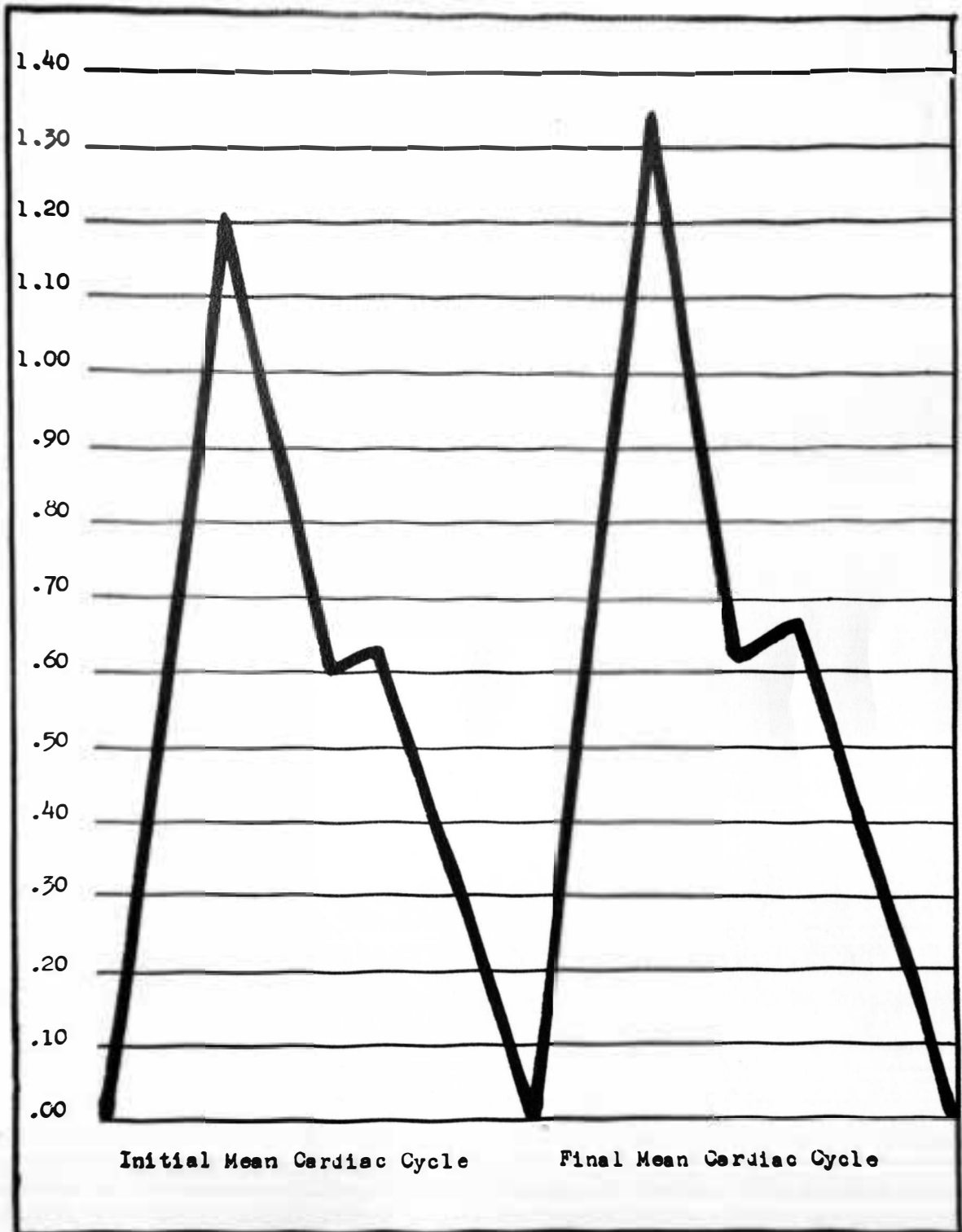


Figure 6. Comparison of Initial Mean Resting Cardiac Cycle with Final Mean Resting Cardiac Cycle

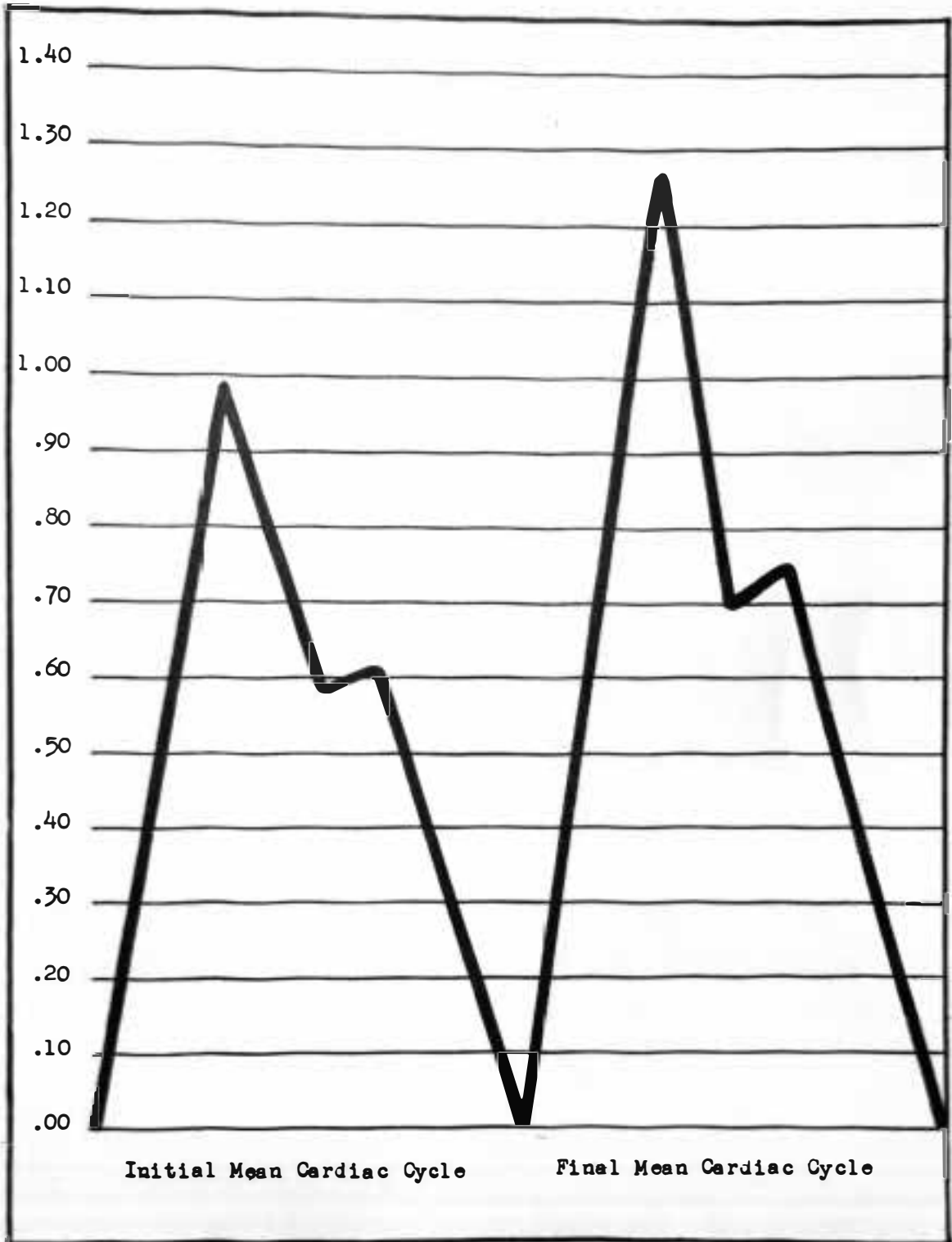


Figure 7. Comparison of Initial Mean Post Exercise Cardiac Cycle with Final Mean Post Exercise Cardiac Cycle

With 32 degrees of freedom ($N-2$) an r must be at least .35 to be significant at the five percent level and .44 to be significant at the one percent level.³⁰

Table IV shows the results of this intercorrelation. A coefficient of correlation (r) of $-.49$ was obtained between the resting heart rate (A) and post exercise fatigue ratio (F). This r was significant at the one percent level. The null hypothesis was therefore rejected and the relationship assumed to be meaningful. The negative correlation indicated that as the resting heart rate decreased, the post exercise fatigue ratio tended to increase.

An r of $-.42$ shows the relationship between resting heart rate (A) and post exercise diastolic pulse wave amplitude (E). In this case the null hypothesis was rejected at the five percent level and a meaningful relationship assumed. The negative correlation was the result of a decrease in resting heart rate and an increase in the post exercise diastolic pulse wave amplitude.

The degree of relationship between resting heart rate (A) and post exercise heart rate (B) was very high. The r indicating the degree of relationship was $.90$, significant at the one percent level. The positive correlation obtained was accepted as meaningful and decreases in resting heart rate associated with decreases

³⁰Ibid., p. 201.

TABLE IV. COEFFICIENTS OF CORRELATION BETWEEN
SELECTED FINAL TEST ITEMS

	F	E	D	C	B	A
A	-.49	-.42	.01	-.31	.90	
B	-.50	-.49	-.10	-.62		
C	.37	.35	.12			
D	-.46	.85				
E	.12					
F						

A - Resting heart rate
 B - Post Exercise heart rate
 C - Recovery index
 D - Post exercise systolic pulse wave amplitude
 E - Post exercise diastolic pulse wave amplitude
 F - Post exercise fatigue ratio

in post exercise heart rate.

A decrease in post exercise heart rate (B) with a tendency toward an increase in the post exercise fatigue ratio (F) resulted in an r of $-.50$ between those test items. This r was significant at the one percent level and the null hypothesis was therefore rejected.

A negative correlation between post exercise heart rate (B) and post exercise diastolic pulse wave amplitude (E) was computed. The r of $-.49$ was significant at the one percent level and the null hypothesis rejected. A decrease in the post exercise heart rate with a corresponding increase in post exercise diastolic pulse wave amplitude

resulted in this negative correlation.

When the post exercise heart rate (B) and the recovery index (C) were correlated a coefficient of $-.62$ significant at the one percent level was obtained. This negative correlation could be attributed in part to the fact that the recovery index was a ratio of resting heart rate to post exercise heart rate and that this ratio increased as the post exercise heart rate decreased provided that the resting heart rate remained relatively unchanged.

The r representing the relationship between the recovery index (C) and the post exercise fatigue ratio (F) was $.37$. This value proved significant at the five percent level so the null hypothesis was rejected. A positive correlation was obtained since the increase in the recovery indices became relatively larger as the post exercise fatigue rates increased.

An increase in both the recovery indices (C) and the post exercise diastolic pulse wave amplitudes (E) resulted in an r of $.35$ between those items. This r was the value necessary for significance at the five percent level and the null hypothesis was rejected and a meaningful relationship assumed.

A coefficient of correlation of $-.46$ indicated the relationship between the post exercise systolic pulse wave amplitude (D) and the post exercise fatigue ratio (F).

This r was significant at the one percent level, therefore the null hypothesis was rejected. An increase in the post exercise systolic pulse wave amplitude was accompanied by a decrease in the post exercise fatigue ratio which resulted in the negative correlation.

A relatively high correlation of .85 was obtained between the post exercise systolic pulse wave amplitude (D) and the post exercise diastolic pulse wave amplitude (E). The correlation was positive since an increase was evident in each test item. The null hypothesis was rejected at the one percent level and the relationship assumed to be real.

In summarizing the results obtained by correlating these factors it will be noticed that the highest relationships were obtained between the resting and the post exercise heart rates and between the systolic pulse wave amplitude and the diastolic pulse wave amplitude. This might have been expected as other investigators have found similar relationships.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The primary purpose of this study was to determine and analyze changes in cardiovascular condition following an eight week program of weight training.

Subjects for the study were 34 freshmen who were members of two weight training classes. For purposes of this study these two classes were combined to form a single group.

During the eight week training period the subjects completed a routine of progressive resistance exercises every Tuesday and Thursday. This routine allowed all subjects to perform the same exercises during each session.

The Cameron Heartometer was employed to test the level of cardiovascular condition at the beginning and end of the training period. Body weight was also determined at the time of these tests.

The initial and final test data were recorded and compared to determine whether there was a difference in any of the test items. This difference, when significant, indicated a change in cardiovascular condition or body weight which might be attributed to the weight training program. To allow for a more thorough analysis of the test

data, the product moment coefficients of correlation between several selected final test items were computed and analyzed.

Conclusions

As a result of this study the following conclusions were reached:

1. The cardiovascular condition of the weight trainers as determined by the heartometer tracings was improved during the eight week training period.
2. The recovery indices increased significantly during the period of training. An increase in this ratio after training indicated an improvement in cardiovascular condition since the hearts of the subjects responded to the same amount of exercise with a decreased number of heartbeats.
3. The post exercise systolic and diastolic pulse wave amplitudes increased significantly. These increases were associated with an improvement in circulatory function.
4. There was a significant increase in the post exercise aortic notch amplitude which indicated an improvement in the level of cardiovascular tone. The elastic rebound of the aorta was increased causing a faster transmittal of pressure to close the semilunar valves. This in turn permitted the heart to rest longer between contractions.

5. There was a statistically significant increase in the resting systolic pulse wave amplitude. This indicated that after training the subjects' hearts pumped more blood during each contraction resulting in increased efficiency.

6. There was a significant increase in body weight which may or may not have resulted from the weight training program.

Recommendations

From the experiences of this study the following recommendations are made:

1. A similar study of weight trainers should be conducted in which other methods of determining the level of cardiovascular condition are employed.
2. That weight training be used in physical education and athletics to increase body weight.
3. That weight training be used to improve the condition of the cardiovascular systems of athletes including those participating in endurance type activities.
4. That similar studies employing the heartometer be made of athletes participating in other sports and activities.
5. That additional research should be done in this area using a larger number of subjects and attempting to

control the actions of the subjects with respect to diet, rest, and activities.

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APPENDIX

DESCRIPTION OF THE WEIGHT TRAINING EXERCISES

B. P. - Beginning Position

R. M. - Range of Movement

1. Curl:

B. P. - The subject stood with palms forward holding the barbell in front of the thighs.

R. M. - The barbell was raised to chest level by flexing the arms at the elbow joints. The arms were then extended at the elbow joints and the barbell lowered to the beginning position. During the exercise the elbows were held close to the body.

2. Military press:

B. P. - The subject stood with palms forward while holding the barbell just in front of the shoulders.

R. M. - The barbell was pushed upward until the arms were fully extended and then slowly lowered to the beginning position.

3. Forward raise:

B. P. - The subject stood with palms facing the body while holding dumbbells at arms length in front of the thighs.

R. M. - With elbows locked the subject raised the dumbbells to a position approximately 45 degrees above shoulder level and then slowly lowered them to the beginning position.

4. Walking squats:

B. P. - The subject stood holding the barbell so that it rested on the shoulders and on the area directly behind the neck.

R. M. - The subject took one step forward with either foot and then squatted down until the buttocks touched the rear heel. He then rose, stepped forward with the opposite foot and

squatted until the buttocks again touched the rear heel.

5. Bench lateral raise:

B. P. - The subject lay on a bench in a supine position while holding dumbbells out to the sides of the body at arms length. The palms up grip was used.

R. M. - The subject kept the elbows locked and raised the dumbbells to a position at arms length directly above the chest. The dumbbells were then slowly lowered to the beginning position.

6. Bench press:

B. P. - The subject lay on a bench in a supine position with the barbell resting against the chest. The barbell was gripped with the palms up.

R. M. - The barbell was pushed upward to an arms length position directly above the shoulders and slowly lowered to the beginning position.

7. Rise-on-toes:

B. P. - The subject stood with his toes resting on top of a length of wood which was two inches in thickness and with his heels touching the floor. The barbell was held so that it rested on the shoulders and the area directly behind the neck.

R. M. - The subject rose on his toes as high as possible and then slowly returned to the beginning position.

8. Lateral raise:

B. P. - The subject stood with the dumbbells held at arms length and to the outside of the thighs. The dumbbells were gripped with the palms facing the thighs.

R. M. - With elbows locked the subject raised the dumbbells to a position of approximately 45 degrees above shoulder level and then slowly lowered them to the beginning position.