AN INVESTIGATION OF THE EFFECTS OF CONDITIONING ON THE BALLISTOCARDIOGRAM OF VARSITY BASKETBALL PLAYERS

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By

Gordon C. Stauffer

A THESIS

Submitted to the School of Graduate Studies of Michigan
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in partial fulfillment of the requirements
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Department of Physical Education, Health,
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G.C.S.

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AN ABSTRACT

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Approved Henry J. Montoye

STATEMENT OF PROBLEM The chief question of this investigation is "Do the components of the ballistocardiogram change significantly before and after exercise as a result of a conditioning program?" Secondary points of interest deal with the changes in relative stroke volume and the pulse rates as a result of conditioning.

REVIEW OF LITERATURE Since ballistocardiography is new in the field of physical education, literature pertaining to this subject is scarce. However, the ballistocardiogram has been established as a valid instrument to measure relative stroke volume. The effects of conditioning on the components of the ballistocardiogram following a standard exercise such as the Harvard Step Test are not known.

EXPERIMENTAL PROCEDURE Ten varsity basketball players were selected by Forrest Anderson, basketball coach, Michigan State College, to take part in this experiment. They were tested five times during the 1954-55 season. Twice before the conditioning program began to obtain a control record and three times during the season. Measurements of the components of the ballistocardiogram were recorded and later analyzed.

CONCLUSIONS After analyzing the data of this investigation the following conclusions were made.

1. The heights of I and J waves did not change significantly with conditioning.

2. The height of the I plus J waves was not a critical factor in determining the relative stroke volume derived by Molomut's formula.[1]
3. The cycles per second is the critical factor in Molomut's formula.[2]
4. The pre-exercise pulse rates did not decrease significantly although the mean values indicated a slight tendency to do so.
5. The post-exercise pulse rates did decrease significantly during the conditioning program and increased with the termination of conditioning.
6. The post-exercise pulse rate is a good index of circulatory fitness.
7. The pre-exercise pulse rate does not indicate the condition of the athlete.
8. The pre-exercise stroke volume did not change significantly.
9. The post-exercise stroke volume did not change significantly although the mean values indicated a trend to increase with a decrease in pulse rate.

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[1]Norman Molomut and S. C. Allen, "Effect of Pressure Breathing on Circulation at High Altitudes as Measured by the Ballistocardiogram," Journal of Aviation Medicine, 17-18: 361, June, 1946.

[2]Ibid.

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INTRODUCTION

JUSTIFICATION OF INVESTIGATION Physical Education is in need of better methods of measuring circulatory fitness. Instruments which reflect the circulatory changes during conditioning are essential to coaches as well as physical educators. Therefore a study dealing with the testing of circulatory fitness should be of some interest to the people connected with physical education.

Ballistocardiography in physical education is just beginning. The effects of conditioning on this type of recording are not known. The reliability of this instrument in measuring cardiac output is still questionable. However, Massey and Hussman recommended in their exploratory study that the effects of exercise on the ballistocardiogram be investigated further because it appeared to be an especially profitable area for further research.[1]

One of the outstanding problems confronting coaches today is that of conditioning. They are interested to find out if there is a peak of conditioning beyond which physical performance diminishes. If there is such a peak, and a decrease in efficiency, what is the cause for this decrease in physical performance? There are a great number of

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[1]Benjamin H. Massey, and B. F. Hussman, "An Exploratory Study of the Ballistocardiogram As A Measure of Circulatory Fitness," Proceeding, 1954 National Convention, American Association for Health, Physical Education, and Recreation, New York, 1954, p. 119.

solutions to this question. A decrease in cardiac efficiency may have an important effect on the performance of an individual. In other words a decrease in cardiac output may contribute to a decrease in performance. It is also possible that the number of capillaries may decrease with conditioning. If this is true then the amount of oxygen being delivered to the muscles and other parts of the body will be decreased. This could result in a decrease in physical performance. Some people are of the opinion that this period of decreased physical performance is purely psychological. This is only a small fraction of the total number of possible solutions to this question. In order to determine if this period of decreased efficiency, commonly referred to as "staleness," is a result of a decrease in circulatory efficiency physical educators must find a way to accurately measure relative changes in cardiac output before and after exercise. In recent years physicians and physiologists have attached considerable importance to the ballistocardiograph as a means of measuring these relative changes in cardiac output.[2]

<u>STATEMENT OF PROBLEM</u> The primary question of this investigation is "Do the components of the ballistocardiogram change significantly before and after exercise as a result of a conditioning program?" Secondary points of interest deal with the relative changes in stroke volume and the pulse rates as a result of conditioning.

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[2] *Ibid.*

GENERAL EXPERIMENTAL PLAN Ten candidates for the Michigan State varsity basketball team were selected by head coach Forrest Anderson to participate in this study. Of the ten selected, six were considered as leading candidates for the first five.

In order to establish a control two tests were given. The first test was given to acquaint the subject to the procedures he was to follow. In this study the second test was used as the control record. After a control had been established, a three week conditioning program was started. Following this three week conditioning program, a third test was given in the same manner as the first and second test.

Following this conditioning program the ten subjects began their regular training program for the coming season. This consisted of regular practice sessions five days a week for about six weeks. Then they began their regular season.

The fourth test was administered after the team had completed half of the schedule. Following this test they continued to practice five days a week.

Upon completion of the regular season the ten men were allowed to do whatever they wanted to in regards to training. Their equipment was collected so they could not work out to any great extent. Five of the ten were graduating seniors, and had no incentive to train since their eligibility was completed. The ten subjects were then tested for the last time about four or five weeks following the completion of the regular season.

The data gathered from the records was handled statistically.

The heights and areas of the I and J waves were measured and the stroke volume was computed using Molomut's simplified formula for changes in relative stroke volume.[3] The pulse rates were obtained by counting the number of "R" waves of the electrocardiogram for thirty seconds and multiplying by two. All of these measurements were taken before and after exercise.

After the data were recorded on the tabulation sheets, an analysis of variance was computed on the relative stroke volume, pulse rate and heights of I and J waves. If there were significant changes occuring in these student's small "t" was then computed.[4]

DEFINITION OF THE BALLISTOCARDIOGRAM The term ballistocardiogram was originated by Starr in 1939.[5] It is a derivative of the Greek word ballein; meaning to throw; kardia meaning heart; and gramma meaning a drawing. Therefore ballistocardiogram means a record of body movements produced by the beat of the heart.[6]

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[3]Norman Molomut, and S. C. Allen, "The Effects of Pressure Breathing on Circulation at High Altitudes as Measured by the Ballistocardiograph," Journal of Aviation Medicine, 17-18: 361, August, 1946.

[4]George W. Sanders, Statistical Methods, (Ames, Iowa: State College Press, 1946) p. 238.

[5]Isaac Starr, and others, "Studies on the Estimation of Cardiac output in man and of abnormalities in cardiac function, From the Hearts Recoil and the Bloods Impact; The Ballistocardiogram," American Journal of Physiology, 127:1, August, 1939.

[6]Herbert Brown Jr., and others, Clinical Ballistocardiography (New York: The MacMillan Company, 1952) p. 3.

The ballistocardiograph complex makes up the pattern of movements of the body with each heart beat. A typical record can be found in Appendix B. Upward deflections represent movements toward the head and downward deflections are footward movements. The ballistocardiogram begins with a headward deflection and begins during the QRS complex of the electrocardiogram.[7] This is designated as the H wave. Usually each beat is made up of two groups of waves.[8] The first group is composed of H, I, J, and K.[9] The second group of waves is composed of L, M, N, and O.[10] In this investigation the height of I and J waves was studied since it is closely related to the output of the heart.[11]

LIMITATION OF THIS INVESTIGATION The purpose of this investigation is to study the changes that occur in the ballistocardiogram both before and after exercise. In order to investigate these changes certain assumptions must be made. First of all we must assume that the loss of fat during a conditioning program will not effect the recording obtained by the Sanborn ballistocardiograph. The second assumption is that the oxygen utilization remains fairly constant. In other words the amount of oxygen being used by the muscles and other parts of the

[7] Ibid., p. 53.

[8] Ibid.

[9] Ibid.

[10] Ibid.

[11] Ibid., p. 56.

body is not increased or decreased by an increase or decrease in the number of capillaries but rather by an increase or decrease in cardiac output. Finally we must assume that the instrument we are using records accurately. With these assumptions in mind, the following groups of measurements are of prime importance: (1) Pulse Rate, (2) Height of I and J waves, and (3) Relative Stroke volume. Relative stroke volume is not the actual amount of blood ejected with each ventricular contraction but an arbitrary figure that is useful in determining changes in stroke volume.

SUMMARY In summarizing this chapter a presentation of some of the questions pertinent to this study seems quite proper. In the first place does a conditioning program decrease the post-exercise pulse rate? Secondly does the stroke volume, as determined with a Sanborn model ballistocardiograph, change during the conditioning period? Finally does the height of the I and J waves increase or decrease significantly?

CHAPTER II.

REVIEW OF LITERATURE

INTRODUCTION The effects of conditioning on the ballistocardiogram have not been studied and therefore literature pertinent to this subject is rather difficult to obtain. As a matter of fact ballistocardiography is so new that it has not been used to a significant extent in research of physical activity or conditioning.

HISTORY OF THE BALLISTOCARDIOGRAPH Since this study is a pioneering effort in the present physical education department at Michigan State, a brief history of the ballistocardiogram seems necessary.

Brown cites in his text that J. W. Gordon in 1887 demonstrated that with each heart beat there is a certain amount of body displacement.[1] From this observation he designed two types of machines to record these movements.[2] The first method used by Gordon to derive body movements was to allow the pointer of the weighing machine to trace out a figure.[3] Later he developed a light frame table suspended by four ropes to record these movements.[4] Following 1887 Landois used this same principle to develop a vertical ballistocardiograph.

[1]Herbert Brown Jr., and others, Clinical Ballistocardiography (New York: The MacMillan Company, 1952) p. 6.

[2]*Ibid.*

[3]*Ibid.*

[4]*Ibid.*

Seventy years later Krahl was designing a simple ballistocardiograph to be used as a teaching aid for his physiology laboratory.[5] This consisted of an ordinary spring bathroom scale, a lever arrangement, and a kymograph drum.[6]

After a series of observations on the volume curve of the heart of the dog, Henderson was led to consider the need for a method of obtaining similiar information as to human circulation under normal and pathological conditions.[7] This study led him to design the Henderson table.[8]

In 1911, the Anglo-American Pikes Peak Expedition, reported by Douglas, Haldane, Henderson and Schneider, used a simplified form of recoil table in studying the effects of altitude on cardiac output.[9] This table consisted of a plank supported on piles of cork.[10] This

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[5] Ibid., p. 7.

[6] Ibid., p. 28

[7] Yandell Henderson, "The Mass Movements of the Circulation as Shown by a Recoil Curve," American Journal of Physiology, 14:287, September, 1905.

[8] Ibid., p. 290;

[9] Isaac Starr et.al, "Studies On The Estimation of Cardiac Output in Man, and of Abnormalities In Cardiac Function, From the Hearts Recoil and The Bloods Impact; The Ballistocardiogram," American Journal of Physiology, 127:1, August, 1939.

[10] Ibid.

was considered to be the first use of the ballistocardiograph in a field experiment.[11]

Harold and Tucker designed a ballistocardiograph that required the subject to stand on a platform suspended from the diaphragm of a drum in 1922.[12] Movement was recorded by changes in the current flowing through a hot wire placed in the drum's air inlet.[13] Normal respiratory activity did not interfere with the record of cardiac mobements and the effect of the respiratory cycle on these movements was clearly shown.[14] Increased amplitude was demonstrated after exercise.[15]

The next development in the field of ballistocardiography came from Germany in 1928. Here two Germans, Angenheister and Laue published five records obtained from a seismograph placed on a rigid table on which their subject lay.[16] Four of these records were similar to those records obtained by Starr in 1939.[17] As a result of this study more foreign physiologists were becoming interested in the ballistocardiograph. In Sweden Abramson built a chair of aluminum alloy suspended from steel springs which were embedded in a cast steel

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[11]Brown, Op. cit., p. 10.

[12]Starr, Op. cit., p. 1.

[13]Ibid.

[14]Ibid.

[15]Ibid.

[16]Ibid.

[17]Ibid.

base on a concrete foundation.[18] The movements were greatly magnified by a patented device and photographed.[19]

The new era of ballistographic research began in 1939 with the advent of Isaac Starr's work.[20] Starr and his co-workers have investigated the ballistocardiograph from both the theoretical and emperical viewpoints.[21] Their contributions are numerous and significant. In 1939 Starr (et. al.) designed a table similar to that employed by Henderson in 1904.[22] With this table they confirmed the findings of their predecessors in this field regarding the general shape of the normal cardiac ballistic curve and the effects of exercise, and certain drugs, upon its amplitude.[23] From these explorations Starr (et. al.) developed new theoretical concepts of the forces involved and derived new formulas for estimating cardiac output.[24] These are but a few of Starr's many contributions.

VALIDITY OF THE BALLISTOCARDIOGRAM IN MEASURING CARDIAC OUTPUT

Much has been said about the validity of the ballistocardiogram as a measurement of cardiac output. Most of the arguments against using

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[18] *Ibid.*

[19] *Ibid.*

[20] Brown, *Op. Cit.*, p. 16.

[21] *Ibid.*

[22] Starr, *Op. Cit.*, p. 2.

[23] *Ibid.*

[24] *Ibid.*

this type of record as a measure of cardiac output stems from the fact that Starr's original formula required the assumption of some value for the size of the aorta.[25] However, Starr correlated the stroke volume as determined by his original formula with the ethyl iodide method. He found the coefficient of correlation to be 0.86 with a standard deviation of .052.[26] The results obtained from the ballistocardiogram averaged two c.c. per beat, 3.9 percent smaller, than those obtained by the ethyl iodide method. This amount was not considered significant. Cournand and Ranges correlated the cardiac output as determined by the direct Fick method and the ballistocardiogram.[27] They found that the direct Fick method was much more difficult to perform but the degree of accuracy was high. Any discrepancy between the results obtained by the direct Fick and by the Ballistocardiograph were assumed to be due to error in the latter.[28] Cardiac output as determined by the direct Fick method was found to be 18.5 percent larger than the value calculated from the ballistocardiogram.[29] Analysis of a large number of data and comparison with other methods,

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[25] Carl J. Wiggers, Physiology In Health and Disease, (Fifth edition; Philadelphia: Lea and Febiger Company, 1954)

[26] Starr, Op. Cit., p. 21.

[27] Andre Courand, H. A. Ranges, and R. L. Riley, "Comparison of Results of the Normal Ballistocardiogram and a Direct Fick Method in Measuring the Cardiac Output in Man," Journal of Clinical Investigation, 21: 287, May, 1942.

[28] Ibid., p. 291.

[29] Ibid., p. 292.

have sufficiently standardized the ballistocardiogram to make it useful in measuring the changes in relative stroke volume in the same subject.[30]

If this is true then these changes should be evident during a training program. In other words if we assume that the oxygen utilization doesn't increase during a conditioning program and that the Sanborn ballistocardiograph is recording accurately, there should be an increase in the amount of blood being pumped out with each beat of the heart as conditioning progressed.

Massey and Hussman conducted an exploratory study of the ballistocardiogram as a measure of circulatory fitness.[31] Their objectives were to determine if the components of the ballistocardiogram differed significantly between two groups believed to differ in circulatory fitness.[32] He concluded that the variables of the ballistocardiogram were in the appropriate direction even if they were not quite statistically significant.[33]

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[30]Wiggers, Op. Cit., p. 711.

[31]Benjamin H. Massey and B. F. Hussman, "An Exploratory Study of the Ballistocardiogram as a Measure of Circulatory Fitness," Proceedings, 1954 National Convention, American Association for Health, Physical Education, and Recreation, New York, 1954, p. 119.

[32]Ibid.

[33]Ibid., p. 4.

HARVARD STEP TEST

A pulse rate test is probably the easiest and simplest way for physical educators to determine circulatory fitness.[34] The chief factor determining the minute volume of the circulation is the control exerted by the respiratory metabolism over the venous return, that is, the volume of blood from the venous reservoirs of the body supplied to the right heart.[35]

Exact coordination of heart action and venous return occurs when the pulse rate is such that during bodily rest and moderate exertion these two factors vary proportionally.[36]

Starling's "Law of the Heart" implies that the energy of contraction is a function of the length of muscle fibers.[37] Therefore a decrease in pulse rate would allow for a longer diastolic filling time, distention of the muscle fibers of the heart and therefore an increase in output.

A necessary condition of all muscular exercise is that the muscles shall be supplied with oxygen in proportion to their requirements.[38]

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[34] Thomas K. Cureton, Physical Fitness Appraisal and Guidance, (The C. V. Mosby Company, 1947), p. 162.

[35] Yandell Henderson, H. W. Haggard, and F. S. Dolley, "The Efficiency of the Heart, and the Significance of Rapid and Slow Pulse Rates," American Journal of Physiology, 82:152, June, 1927.

[36] Ibid.

[37] Ernest H. Starling, Principles of Human Physiology, (Philadelphia: Lea and Febiger, 1930), p. 738.

[38] Ibid., p. 811.

Since the arterial blood is almost saturated with oxygen, such increases in the oxygen usage by the muscles implies a great increase in the blood supplied to them, though a certain amount of oxygen may be gained by a more complete utilization of the oxygen of the blood as it flows through the working tissues.[39]

Therefore it seems logical that an athlete undergoing a rigorous conditioning program should lower his pulse rate and increase his stroke volume. This trend of thinking is backed by an experiment by Henderson, Haggard, and Dolley in 1927.[40] They were reporting on the typical examples of the circulation and cardiac efficiency in fifty college students.[41] They found that in athletes the pulse rates tend to be much slower and the stroke volume much larger both during rest and during exercise than in non-athletes.[42]

With these basic physiological facts concerning the meaning of pulse rates in mind let us consider the Harvard Step Test.[43] This test consists of stepping up and down on a twenty inch stool thirty times a minute, (once every two seconds) for five minutes. Following the exercise, pulse rates are taken from one to one and a half minutes, from two to two and a half minutes, and from three to three and a half minutes. Taylor found that the latter two pulses are "dead wood" by correlating the Johnson-Brouha "recovery index" computed in the recommended way

[39] Ibid.

[40] Henderson, Op. cit., p. 513.

[41] Ibid., p. 523.

[42] Ibid.

[43] Cureton, Op. cit., p. 174.

with one in which the latter two pulse counts are omitted.[44] In thirty-four cases the r was 0.99.[45] In the present study the one and five minute counts were taken.

The recuperation of pulse rate after a standard exercise such as the Harvard Step Test is one of the most acceptable tests of circulator fitness.[46] The pre-exercise pulse rate is not a very good means of selecting individuals who are in superior athletic condition. Salit and Tuttle reported that most cardiovascular measures do provide a good means of selecting individuals who are in superior condition.[47] Of all the scores obtained in their study, the post-exercise heart rate and the increase due to exercise, were found to be most promising.[48] Montoye analyzed the results found by Gallagher and Brouha and found that the post exercise pulse rate was sensitive to a conditioning program.[49] He found that as the conditioning progressed the maximum pulse rates during exercise decreased and therefore the recovery

[44]Craig Taylor, "A Maximal Pack Test of Exercise Tolerance," Research Quarterly, 15:201, December, 1944.

[45]*Ibid.*

[46]Cureton, Op. Cit., p. 178.

[47]Elizabeth Powell Salit and W. W. Tuttle, "The Validity of Heart Rate and Blood Pressure Determinations as Measures of Physical Fitness," Research Quarterly, 15:253, October, 1944.

[48]*Ibid.*

[49]Henry J. Montoye, "Interrelation of Maximum Pulse Rate During Moderate Exercise, Recovery Pulse and Post-Exercise Blood Lactate," Research Quarterly, 24: 453-458, December, 1953.

time decreased.[50] This seems to indicate that as conditioning progressed the heart pumped out more blood and didn't have to work as hard during exercise. Therefore it took less time for it to recover. In view of these facts, it seems logical to assume that the ballistocardiogram would demonstrate an increase in relative stroke volume, heights of I and J waves and a decrease in pulse rate during a conditioning program.

SUMMARY In summarizing this chapter a review of the main points of this chapter is presented. Ballistocardiography in physical education is an entirely new field. The effects of conditioning on the ballistocardiogram are not known. Analysis of a large number of data and comparison with other methods, have sufficiently standardized the ballistocardiogram to make it useful in measuring the changes in relative stroke volume in the same subject.[51] The recuperation pulse rate after a standard exercise is one of the most acceptable tests of circulatory fitness.[52] Although a certain amount of oxygen may be gained by a more complete utilization of the oxygen of the blood as it flows through the working tissues, an increase in oxygen usage by the muscles indicates a great increase in blood supplied to them.[53] Therefore a decrease in pulse rate may be an indication of a corresponding increase in stroke volume.

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[50] Ibid.

[51] Wiggers, op. cit., p. 711.

[52] Cureton, op. cit., p. 162.

[53] Starling, op. cit., p. 738.

CHAPTER III

METHODOLOGY

SUBJECTS The ten men were selected for this study by the varsity coach Forrest Anderson. He selected the boys who were most likely to make the first two teams. As it turned out five of these boys were considered as starters. Two were not considered starters but played a great deal. The last three were on the first ten for the whole season but did not see much action.

Each subject was instructed not to eat just prior to being tested. He was also told to walk or ride to the place where he was to be tested. Upon arrival he rolled up his trouser legs, took off his shirt and reclined on a mattress covered table for the recording of the resting electrocardiogram, respiration and heart sounds. Once his pulse rate was steady the recording was started.

EQUIPMENT It has been found that a subject lying on a rigid table with support under his ankles will move in response to the cardiac beat.[1] The motion of the patient's body with regard to the table is very complex and is determined by the thrust forces developed within the patient's body acting on a mechanical system made up of the patient's body and the supports between body and table.[2] Therefore

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[1]Sanborn Ballistocardiograph, Sanborn Co., Sec. II., p. 1, Cambridge, Mass., 1953.

[2]Ibid.

mattresses or sponge rubber pads should not be used.

The Sanborn Ballistocardiograph is comprised of two units. One of these is the light projedtor and the other is the photo cell.[3] The light projector is placed on the patient's shins and moves with the patient. It was discovered in this study that by placing the transducer at different distances from the ankle will cause a variation in the amplitude of the component parts of the ballistocardiogram. Therefore it was necessary to place the transducer in the same place as the previous test. This was done by measuring from the subject's internal talus to the front of the transducer element and also to the ankle bar.

The field of light that is transmitted to the photo-cell by the transducer is in the form of a rectangle. The photo-cell is placed about a quarter of an inch away from the transducer element. It must not be touching. The motion of the transducer therefore moves the light back and forth across the face of the photo-cell. The relative positions are adjusted so that approximately one quarter of the active area of the photo-cell is illuminated by the projected light.

The patient's body is subject to motions which are not all of cardiac origin.[4] The most prominent of these is produced by normal respiration. One method of overcoming this is to have the subject hold his breath. This is not advisable because Mueller or Valsalva effects

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[3] Ibid.

[4] Ibid.

may be introduced.[5] These variations may be reduced by introducing an electrical filter between the photo-cell and the recording system. This is done in the Sanborn instrument by throwing a switch located on the photo-cell.

The photo-cell is plugged into the Poly-Viso-Recorder model 109 and the electrocardiogram, respiration and ballistocardiogram can be recorded simultaneously. By recording all three of these at once the electrocardiogram can be used as an orienting point. The R wave just proceeds the ballistocardiographic H wave.

The Sanborn ballistocardiograph has the following components and controls as shown in Figure one.[6] (See page 20.)

I. LEG PIECE

A. Switch and Lamp Voltage Control. Turns to lamp (D) and to set meter needle on red line.

B. Meter. Note red line for determination of standard intensity of light.

C. Battery Hood. Lifts off to expose battery.

(Note: Do not attempt to lift or carry leg piece while grasping battery hood.)

D. Lamp Holder. Lifts out for replacement of lamp bulb.

E. Light Slot. Directs rectangle of light to hood of photocell unit.

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[5] *Ibid.*

[6] *Ibid.*, Sect. III, p. 1.

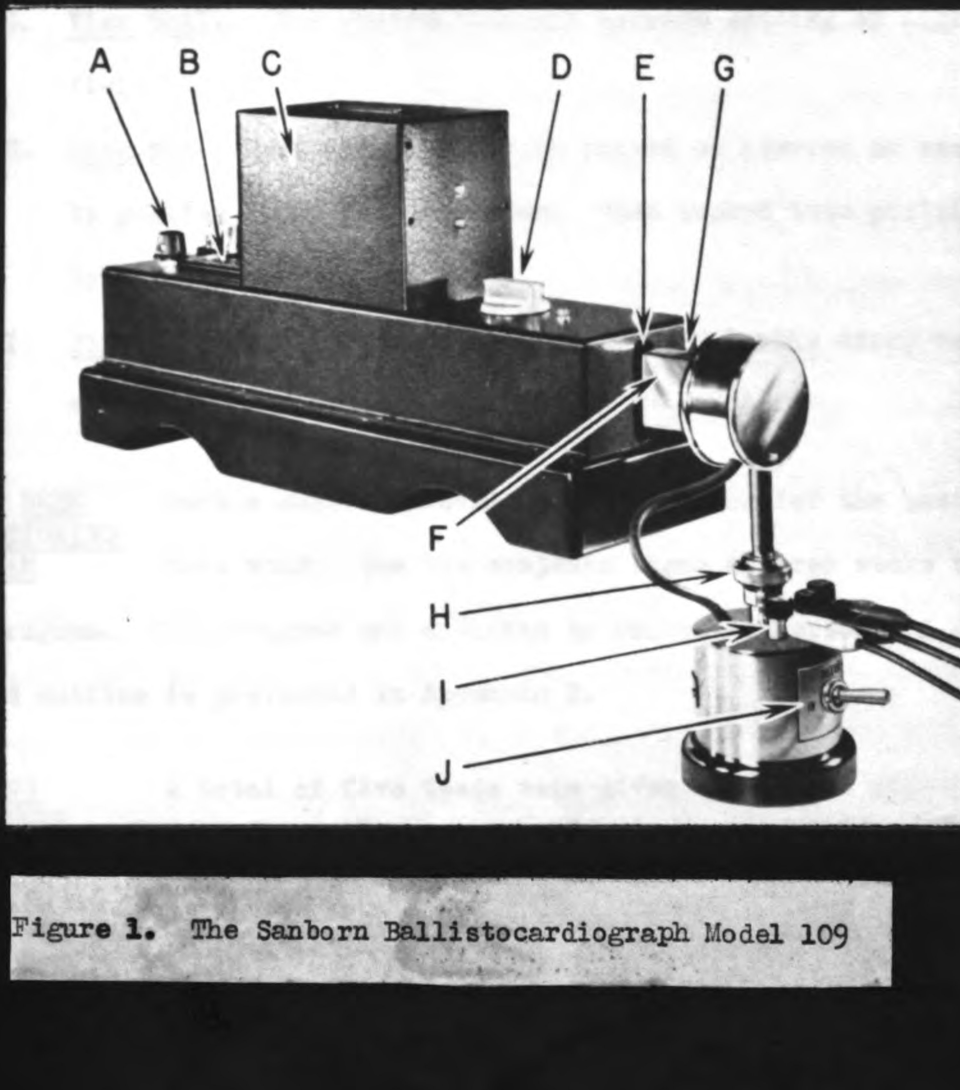

Figure 1. The Sanborn Ballistocardiograph Model 109

II. <u>PHOTOCELL UNIT</u>

F. <u>Rectangular Hood</u>. Receives rectangular light field from light slot of leg unit, and directs it to photoelectric cell.

G. <u>View Scale</u>. For observation and correct setting of light field.

H. <u>Lock Nut</u>. Hood and cell may be raised or lowered as required by pulling up or pressing down. Then locked into position by this nut.

I. <u>Binding Post</u>. For connection of E. C. G. cable tips, as marked.

<u>THREE WEEK CONDITIONING PROGRAM</u>

Once a control record was established for the basis of this study, the ten subjects began a three weeks training program. This program was outlined by Forrest Anderson. A detailed outline is presented in Appendix B.

<u>TESTING PROCEDURE</u>

A total of five tests were given during the 1954-55 season. Each test was administered in nearly the same manner as the first. It was impossible to arrange for the subjects to be tested at the same time for every test due to their class schedule and also the availability of the physiology laboratory. However, each subject was tested sometime during the day prior to four o'clock.

As the subject reported for the test he would roll up his trouser legs above his knees and remove his shirt and undershirt. He then proceeded to the table and reclined for approximately ten to fifteen minutes until his pulse count would become steady.

While reclining at this table, he was wired to record the standard resting electrocardiogram. Electrodes were placed on the right and left leg above the leg muscle so they would not slip during exercise, on the right and left arm below the elbow, and six leads were placed on his chest. Care was taken to avoid strapping the electrodes on too tightly. He was also prepared to record respiration and heart sounds.

The first part of the test was merely an electrocardiograph recording. These leads were recorded in this order. The three standard leads I, II, and III were recorded first. Then AVR, AVL, and AVF were recorded; next the three chest leads V_1, V_2, V_3. After shifting the cables to the last three chest leads, V_4, V_5, V_6, were recorded.

The second part of the test involved a recording of lead II, heart sounds and respiration. The heart sounds were recorded by placing a small microphone over the point where the heart sound was the loudest. This was determined by using a stethescope.

From here the subject moved to another table. Here a resting ballistocardiograph, lead II, and respiration were recorded.

Following this he proceeded to do the Harvard Step Test. This consisted of stepping up on a stool with both feet and back down once every two seconds or thirty times a minute. The stool was approximately seventeen inches high. The subject was assisted by one of the examiners by having the cycles counted out loud to make sure of thirty complete cycles per minute.

The fifth part of this test was the post-exercise. Following the Harvard Step Test the subject returned to a hard table and reclined.

One minute after exercise had stopped an electrocardiogram was recorded. This lasted for thirty seconds. The subject was allowed to rest on the table and five minutes after the end of exercise Lead II, respiration and the ballistocardiogram were recorded.

MEASURING PROCEDURE The records obtained in these tests were put together, folded and filed. The date of the test, measurements for placing the transducers and ankle support were written on the outside of a manila folder, along with the subject's name.

Upon inspection of the record three sample ballistocardiograms were selected, both before and after exercise. These three all occurred during the inspiration phase throughout the test. This was done because the inspiration and expiration phases have a varied effect on the relative cardiac output. This helped to standardize the measurements throughout the testing program.

After selecting the three ballistocardiograms a baseline was drawn using the standardization line. Then these measurements illustrated in Table I were made, and the averages entered on the tabulation sheet. The areas were measured in square inches by using the Ott Compensating planimeter. The heights were obtained by measuring from the base line to the inside tip of the I and J waves.

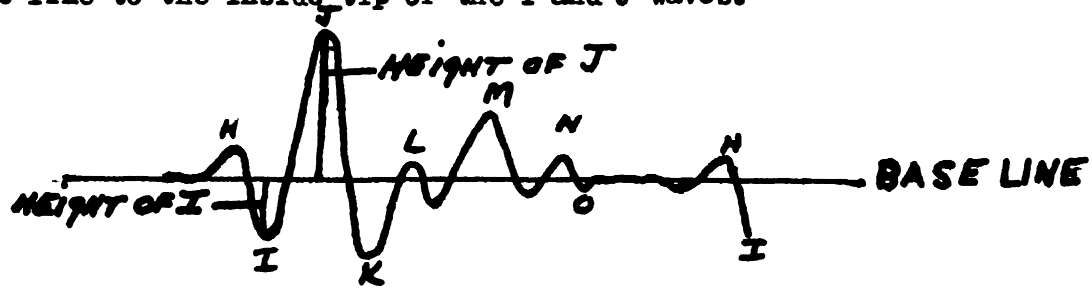

Figure 2. Technique of Measuring I and J Wave Amplitude.

TABLE I.

SAMPLE RECORDING SHEET FOR, BOTH PRE- AND POST-EXERCISE, BALLISTOCARDIOGRAM MEASUREMENTS

Area	First Wave (sq.in.)	Second Wave (sq.in.)	Third Wave (sq.in.)	Mean (sq.in.)
I	.07	.06	.05	.06
J	.04	.05	.06	.05
I & J	.11	.11	.11	.11
Height	(mm)	(mm)	(mm)	(mm)
I	1.9	2.3	2.4	2.2
J	10.5	9.4	9.2	9.7
I & J	12.4	11.7	11.6	11.9

After these measurements had been recorded the pulse rates were then computed. Pulse rates were taken while resting, one to one and a half minutes after exercies, and five to five and one half minutes after exercise. These were also counted from the records.

COMPUTATION OF RELATIVE STROKE VOLUME Molmut and Allen derived a formula for measuring relative volumes while studying the effects of pressure breathing on circulation at high altitude.[7] Since this study is concerned with the relative changes in stroke volume, this formula was used: :

$$\text{Relative SV} = \sqrt{(I + J)\ C^{3/2}}$$

[7]Molomut, Norman and S. C. Allen, "Effect of Pressure Breathing on Circulation at High Altitudes as Measured by the Ballistocardiograph," Journal of Aviation Medicine, 17-18: 361, June, 1946.

where I and J represents the height of I and J in millimeters. The factor C is the length of the cycle in seconds.[8]

After these data were recorded on tabulation sheets an analysis of variance was computed on the following three groups of measurements:

(1) Pulse Rates - before and after exercise.

(2) Relative Stroke Volume - before and after exercise.

(3) Height of "I and J" before and after exercise.

If the analysis of variance were significant the "t" technique to test the significance of the difference between any two of the group means was employed.[9]

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[8] Ibid.

[9] George W. Sanders, Statistical Methods, (Ames, Iowa: State College Press, 1946), p. 238.

CHAPTER IV

ANALYSIS OF DATA

INTRODUCTION The purpose of this investigation was to study the effects of conditioning and the components of the ballistocardiogram. Ten subjects were tested five times during the basketball season. Here are the results.

HEIGHT OF I & J Three complete cycles of the ballistocardiogram both before and after exercise were selected for measuring the I and J amplitudes. These six cycles occurred at approximately the same time during the inspiratory phase of respiration. Each set of three was measured by using calipers and measuring from the standardization line to the top of I and J respectively.

An analysis of the pre- and post-exercise heights indicated that there were no significant changes in amplitude. Therefore the "t" test was not applied. The mean values as plotted in Figure 3, indicate that instead of the amplitude increasing with conditioning it decreased. This did not affect the relative stroke volume as derived by Molomut's formula because it had a tendency to increase with conditioning.[1] It is evident that at this point the height of I and J in Molomut's formula does not play an important part in determining the increase

[1]Norman, Molomut, and S. C. Allen, "The Effects of Pressure Breathing on Circulation At High Altitudes as Measured by the Ballistocardiograph," Journal of Aviation, Medicine, 17-18: 361, August, 1946.

TABLE II

ANALYSIS OF VARIANCE OF PRE- AND POST-EXERCISE HEIGHTS OF I AND J WAVES OF THE VARSITY BASKETBALL PLAYERS

Item	Sum of Squares	Degrees of Freedom	Variance Estimate	Variance Ratio	Probability
Pre-Exercise					
Between Columns----	16.80	3	5.60	.55	Greater than .05
Within Columns---	359.33	35	10.27		Greater than .05
Total ----	376.13	38			
Post-Exercise					
Between Columns----	59.28	3	19.76	.40	Greater than .05
Within Columns--	1731.20	35	49.46		Greater than .05
Total----	1790.48	38			

or decrease in relative stroke volume.[2] Therefore the cycles per second (C) in the formula seems to be the controlling factor.[3] The trend for the amplitudes to decrease with training instead of increase may be due to the decrease in body fat. It was pointed out earlier in the investigation that placing the transducer element at varying distances from the subject's internal talus altered the amplitude of the waves and measurements were used to place the transducer element

[2] Ibid.

[3] Ibid.

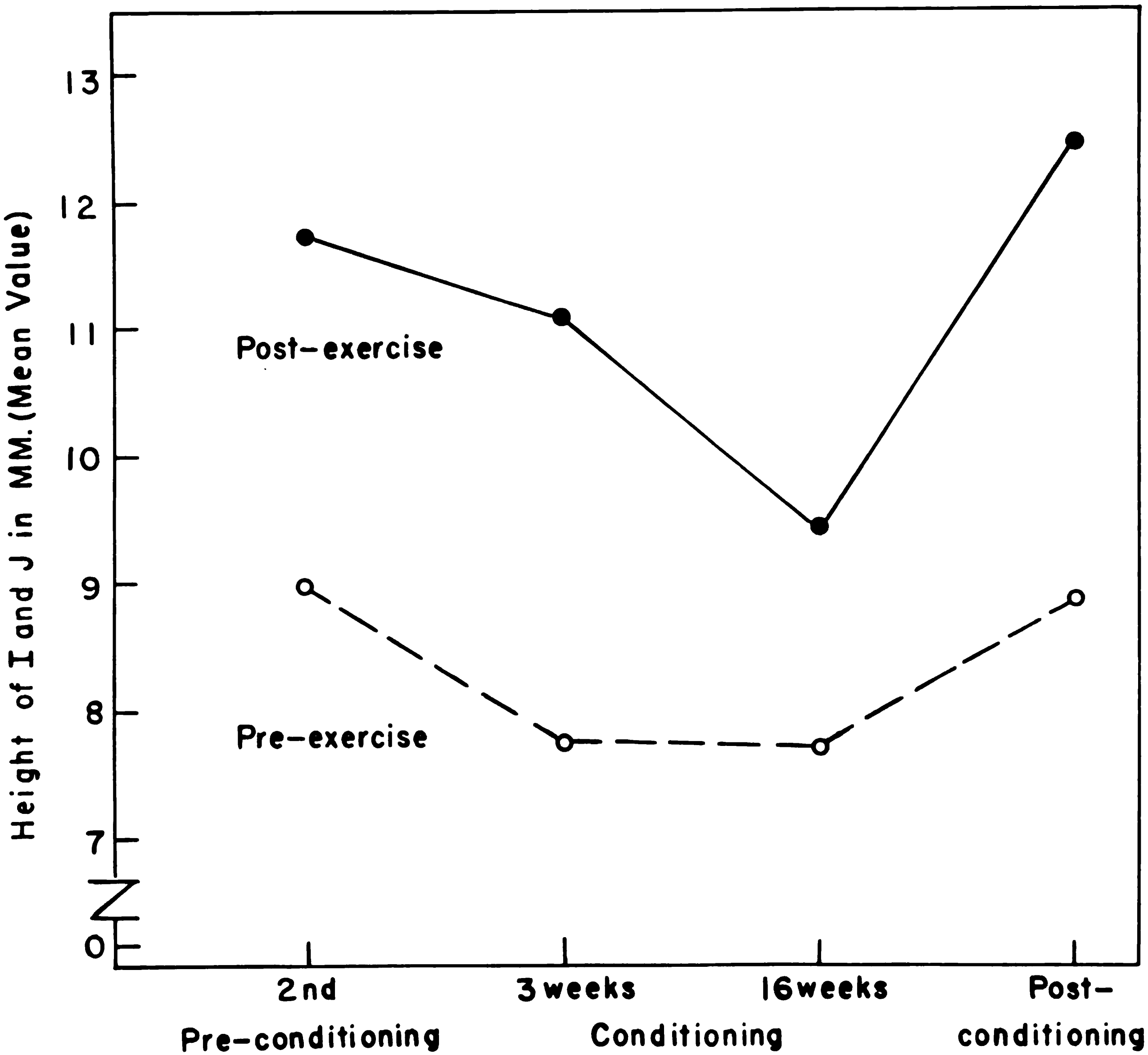

Figure 3. Mean Heights of I and J Ballistocardiogram Waves Before and After a Standard Exercise in Ten Varsity Basketball Players.

in the same position each test. A careful examination of this effect on amplitudes should be conducted before further research is continued.

PULSE RATES The pulse rates were computed by counting the R waves for a thirty second period and multiplying by two to get the rate per minute. Both pre- and post-exercise counts were taken.

Following an analysis of variance of pre-exercise pulse rates, it was found that the changes were not statistically significant. Therefore further analysis was deemed unnecessary. The mean values plotted in Figure 4 did not indicate a definite tendency to decrease

TABLE III

ANALYSIS OF VARIANCE OF PRE-EXERCISE PULSE RATES OF TEN, BASKETBALL PLAYERS

Item	Sum of Squares	Degrees of Freedom	Variance Estimate	Variance Ratio	Probability
Between Columns----	285.28	3	95.09	.98	Greater than .05
Within Column---	3383.50	35	96.67		Greater than .05
Total ---	3668.78	38			

with conditioning and increase with deconditioning. The first pre-conditioning pulse rate of 59.3 beats per minute increased to 64.3 beats per minute in the second pre-conditioning test. Following three weeks of conditioning the mean pulse rate decreased to 58.1 beats per minute. This decrease was followed by a slight rise in pulse rates following sixteen weeks of conditioning. One month after the end of the conditioning program the pulse rates rose to 63.6 beats per minute. The insignificance of the pre-exercise pulse rates tends to support the work of Salit and Tuttle.[4]

TABLE IV

ANALYSIS OF VARIANCE OF POST-EXERCISE PULSE RATES OF TEN, BASKETBALL PLAYERS

Item	Sum of Squares	Degrees of Freedom	Variance Estimate	Variance Ratio	Probability
Between Columns--	3772.48	3	1257.49	10.42	.001
Within Columns--	4222.50	35	120.64		.001
Total----	7994.98	38			

TABLE V

SIGNIFICANCE OF "t" FOR POST-EXERCISE PULSE RATES OF TEN VARSITY BASKETBALL PLAYERS

	3 Weeks Conditioning	16 Weeks Conditioning	Post Conditioning
Pre-Conditioning---	1.91	4.47**	0.19
3 Weeks Conditioning---		4.41**	5.16**
16 Weeks Conditioning---			1.06

**This figure is significant at .001 level of significance.

[4]Elizabeth Powell Salit and W. W. Tuttle, "The Validity of Heart Rate and Blood Pressure Determinations as Measures of Physical Fitness," Research Quarterly, 15: 253, October, 1944.

An analysis of variance of the post-exercise pulse rates indicated that changes occurring within the groups were significant at the 0.001 level of significance. Therefore a "t" test was computed to determine the significance occurring among the mean values of the four tests.

Changes in the mean pulse rates from the pre-conditioning test to the three-week conditioning test were found to be insignificant at the five percent level of significance. Also found insignificant were the changes occurring between the pre-conditioning test and post-conditioning and between the sixteen weeks test and post-conditioning test. The changes occurring between the pre-conditioning phase and sixteen weeks of conditioning were significant at the one tenth percent level. Also found significant at the one tenth percent level were the differences between three weeks of conditioning and sixteen weeks of conditioning and between three weeks conditioning and post-condition. The mean values plotted in Figure 4 also indicate the decrease of pulse rates with conditioning and an increase in rate following one month of inactivity.

These results substantiate the work of Gallagher and Brouha, Brouha and Savage, as cited by Montoye.[5] It also indicates that the recuperation pulse is one of the most acceptable tests of circulatory-respiratory fitness.[6]

[5]Henry J. Montoye, "Interrelation of Maximum Pulse Rate During Moderate Exercise, Recovery Pulse, and Post-Exercise Blood Lactate," Research Quarterly, 24: 453-458, December, 1953.

[6]Thomas K. Cureton, Physical Fitness, Appraisal, and Guidance, (The C. V. Mosby Company, 1947), p. 178.

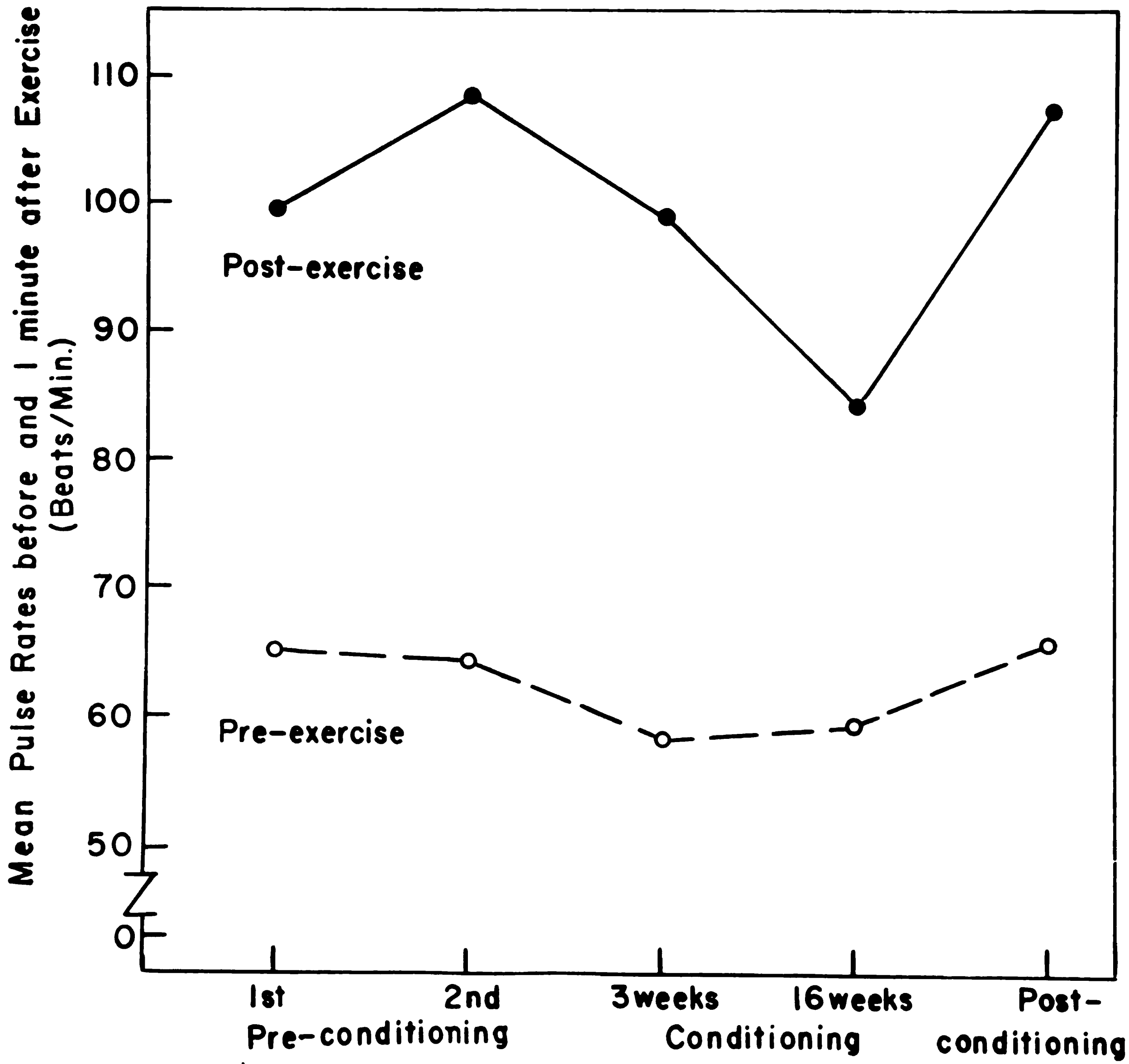

Figure 4. Mean Pulse Rates Before and One Minute After A Standard Exercise in Ten Varsity Basketball Players.

STROKE VOLUME The relative stroke volume was computed by using Molomut's formula for changes in relative stroke volume.[7]

The analysis of variance of the pre-exercise stroke volume was found to be insignificant. The mean values plotted in Figure 5 indicated that the stroke volume did not increase with a decrease in pulse rate.

TABLE VI

ANALYSIS OF VARIANCE OF PRE-EXERCISE STROKE VOLUME OF TEN VARSITY BASKETBALL PLAYERS

Item	Sum of Squares	Degrees of Freedom	Variance Estimate	Variance Ratio	Probability
Between Columns---	0.157	3	0.052	.115	Greater than .05
Within Columns---	15.954	35	0.455		Greater Than .05
Total-----	16.111	38			

The changes occurring in post-exercise stroke volume were also insignificant. However, the mean values plotted in Figure 5 indicated a definite tendency to increase with a decrease in pulse rates. The mean value for stroke volume increased from 2.39 to 2.52 following the three week conditioning program. After sixteen weeks of conditioning, it increased to 2.54. A month after the end of conditioning it decreased to 2.47.

[7]Molomut, op. cit., p. 361.

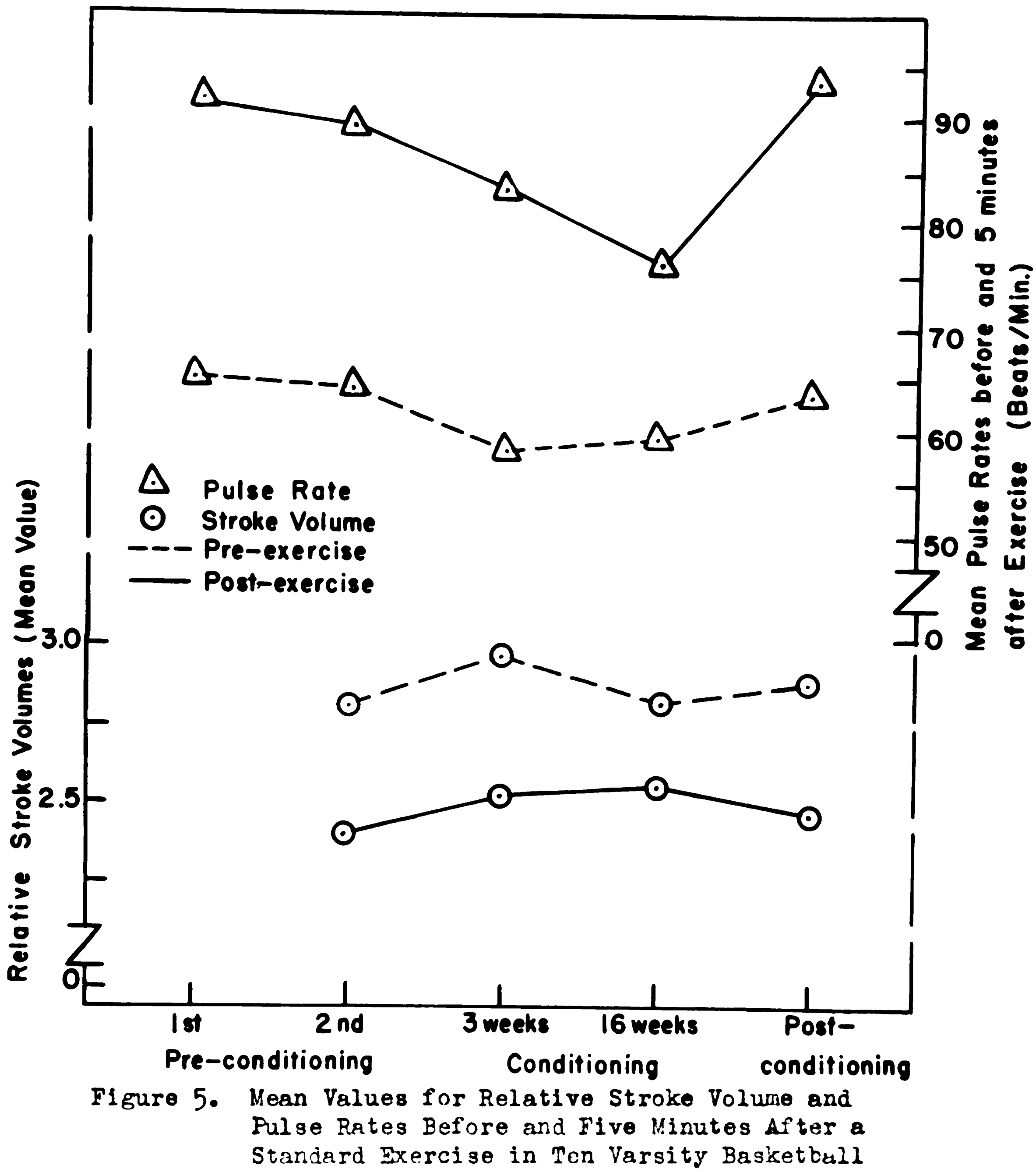

Figure 5. Mean Values for Relative Stroke Volume and Pulse Rates Before and Five Minutes After a Standard Exercise in Ten Varsity Basketball Players.

TABLE VII

ANALYSIS OF VARIANCE OF POST-EXERCISE STROKE VOLUME OF TEN BASKETBALL PLAYERS

Item	Sum of Squares	Degree of Freedom	Variance Estimate	Variance Ratio	Probability
Between Columns---	0.131	3	.044	.019	Greater than .05
Within Columns---	16.816	35	.480		Greater than .05
Total------	16.947	38			

Even though the results of the pre- and post-exercise stroke volume were insignificant, the mean values of the post-exercise stroke volume indicated a definite trend to increase with a lower pulse rate. This tendency follows the current trend of thought that as pulse rates decrease, stroke volume increases.[8] It is quite possible that the insignificance of changes in stroke volume could be a result of an increase in oxygen utilization.[9] This seems to be a profitable area for further research. It is also possible that had a larger number of subjects been used the results may have been significant.

[8] Yandell Henderson, H. W. Haggard, and F. S. Dolley, "The Efficiency of the Heart and the Significance of Rapid and Slow Pulse Rates," American Journal of Physiology, 82: 152, June, 1927.

[9] Ernest H. Starling, Principles of Human Physiology, (Philadelphia: Lea and Febiger, 1930), p. 738.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY Ten members of the Michigan State varsity basketball team were tested to determine the effects of conditioning on the components of the ballistocardiogram. Three complete cycles of the ballistocardiogram before and after exercise were selected for measurement. Each cycle occurred during the expiratory phase of respiration. The average values for these measurements, before and after exercise, were computed and recorded on tabulation sheets. An analysis of variance was then made to see if there were any significant changes within the group. If significant changes occurred, Student "t" test was computed to determine the significance between the individual mean values.[1]

CONCLUSIONS After analyzing the data of this investigation the following conclusions can be made.

1. The heights of I and J waves did not change significantly with conditioning and the mean values did not indicate an increase with conditioning.
2. The height of the I and J wave is not a critical factor in determining the relative stroke volume derived by Molomut's formula.[2]

[1]George W. Sanders, Statistical Methods, (Ames, Iowa: State College Press, 1946), p. 238.

[2]Norman Molomut and S. C. Allen, "Effect of Pressure Breathing on Circulation at High Altitudes as Measured by the Ballistocardiogram," Journal of Aviation Medicine, 17-18: 361, June, 1946.

3. The cycles per second is the critical factor in Molomut's formula.[3]
4. The pre-exercise pulse rates did not decrease significantly although the mean values indicated a slight tendency to do so.
5. The post-exercise pulse rates did decrease significantly during the conditioning program and increased with the termination of conditioning.
6. The post-exercise pulse rate is a good index of circulatory fitness.
7. The pre-exercise pulse rate does not indicate the condition of the athlete.
8. The pre-exercise stroke volume did not increase significantly and the mean values did not indicate a tendency to do so.
9. The post-exercise stroke volume did not increase significantly although the mean values indicated a trend to increase with a decrease in pulse rate.

RECOMMENDATIONS Since this investigation was exploratory in nature, experimentation in this field should be continued. An investigation similar to this combined with one dealing with oxygen utilization appears to be a profitable area for further research for this reason. If the stroke volume doesn't increase with a decrease in pulse rate then the oxygen utilization to the working tissues may increase. If

[3] *Ibid.*

this can be demonstrated by a study similar to this, then the whole concept of an increase in stroke volume resulting from a decrease in pulse rate may be altered. It is also recommended that the effect of body fat on the Sanborn Ballistocardiogram be investigated before research in this area is continued.

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APPENDIXES

APPENDIX A

1. Raw Scores.

MICHIGAN STATE COLLEGE
DEPARTMENT OF PHYSICAL EDUCATION, HEALTH AND RECREATION FOR MEN
GRADUATE STUDIES AND RESEARCH

TABULATION SHEET

TOPIC Raw Scores

DATE OF TABULATION May 13 1955

TABULATED BY Gordon C. Stauffer

#	Pre Exercise	Area of I	Area of J	Area of I+J	Height of I	Height of J	Height of I+J	Pulse Rate Per Min.	St. (I+J) X ½	Post Exercise	Area of I	Area of J	Area of I+J	Height of I	Height of J	Height of I+J	Pulse Rate 1 min. Aft. Ex.	Pulse Rate 5 min. Aft. Ex.	St. (I+J) X ½	Date of Test	Test No.
1	Ferrari Al	.04 sq in	.290 sq in	.330 sq in	3.466 mm	10.100 mm	13.566 mm	58.0.	3.78		.092 sq in	.296 sq in	.383 sq in	3.670 mm	8.83 mm	12.500 mm	94	86	2.69	10/2/54	I
2	Harris Jim	.023	.160	.183	1.200	5.000	6.200	58	2.56		.066	.140	.206	3.400	5.266	8.666	124	98	2.04	″	
3	Hillemeyer Wm	.10	.230	.330	4.500	7.500	12.000	70	3.08		.073	.217	.290	3.666	7.366	11.032	102	82	2.63	″	
4	Corbitt Rex	.09	.133	.223	3.001	3.500	6.501	63	2.48		.103	.170	.273	6.000	5.833	11.833	120	84	2.67	″	
5	Deveny Robert	.083	.123	.206	2.333	5.067	8.400	72	2.52		.483	.570	1.053	18.000	17.933	35.933	120	108	3.83	″	
6	Olson Duane	.063	.217	.308	3.166	8.600	11.766	76	2.87		.05	.100	.150	2.833	5.433	8.266	110	90	2.12	″	
7	Peterson Duane	.023	.117	.140	1.100	4.067	5.167	47	2.73		.027	.053	.08	2.033	2.767	4.800	98	76	1.83	″	
8	Armstrong Rob.	.037	.180	.217	1.100	5.033	6.133	64	2.47		.047	.166	.213	2.433	5.700	8.133	115	94	1.99	″	
9	Rasper David	.02	.123	.170	1.100	4.267	5.367	65	2.18		.023	.100	.123	1.533	3.933	5.466	89	86	1.78	″	
10	Godfrey Walter	.097	.213	.310	4.600	9.333	13.933	70	3.33		.02	.257	.277	1.87	9.133	10.200	112	92	2.37	″	
11	ΣX						85.64	643	28.00	ΣX						117.32	1084		23.95	″	
12	ΣX^2						912.8314	4987	80.4612	ΣX^2						2085.8250	118810		60.7011	″	
13	N						10	10	10	N						10	10		10	″	
14	M_x						8.96	64.3	2.80	M_x						11.74	1084		2.39	″	
15	$(\Sigma X)^2$						8035.3296	413449	784.000	$(\Sigma X)^2$						13763.982	1175056		573.6025	″	
16																	130.44				
17																					
18	Ferrari Al	.047 sq in	.274 sq in	.321 sq in	2.200 mm	9.700 mm	11.900 mm	37	5.34		.103 sq in	.427 sq in	.530 sq in	7.470 mm	16.06 mm	23.530 mm	86	68	4.41	11/16/54	II
19	Harris Jim	.063	.213	.276	1.100	4.560	5.660	49	2.81		.046	.290	.336	1.430	7.700	9.130	108	82	2.39	″	
20	Hillemeyer Wm	.033	.150	.183	1.766	4.960	6.726	69	2.33		.08	.260	.340	4.230	7.730	11.960	108	84	2.69	″	
21	Corbitt Rex	.103	.130	.233	4.567	5.633	10.200	60	3.19		.073	.087	.160	1.633	2.633	4.266	96	84	1.60	″	
22	Deveny Rob.	.05	.126	.176	2.167	5.167	7.334	71	2.38		.043	.620	.663	3.200	18.867	22.067	116	104	3.11	″	
23	Olson Duane	.100	.156	.256	3.867	7.466	11.333	63	3.25		.08	.303	.383	3.067	11.166	14.233	104	84	2.93	″	
24	Peterson Duane	.043	.063	.106	1.567	3.266	4.833	39	2.58		.033	.163	.196	2.100	4.100	6.200	86	70	2.22	″	
25	Armstrong Rob.	.017	.110	.127	1.133	4.367	5.500	59	2.37		.013	.177	.190	1.300	6.067	7.367	96	86	2.07	″	
26	Rasper David	[illegible]	.116	.143	2.200	4.200	6.400	69	2.27		.023	.087	.110	1.700	3.233	4.933	92	90	1.64	″	
27	Godfrey Walter	.057	.166	.223	3.000	4.867	7.867	65	2.67		.06	.113	.173	2.800	4.500	7.300	98	80	2.17	″	
28	ΣX						77.75	581	29.59	ΣX						110.99	990		25.23	″	
29	ΣX^2						661.5521	35129	950227	ΣX^2						1658.2219	98892		69.8257	″	
30	N						10	10	10	N						10	10		2.52	″	
31	M_x						7.78	58.1	2.96	M_x						11.09	99.0		636.5529	″	
32	$(\Sigma X)^2$						6045.0625	337.561	875.5681	$(\Sigma X)^2$						12319.7801	980100				
33																					
34																					
35																					

0-412

MICHIGAN STATE COLLEGE
DEPARTMENT OF PHYSICAL EDUCATION, HEALTH AND RECREATION FOR MEN

GRADUATE STUDIES AND RESEARCH

TOPIC RAW SCORES

TABULATION SHEET

DATE OF TABULATION MAY 13 1955

TABULATED BY GORDON C. STAUFFER

PRE EXERCISE	AREA OF I	AREA OF J	AREA OF I+J	HEIGHT OF I	HEIGHT OF J	HEIGHT OF I+J	PULSE RATE PER MIN.	[illegible]	POST EXERCISE	AREA OF I	AREA OF J	AREA OF I+J	HEIGHT OF I	HEIGHT OF J	HEIGHT OF I+J	PULSE RATE 1MIN AFT.EX.	PULSE RATE 5MIN AFT.EX.	[illegible]	DATE OF TEST	TEST No.	
1 FERARRI AL	.140 sq in	.126 sq in	.263 sq in	3300 mm	4.967 mm	8267 mm	53	3.16		.173 sq in	.223 sq in	.396 sq in	4.300 mm	7.533 mm	11833 mm	65	62	3.36	1/29/55	III	1
2 HARRIS JIM	.08	.136	.216	2.900	4.660	7.560	55	2.94		.02	.143	.163	.930	5.630	6.460	88	68	2.31	"		2
3 HILLEMEYER Wm	.110	.233	.343	5733	4367	10.100	54	3.49		.087	.343	.430	2.630	10.370	13.000	98	88	2.71	"		3
4 CORBITT REX	.130	.153	.283	3.933	5000	8.933	59	3.03		.08	.106	.186	3.233	3.933	7.166	85	78	2.20	"		4
5 DEVENY ROBERT	.05	.103	.153	2.600	4.933	7.533	65	2.58		.05	.096	.146	2.800	4367	7.167	94	88	2.01	"		5
6 OLSON DUANE	.063	.203	.266	3.233	6.433	9.666	59	3.15		.153	.297	.450	7.400	11.733	19.133	80	78	3.59	"		6
7 PETERSON DUANE	.036	.077	.113	1.533	3.000	4.533	51	2.40		.017	.093	.110	1.933	4.133	6.066	68	56	2.59	"		7
8 ARMSTRONG ROB.	.053	.100	.153	2.433	4.100	6.533	65	2.40		.067	.220	.287	3.367	6.933	10.300	74	74	2.74	"		8
9 RASPER DAVID	.037	.136	.173	1.767	3.066	4.833	71	1.94		.013	.057	.07	1.500	2.833	4.333	100	92	1.57	"		9
10 GODFREY WALTER	.04	.167	.207	2.833	6.600	9.433	61	3.03		.07	.167	.237	2.933	5.700	8.633	90	78	2.41	"		10
11 ΣX						77.38	593	28.12	ΣX						94.09	842		25.43	"		11
12 ΣX^2						632.9269	35525	81.0336	ΣX^2						1055.6159	72234		68.0419	"		12
13 N						10	10	10	N						10	10		10	"		13
14 M_x						7.74	59.3	2.81	M_x						9.41	84.2		2.54	"		14
15 $(\Sigma X)^2$						5987.6644	351649	790.7344	$(\Sigma X)^2$						8852.9281	708964		646.6849	"		15
16																					16
17																					17
18 FERARRI AL	.06 sq in	.133 sq in	.193 sq in	3367 mm	6.466 mm	9.833 mm	71	2.76		.123 sq in	.223 sq in	.346 sq in	5.633 mm	9.467 mm	15.100 mm	100	86	2.97	4/19/55	IV	18
19 HARRIS JIM	.02	.05	.07	1.100	2.233	3.333	61	1.80		.02	.116	.136	1.367	4.133	5.500	110	86	1.49	"		19
20 HILLEMEYER Wm	.06	.127	.187	2.667	5.566	8.233	66	2.67		.057	.303	.360	3.000	10.567	13.567	104	96	2.59	"		20
21 CORBITT REX	.140	.173	.313	6.033	7.100	13.133	71	3.19		.047	.280	.327	3.567	11.166	14.733	118	106	2.50	"		21
22 DEVENY ROBERT	.07	.260	.330	4.400	9.000	13.400	83	2.89		.06	.413	.473	11.767	16.800	28.567	102	108	3.42	"		22
23 OLSON DUANE	.067	.380	.447	3.833	11.733	15.566	65	3.71		.057	.266	.323	3.133	9.733	12.866	116	84	2.78	"		23
24 PETERSON DUANE	.063	.093	.156	2.333	3.000	5.333	65	2.53		.063	.170	.233	2.300	5.833	8.133	120	102	1.68	"		24
25 ARMSTRONG ROB.	.03	.130	.160	1.767	3.533	5.300	53	2.17		.013	.137	.150	1.333	3.700	5.033	104	88	1.91	"		25
26 RASPER DAVID	.05	.140	.190	2.667	4.500	7.167	72	2.36		.023	.263	.286	1.900	9.167	11.067	110	96	2.34	"		26
27 GODFREY WALTER	.043	.143	.186	2.533	4.700	7.233	48	3.18		.063	.217	.280	2.633	7.533	10.166	94	82	2.52	"		27
28 ΣX						91.30	636	28.60	ΣX						127.61	1075		24.70	"		28
29 ΣX^2						992.3964	41458	86.2630	ΣX^2						2053.5421	116261		64.9404	"		29
30 N						10	10	10	N						10	10		10	"		30
31 M_x						9.13	63.6	2.86	M_x						12.76	107.5		2.47	"		31
32 $(\Sigma X)^2$						8335.6900	404496	817.9600	$(\Sigma X)^2$						16284.3121	1155625		610.090	"		32
33																					33
34																					34
35																					35

APPENDIX B

1. Pre-exercise Ballistocardiogram.
2. Post-exercise Ballistocardiogram.
3. Three Week Conditioning Program.

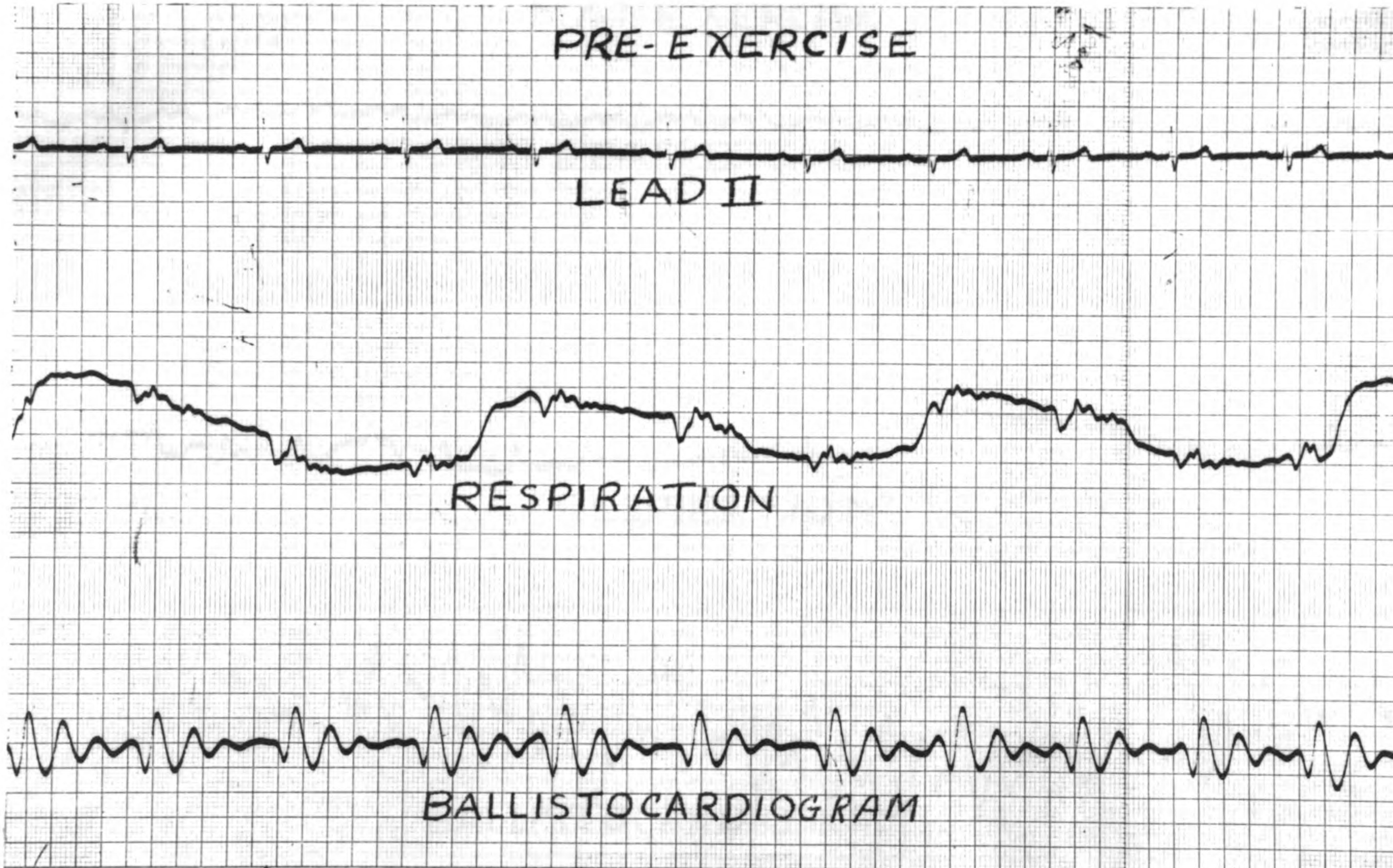

Figure 6. **A Pre-Exercise Ballistocardiogram**

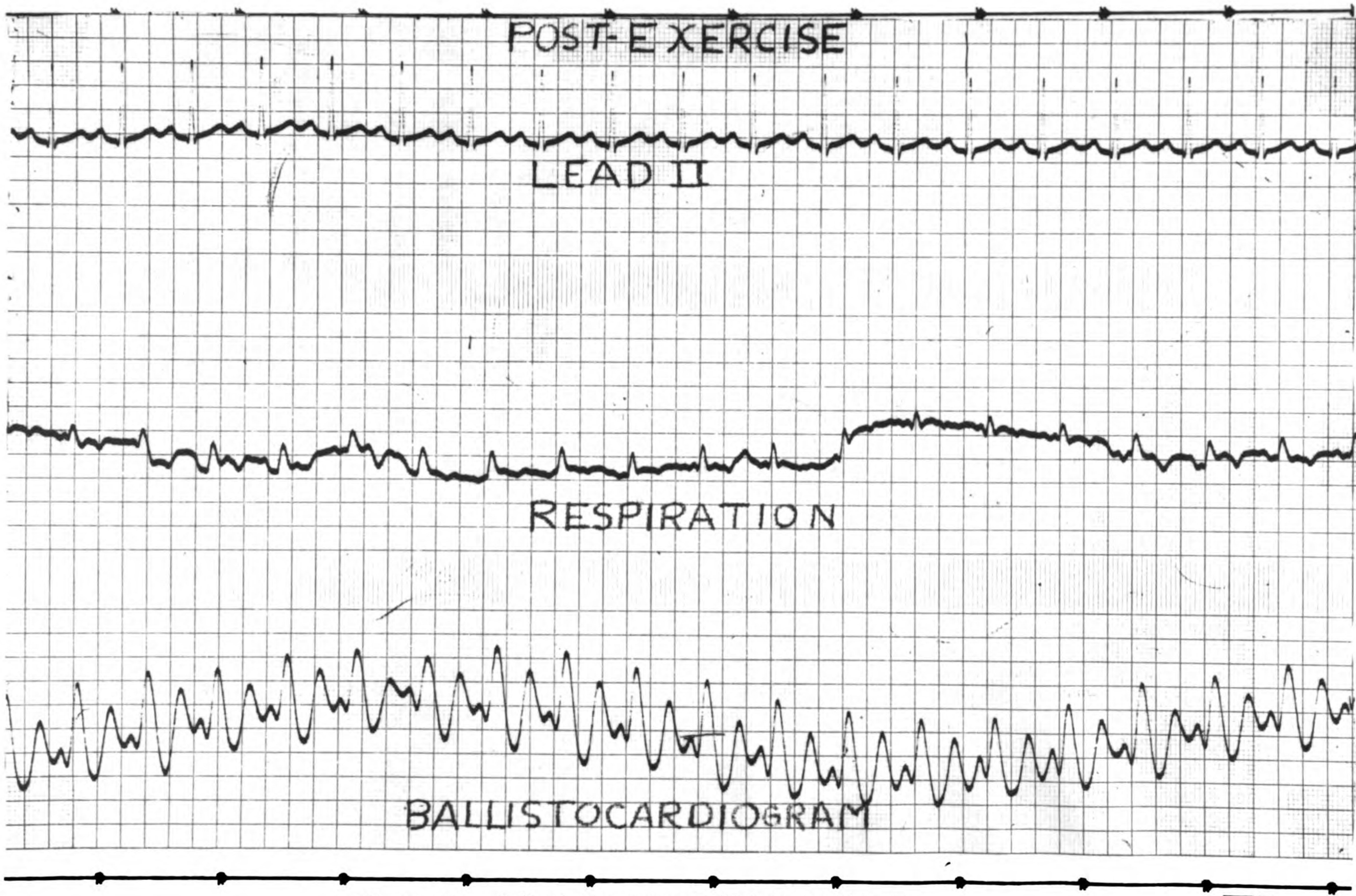

Figure 7. A Post-Exercise Ballistocardiogram

THREE WEEKS CONDITIONING PROGRAM.

LESSON I.

I. Four Laps - (Individually)

(A) Emphasize

(1) Proper Breathing - timing

(2) Run on Balls of feet

(3) Easy relaxed arm carriage

II. Deep Breathing Exercise

(A) Inhale while raising arms and standing on toes.

(B) Exhale while lowering arms and coming down off toes.

III. Sprints - Four in a Group - One lap.

(A) Emphasize

(1) Quick Start

(2) Low Charge

(3) Ten full strides before relaxing.

IV. Ankle Exercise

(A) Turn ankle out as far as possible on count of one

(B) Turn ankles in as far as possible on count of two.

V. Change of Pace - One Lap

(A) Emphasize

(1) Straight line running

(2) Slow - Fast - Stops All types of pace changes.

VI. Change of Direction - One Lap

(A) Emphasize

(1) Slow approach to left side of track

(2) Make good head, shoulder and eye fake

(3) Place weight on left foot, lift the foot and drive off the left foot.

(4) Repeat on the right side.

LESSON TWO.

A. Lapps - Review

B. Quarter Drill - Review Sprints - One Lap

C. Deep Breathing Exercise

D. Change of Pace - Review

E. Ankle Exercise

F. Change of Direction - Review

LESSON THREE

A. Laps

B. Deep Breathing Exercise

C. Sprints

D. Ankle Exercise

E. Change Pace

F. Change of Direction

G. Leapfrog - One lap around inside of track

LESSON FOUR

A. Laps in a group

1. Small men in front

2. No Stopping

B. Deep Breathing Exercise

C. Sprints

D. Ankle Exercise

E. Change Pace

F. Change of Direction

G. Leapfrog

LESSON FIVE

A. Laps in a group

B. Deep Breathing Exercise

C. Change of Pace

D. Ankle Exercise

E. Change of Direction

F. Short Sprints

G. Volleyball

LESSON SIX

A. Laps in a group

B. Race 50 yards (Centers separate)

C. Change Pace

D. Change Direction

E. Volleyball

LESSON SEVEN

A. Laps in a group

B. Races

C. Change Pace

D. Change Direction

E. Volleyball

LESSON EIGHT

A. Laps in a group

1. Small men in front

2. No stopping

B. Sprints

C. Change Pace

D. Change Direction

E. Leapfrog

LESSON NINE

A. Laps in a group

B. Change of Pace

C. Change of Direction

D. Short Sprints

E. Volleyball

LESSON TEN

A. Laps in a group

B. Races - 50 yards (Centers separate)

C. Change Pace

D. Change Direction

E. Volleyball

LESSON ELEVEN

A. Laps in a group

B. Races

C. Change Pace

D. Change Direction

E. Volleyball.

Date Due

Dec 17 '57			
~~1959~~			
~~JUL~~			
~~11 1971~~			
		ONLY	