THE VALIDITY OF THE PULSE RATE RECOVERY IN PREDICTING EFFICIENT CARDIOVASCULAR PERFORMANCE

A Research Paper
Presented to
Professor Dave Aaron
Austin Peay State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in Education

by
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To the Graduate Council:

I am submitting herewith a Research Paper written by Gerald Joseph McCall entitled "The Validity of The Pulse Rate Recovery in Predicting Efficient Cardiovascular Performance." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Administration and Supervision in Education.

Major Professor

Accepted for the Council:

Dean of the Graduate School

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INTRODUCTION

In our automated, push button society, people are experiencing vigorous activity deficiencies; corpulent bodies and heart diseases are our number one killers. Our rapidly changing society has more deliterious effects; however, the above mentioned have a direct bearing on this study.

The author has had personal interest for some time in developing health and physical fitness. Personal interest in health and physical fitness was responsible for the course of study chosen by the writer as an undergraduate and is the probable reason the writer thought of such a problem for research.

In recent times, (the last decade or so), much has been talked about, and written, about ways to become physically fit. The terms "physical fitness," "being in condition," and the like, have been used rather loosely, and exhorted extensively. Despite the exhortations by devotees, many people are disillusioned as to what improved physical fitness is, and how one may go about attaining it. For evidence of this, one has only to notice the amount of money people spend for joining health studios, weight lifting apparatus, isometric paraphernalia and exergenies. The use of these devices to improve the fitness of an individual do very little to improve the most important aspect of the health and physical fitness improvement process - the cardiovascular effectiveness. Prior to recently (before the era of joggers), people erroneously associated muscular bulk, and feats of strength with the idea of health and fitness. Research has proven that to improve health, and the feeling of "being healthy", one must compose an exercise program consisting of the entire time, or the larger percent of time, in activities which vigorously activate the heart and circulatory system.

Many times, strength and muscle building activities give false feeling of health. This feeling is believed by psychologists to be a psychological phenomenon. From a purely psychological standpoint, strength and muscle building exercises do nothing to improve the efficiency of the cardiovascular system. Improving one's physical fitness through cardiovascular activities is essentially due to the improved ability of the heart and blood vessels to supply greater oxygen and glucose to more cells of the body. Increased vascularity in the body is concurrent with the feeling of improved health. By virtue of the previous facts, it can be assumed that the more efficient the cardiovascular performance becomes the more activity that can be done with a surfeit of energy remaining.

This study will help to increase the knowledge of cardiovascular performance and improve methods of accurately assessing cardiovascular efficiency.

BACKGROUND OF THE SUBJECTS STUDIED

The boys and girls used in this research are dependents of military personnel. The most salient characteristic of people in the military, due to the amount of travel, is that they are less given to being parochial and they tend to be culturally pluralistic.

The fathers' of the children that were tested are all non-commissioned officers. The ranks of their fathers vary according to the different stratifications of military positions in the Army. Generally speaking, from empirical judgement, and home visitations, the author would assess the socio-economic level to be middle-middle to middle-lower. The construction of the houses are uniform, the author would consider them as lower-middle class construction. The differences lie in the interior of the houses. Monthly income is a factor for consideration concerning material goods; although the primary difference is in the individual priorities set by the parents.

Medical facilities and care is adequate and readily available for the children. Extensive screening programs are carried on in each of the schools.

An adequate noon day meal is provided every school day for the children. These meals are sufficient in preparation, balance, proportions and quality.

Basic health instruction is given to pupils, along with a planned vigorous physical education program offered to each child, every school day.

HYPOTHESIS

1. The pulse rate recovery is a valid measure in predicting the efficiency of cardiovascular performance.
    a. The subjects recorded in the upper fiftieth percentile in the pulse rate recovery will have lower heart rates, before and after, in the Harvard Step Test, than those subjects in the lower fiftieth percentile.
    b. Those subjects in the upper fiftieth percentile, in the pulse rate recovery, will have lower times on the cardiovascular test, than those subjects in the lower fiftieth percentile.
2. There is a positive relationship of the pulse rate recovery and cardiovascular performance.
    a. Subjects who have faster recoveries after the Harvard Step Test will also have lower times in the 600 yard run.

ASSUMPTIONS

As a result of scientific research, it may be assumed that lower pulse rates, before and after vigorous activity, is indicative of greater efficiencies in cardiovascular performances. It is also assumed that endurance running is the most demanding upon the cardiovascular system; therefore, a more efficient cardiovascular system would perform a 600 yard run more adequately and with greater ease than would a less efficient cardiovascular system. The pulse rate recovery is a valid means of assessing the efficiency of the cardiovascular performance. It is assumed that an efficiently working cardiovascular system has a slower resting pulse rate, a slower rate during physical work and a quicker return to resting rate after work has ceased.

LIMITATIONS

In this research the problem of discovering how valid the pulse rate recovery is in predicting efficient cardiovascular performance deals only with the physiological aspect of the heart and all its auxillary vessels and organs that assist in the efficient circulation of blood throughout the working body. This study does not measure or control the neurological or psychological aspects which might influence changes in the amount of specific work one does in the Harvard Step Test. Neurological influences, which might influence the amount of specific work one might do in the Harvard Step Test, would be coordination, timing, balance and rhythm which would have a bearing on the difficulty of the work loads thereby causing an added burden on the cardiovascular system which would increase the pulse rate. The psychological influences which might influence the amount of specific work one might do in the Harvard Step Test would be the mental attitude of the subject toward the testing.

This research is limited to the mechanical or structural advantage in different body types which may have an influence on an individual's performance in both the Harvard Step Test and the testing for the efficiency of the cardiovascular performance. The mechanical aspects to consider would be the length of the thigh, leg and foot. The structural aspects to consider would be directly related to body composition, such as the length, thickness, flexibility of the muscle tissue in the hips, thighs, legs and feet and adipose tissue around these areas and over the entire body.

Other mental influences may cause variables in the testing, which are not controlled and, therefore, not included in this experiment. They are intrinsic qualities which influence physical performances, such as fortitude, determination and motivation.

This problem of testing the validity of the pulse rate recovery in predicting efficient cardiovascular performance is limited only to the physiological aspects that determine its effectiveness to supply the cells with ample oxygen and glucose for adequate functioning during vigorous physical activity. This research does not measure the psychological, neurological and mechanical or structural influences which might effect differences in performances on the pulse rate recovery and the 600 yard run.

This study is limited to ten year old boys and girls at Lincoln Elementary School. The socio-economic levels of the subjects tested are middle middle-class and lower.

SIGNIFICANCE OF THE STUDY

If the pulse rate recovery proves to be a valid means of predicting efficient cardiovascular performance during vigorous work, then it is significant for the following reasons:

a. Testing of cardiovascular performance can be done indoors, regardless of the weather, whereas previously cardiovascular testing of running was done outside.

b. The facilities for cardiovascular testing would be less expensive, for example, no large space or track would be needed for running.

c. The facilities for cardiovascular testing would be more convenient, for example, a 14" bench and a watch is all that is needed.

d. The facilities for cardiovascular testing will require less space.

e. Cardiovascular testing can be conducted without physiological discomfort which may cause inaccurate evaluation in some individuals, for example, a person who lacks the discipline to continue during fatigue.

f. Cardiovascular testing can be conducted without the chance of possible deleterious effects on the extremely unfit individuals, for example, muscle cramps, heat exhaustion, muscular exhaustion.

g. An athlete may use improvement in pulse rate recovery in predicting physiological improvement during his particular athletic endeavor, for example, a runner who experiences a reduction in the pulse rate can assume with assurance that he will better his performance in his running event.

If the pulse rate recovery proves to be an invalid means of predicting efficient cardiovascular performance during vigorous work, then it is significant for the following reasons:

a. That the pulse rate recovery is not a valid means of predicting efficient cardiovascular performance during vigorous work.

b. Physical fitness tests which include long endurance running type of work to evaluate cardiovascular performance are not measuring what they purport to measure.

c. Pulse rate recovery is a more valid means of measuring efficient cardiovascular performance.

UNCONTROLLED VARIABLES

1. Differences in the time of day when subjects were tested on the pulse rate recovery.
2. Differences in the health habits of the subjects, such as sleep, diet, mental health and the physical activity engaged in outside of their daily physical education class.
3. Differences in neurological performances, such as muscular coordination, timing, balance and rhythm, which may cause differences in the performance of the Harvard Step Test. Differences in the difficulty of the Harvard Step Test will cause variences in the pulse rate.
4. Differences in the psychological aspect, which is responsible for the subjects' attitudes toward the test, may cause differences in the results of the Harvard Step Test and the 600 yard run.
5. Differences in the mechanical aspects such as the length of the thighs, the length of the legs and the length of the feet may cause differences in the degree of difficulty of the Harvard Step Test and the 600 yard run.
6. Differences in the structural aspect, such as the length, density and elasticity of the muscles of

the hips, thighs and legs.

7. Differences in subcutaneous adipose tissue which hamper muscular contraction and places a surfeit amount of strain on the heart.

8. Differences in intrinsic personal qualities, such as courage, determination and desire may influence differences in the performances in the Harvard Step Test, and the 600 yard run.

DATA ANALYSIS

This research data was analyzed by establishing a median of the pulse rate recovery scores. Since all of the pulse rate recovery scores were recorded in order of recovery, for example, the best recovery first, the next best recovery second, etc., all scores above the median represented the upper fiftieth percentile, and below the median represented the lower fiftieth percentile of the pulse rate recovery.

The means and ranges of the ages, heights, weights, temperatures during testing and time of day during testing of the upper fiftieth percentile, and lower fiftieth percentile were recorded for subsidiary information bearing on the problem.

All mean scores were calculated by using the following formula:

$$\text{Mean } (M) = \frac{\Sigma M}{N}$$

REVIEW OF RELATED LITERATURE

The easiest way one can determine the heart rate per minute is through the pulse readings. This can be taken in the wrist, (radial), upper arm (brachial), top of the chest (subclavian), neck (jugular), temple, or the junction between the thigh and trunk (femoral).

Many individuals upon taking the pulse reading become very concerned as to whether or not their pulse is normal. They fail to realize that the term normal pulse is not a set figure. According to the American Medical Association, normal range is from 50 to 100 beats per minute. Rates outside this range should be carefully re-examined before they can be accepted as normal and not exceptional.[1]

According to Karpovich and researchers, the pulse rates in women are from 7 to 8 beats higher than for men.[2]

PULSE RATE AND AGE

Again we see that the word normal becomes increasingly arbitrary when we consider the age of the individual. According to information compiled by Morehouse and Miller, the heart rate at birth is the highest rate that will ever be reached.[3]

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[1]Peter V. Karpovich, Physiology of Muscular Activity, (Philadelphia & London: W. B. Saunders Co.,) 1953, p. 175.

[2]<u>Ibid</u>., p. 177

[3]Lawrence E. Morehouse and Augustus Miller, Ph.D, M.D. Physiology of Exercise, (St Louis: The C.V. Mosby Co.,) 1953, p. 98.

Karpovich says this may be as high as 130 at rest.[4] All authorities agree that a slowing trend begins to take place and continues until maturity at which time it maintains this low rate. In old age there is a gradual increase in the heart rate.

Pertinent to my particular research is the research done in pulse per minute and age. Tables were established by Paten and Tabellen in 1888 recording the mean pulse rate for nine to ten year olds showing 91.8, whereas the mean for ten to eleven year olds was 87.9.[5] According to the mean score of the resting pulse rate of all the children that were tested in this research was 84.8 for ten year old boys and girls. This is somewhat lower, however, and is understandable since his study was conducted in 1888 and since that time children have become healthier with stronger hearts.

THE POSITION OF THE BODY AND PULSE

Conclusive evidence has shown that the pulse rate is lowest in a supine position. There is somewhat of an increase in rate from the lying to the sitting position. The greatest increase in pulse occurs when one is standing. According to Karpovich, men who are physically fit show a smaller difference

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[4]Karpovich, op. cit., p. 111.

[5]Ibid., p. 176.

between lying and standing pulse rates than do less fit men.[6]

Due to the alleviation of the gravitational pull while lying the heart rate is lowered. When a person rises from a recumbent position the heart must meet the demand of pumping blood upward to the head. Consequently, the heart rate accelerates. Many eminent authorities in physiology of the heart say that the degree in which the heart rate differs from the lying to the upright position can be used to measure the efficiency of a person's heart. They base these on research and the theory that the more efficient, stronger heart will not have to increase in rate to the degree that a weaker heart, because of the thicker, more powerful ventricular wall of the heart. This transition that the heart must adjust to from a relaxed position to a more strenuous position is the sudden dizziness one experiences when suddenly rising from a chair.[7]

The heart rate will increase at times when the body is digesting food. Karpovich says that digestion of food invariably accelerates the heart rate for two or three hours.[8] It would seem logical that the individual with the least efficient cardiovascular system would feel more soporiferous after a meal than one with a stronger heart. This is based on the

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[6] Ibid., p. 170 [7] Ibid., p. 177.

[8] Ibid., p. 177.

assumption that a stronger heart would be better able to meet the demands of digestion without decreasing the supply to the brain, which with the less efficient heart would cause drowsiness. One may conjecture, that with all other things being equal, that the individual with the more efficient cardiovascular system would be least likely to regurgitate as a result of maximal exercise after a heavy meal.

ENVIRONMENTAL CONDITIONS AND PULSE RATES

According to Morehouse and Miller, excessive heat and humidity will cause an increase in heart rate. This is due to the periferal demands of the skin in displacement of heat. Relative to altitude Morehouse and Miller state:

> A high environmental temperature may greatly increase the frequency of heartbeat. Besides the increased work of the heart to provide a sufficient amount of blood for the active muscles, an additional strain will be imposed because of an augmented peripheral (skin) circulation for the purposes of heart dissipations. This double work may sometimes be fatal.[9]

EMOTIONS AND HEART RATE

Mental states such as anger, fear, and apprehension will increase the heart rate. This increase in heart rate is controlled in the cortex of the brain. It is also influenced

[9]Morehouse and Miller, *op. cit.*, p. 200.

chemically by the cortex of the adrenalin glands. This chemical emission of adrenalin is triggered by the brain in emergencies or sudden states of anxiety or grief. It seems that fainting is caused by an emotional trauma which seems to be diametrically opposed to what has been previously stated in regards to the heart rate increasing during emotional stress. The heart rate is still increased in a state of shock or fear; however, concomitant with the increase in rate is a phenomenon of dilatation of the blood vessels. This dilatation causes a lowering of blood pressure which results in insufficient blood supply to the brain which causes fainting.

Morehouse and Miller have made this assertion:

> Emotion increases the heart rate at rest and in light exercise, but has little influence on the maximal heart rate. The same is true to a lesser degree perhaps, of an elevation in environmental temperature and humidity.[10]

Karpovich has discussed emotional influences in ascertaining resting pulse rate.

> Because emotions accelerate the pulse rate, it is sometimes very difficult and even impossible to obtain a normal resting pulse rate. The subject may appear relaxed while his pulse rate tells a different story. Variations in the emotional state affect the pulse rate much more than do postural changes.[11]

Karpovich says that finding resting pulse rates in children is even more difficult. With children a seemingly

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[10] *Ibid.*, p. 177.

[11] Peter V. Karpovich, Physiology of Muscular Activity, (Philadelphia and London: W. B. Saunders Co.,) 1953, p. 195.

simple thing like waiting for a test may greatly affect the rate of the pulse. Obtaining a reliable resting pulse in children is much more difficult than obtaining a reliable count in adults. Besides being more excitable, children are usually restless while waiting for a test.

HEART RATE AND WORK LOAD

The heart rate responds relative to the intensity and duration of the work. Heart rate reaches maximal during extremely intense work such as sprinting. If submaximal work is continued long enough there is a secondary rise in heart rate. Karpovich states that:

> The effect of training on the absolute rate may be well observed during physical reconditioning of convalescents. With the regaining of physical fitness, their pulse rates in response to a standard exercise gradually begin to decrease. Absence of this decrease may be interpreted as a lack of improvement or as an indication that the exercise is too strenuous (maximal).

During exercise Karpovich concludes that at the beginning of muscular exercise, the pulse increases rapidly. "The greatest rise takes place within one minute. Sometimes half of this increase occurs within fifteen seconds."[12]

It has been noted that there is great difficulty in arriving at a true resting pulse due to emotional and environmental conditions that bring about a rise in rate.

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[12] _Ibid._, p. 195

Tuttle and Dickerson have stated that even in exercise if
there is not adequate environmental conditions, inaccurate pulse readings may occur.

> The reliability of the pulse rate for two minutes after exercise is directly related to the strenuousness of the exercise. Thus, if the response of the heart to exercise is to be measured, the exercise must be strenuous enough to overshadow environmental stimuli which affects the pulse rate after light exercise.[13]

HEART RATE AND FITNESS

Most all authorities today agree that with an increase in physical fitness, there is a tendency for the pulse rate to become lower. Morehouse and Miller have expressed this in the following way:

> The relative participation of the heart in the increased cardiac output of exercise depends on the contractile power of the heart. In response to a moderate increase in venous return, a moderate amount of dilation enables a powerful ventricle to develop sufficient contractile force to empty itself completely and little or no increase in heart rate may occur. In a less powerful (thinner walled) ventricle, even a maximal degree of dilatation may not result in adequate contractile force so that emptying is incomplete. The resulting accumulation of blood in the right heart and the rise in venous pressure, through the agency of the Brainbridge reflex, bring about an acceleration of the heart. In this lessened contractile power of the heart; the less powerful the heart, the greater will be the acceleration of the heart rate necessary to maintain a given cardiac output.[14]

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[13]W. W. Tuttle; R. E. Dickerson, "A Simplification of Pulse Ratio Technique For Rating Physical Efficiency and Present Conditions." Research Quarterly, March, 1942, p. 3.

[14]Lawrence E. Morehouse., Ph. D. and Augustus Miller, Ph. D., M.D., Physiology of Exercise, (St. Louis: The C. V. Mosby Company, 1953), p. 98.

THE RESTING HEART RATE

When a researcher attempts to do any work concerning the effects of exercise relative to the heart rate, the obtaining of a valid resting rate is most problematic. Morehouse and Miller say that the heart rate begins to increase as soon as work begins and possibly before work. They have termed this preliminary effect of increased heart rate as "getting ready" for physical work. In addition to this, Morehouse and Miller included the reason for this is as follows: "The preliminary increase in heart rate is believed to be due to the influence of the cerebral cortex on the heart rate controlling center in the medulla."[15]

PULSE RATE RECOVERY FROM STEP UP TEST

In this research the researcher uses the step up test as a valid and reliable means to insure equal work for all and as a means to record the pulse rate recovery. All exercise physiologists respect the value of the step test in studying the pulse rate recovery. Tuttle and Dickerson say "The simplicity and practicability of the Harvard Step Test justifies exhaustive investigations of its validity."[16]

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[15]Ibid., p. 91.

[16]Tuttle and Dickerson, op. cit., p. 73.

The time the pulse reading is taken is a major consideration among researchers who are charting the pulse rate recovery. Karpovich recommends that the pulse rate taken from sixty to ninety seconds after exercise is a sufficiently long period of time for the return of the pulse to normal.[17]

RECOVERY OF PULSE RATE FROM STEP UP TEST AND ENDURANCE RUNNING

By virtue of the fact that the more efficient cardiovascular system will recover more effectively from the step up test, hence the more efficient cardiovascular system will be able to perform better during endurance running, for example, which is also a cardiovascular activity.

After physical stress such as the step test and/or long distance running, the heart with weak ventricular wall, and consequently a shorter stroke volume will require more time to recover to resting pulse rate. According to Cotton and Dill, the time required for the heart rate to return to normal depends on the work load of the exercise period and the physical condition of the subject. "In persons in good physical condition, the return occurs more rapidly than in fatigued and poorly trained subjects."[18]

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[17] Karpovich, op. cit., p. 183

[18] Lawrence E. Morehouse, Ph. D. & Augustus T. Miller, Ph. D., M. D., Physiology of Exercise, (St. Louis: The C. V. Mosby Company, 1953), p. 92.

Evidence that a true resting pulse is invalid is when the pulse rate falls below the pre-exercise level. Karpovich says that this happens even in those subjects whose resting pulse rates have been obtained under carefully controlled conditions. A drop below normal may, obviously, be expected in subjects whose pre-exercise pulse rates have been elevated on account of various factors, some of which may be psychological.[19]

The value of a low resting pulse rate is clarified by Karpovich as he explains that maximal heart rate is the same for each individual. The higher the resting pulse, the smaller the difference between it and the maximal pulse. Therefore, with an increase in the resting pulse there is a resultant decrease in the rising of the pulse through exercise. Karpovich states that "The chief complication in studying the relationship between the resting and the post exercise pulse rates is the difficulty of obtaining a true resting pulse."[20]

Morehouse and Tuttle report in their study of the Post Exercise Heart Rate that the post exercise increase in pulse rate is directly related to the intensity of the exercise.[21]

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[19] Peter V. Karpovich, M.D., Physiology of Muscular Activity, (Philadelphia & London: W.B. Saunders Co., 1953), p. 187.

[20] Ibid., p. 189.

[21] L. E. Morehouse, and W. W. Tuttle, "A Study of the Post-Exercise Heart Rate." Research Quarterly, 1:3, 1938.

They conclude that where exercises are used to differentiate individuals on the basis of the post exercise pulse rate and the recovery time, they must be strenuous in order to give reliable results.

The type of exercise influences the amount of increase in the heart rate. McCurdy found that the greatest increase resulted from speed activities (sprinting) and that the lowest increase from exercises of strength (weight throwing). In exercises of endurance (distance running) the heart rate was between those of speed and strength; however it remained elevated for a longer time following the cessation of exercise. He also added that exercises of strength do not invariably increase the heart rate. This was tested by recording rates of weight lifter while performing the three Olympic Lifts. It was found that in the snatch, the heart rate increases more than the clean and jerk which is second, and the press which was shown to be the least effective in increasing the pulse rate. Out of the three lifts, the snatch is the fastest lift and the press the slowest. This study parallels the McCurdy theory of the increase of pulse rate relative to the type of exercise.[22]

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[22]Morehouse and Miller, op. cit., p. 91.

McCurdy finally brings out the effect of fitness of the individual relative to heart rate and activity.

> For a given work load, the increase in heart rate is less in a fit subject than in an unfit subject. The greater stroke volume of the trained individual enables him to achieve the necessary cardia output with a smaller increase in heart rate. This involves less strain on the heart, since an increase in heart rate is brought about primarily by cutting short the rest period of the heart, i.e., the pause between beats.[23]

SIGNS OF A STRENGTHENED HEART

Morehouse and Miller have spelled out four indications of an improving cardiovascular fitness.

> The ventricular musculature becomes thicker and stronger. The resting pulse rate is often slower, due to increase in vagal tone.
>
> As a result of the slower heart rate, diastolic filling is increased and the greater contractile power of the ventricular muscle ensures a more complete emptying. The greater stroke volume permits an increased cardiac output with a smaller increase in heart rate. Since the rest pause makes up a larger fraction of the time occupied by each cardiac cycle, fatigue of the heart is postponed.[24]

STRENGTHENING THE HEART

To the untrained observer, it would seem logical that the heart would be strengthened by those activities which bring the heart rate to near maximal. Fast running would be a good example of an activity that would bring the pulse rate

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[23] *Ibid.*, p. 92. [24] *Ibid.*, p. 99.

to near maximal. On the contrary, it is a well accepted fact that only exercises of long duration and moderate intensity test and strengthen the heart. Activities like distance jogging, swimming or bicycling are good activities for improving the efficiency of the heart. Karpovich says that: "Submaximal exercise of the 'endurance' type seem to have more effect on slowing down the resting pulse than maximal ones of the 'sprint type'."[25]

THE INEFFECTIVE CARDIOVASCULAR SYSTEM

Morehouse and Miller comment on the heart of the unfit who is unaccustomed to violent exertion by comparing the heart to a weak skeletal muscle which has a limited capacity for increasing its activity.

> The ventricular musclature is relatively thin, so that its contractile force for a given diastolic volume is low. This means that excessive dilatation is required to increase the stroke volume in response to the increased venous inflow in exercise. The stroke volume is smaller than might be anticipated from the diastolic volume, due to incomplete systolic emptying. Since the maximal increase in stroke volume at the point where further dilations of the heart is checked by the pericardium, is often inadequate to meet the needs of exercise, the heart rate is ordinarily increased even in moderate exercise. An increased cardiac output is the heart rate. Since this curtails the pause between beats, which is the only 'recovery' period of the heart, fatigue of the heart rather quickly brings about exhaustion and cessation of activity. Fatigue of the heart is manifested by a

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[25]Karpovich, op. cit., p. 194.

decline in the contractile force for any given diastolic volume, or by a decrease in the cardiac output if dilatation is maximal.[26]

CARDIOVASCULAR ENDURANCE

Tuttle and Dickerson have given thoughtful consideration that conclusively demonstrates that the physical condition of an individual has a pronounced effect on both rate increase due to exercise and the time required for the heart to return to normal after the cessation of the exercise. It has also been shown, and more importantly under this heading, that the individual who is physically trained so that he possesses considerable endurance, will be less affected by a given amount of exercise than one in poorer condition, and those possessing less endurance. It is on these facts that the pulse rate has been proven reliable as a measure of physical efficiency, present condition, and endurance.[27]

According to Franklin and Kleeberger, cardiovascular endurance is "the ability of an organism to continuously maintain a certain work output. The ability to maintain a relatively high work output without decrement."[28]

[26]Morehouse and Miller, op. cit., p. 98.

[27]Henry M. Franklin and Frank L. Kleeberger, "The Validity of The Pulse-Ratio Test of Cardiac Efficienty." Research Quarterly, 1938, p. 32.

[28]Ibid., p. 121.

McCurdy, in his studies of blood changes in exercise, uses "long races" as exercises of endurance. He refers to the term "exercises of endurance such as distance running."[29]

According to what this writer has noticed in all the literature to be the reason for cardiovascular endurance during running is within heart functioning itself or, more specifically, the stroke volume of the heart. The stroke volume deals with the left ventricle of the heart which contraction causes an ejection of blood out of the heart, to the various points of the body. The stronger the ventricular wall, the greater the stroke volume resulting in the release of more oxygenated blood per cardiac cycle. If the stroke volume is greater, there is a more complete emptying of the ventricle. This complete emptying of the ventricle brings about a longer diastolic period, which gives the ventricles a longer resting period and a complete emptying of the systol. The greater the stroke volume per cardiac cycle, the greater the rest period of the heart. This results in less heart contractions per minute, or a slower heart rate. An excellent test of the efficiency of the heart would be during periods of physical stress at which time the heart must meet the increased demands of blood to its working parts. The less effective heart will not have a greater stroke volume and

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[29]*Ibid.*, p. 92.

will lose its ability for complete emptying of the ventricle before sytole begins. This results in an increased heart rate. Since maximal heart rate is uniform for all, the heart rate that increases more during exercise is less able to efficiently and comfortably meet the demands of the body and have a lower capacity for increased work loads. Conversly, the cardiovascular system with a greater stroke volume, (although the maximal pulse rate is the same) can do more work with less fatigue and with a faster, more complete recovery.

RUNNING AND THE CARDIOVASCULAR SYSTEM

There has been increasing recognition that cardiovascular conditioning is a prime factor, if not the most important one in physical fitness. Several means of assessing cardiovascularity have been developed that are highly valued and reliable. The researcher is speaking of the pulse recovery tests that are used for purposes of cardiovascular assessment. Clinical in nature, these tests are limited in application, requiring one or more trained technicians using sophisticated equipment, and requiring considerable time to administer. This has led to the development of field tests, such as the 600 yard run walk, which is a valued and reliable cardiovascular test.[30] The American Association of Health,

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30T. L. Doolittle and Rollin Bigbee, "The Twelve-Minute Run-Walk: A Test of Cardiovascular Fitness of Adolescent Boys." Research Quarterly, October, 1968, p. 49

Physical Education and Recreation, and the President's Council on Youth Fitness give the 600 yard run-walk as a measure of cardiovascular performance.[31]

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[31]American Association For Health, Physical Education and Recreation. "The Test and The National Norms," <u>Youth Fitness Test Manual</u>, Revised Edition, 1965, p. 7.

CHAPTER II

METHODS AND PROCEDURES

<u>Design</u>. All subjects selected for the research were ten years old. Boys and girls were studied and kept separately throughout the test. The major parts of the test were as follows:

Part I Pulse Rate Recovery

Part II Cardiovascular efficiency test.

In the pulse rate recovery phase, each subject was administered the test individually. Following the collection of data on the pulse rate recovery, all subjects were listed in order of recovery. For example, the most complete pulse recovery was listed first, followed by the second most complete recovery, and so on down to the least complete recovery. The list of pulse rate recovery data was then divided into three gradations of recoveries - the upper 33 1/3 percentile, middle 33 1/3 percentils and lower 33 1/3 percentile.

The efficient cardiovascular performance phase of the test consisted of giving the 600 yard run as a means to assess the efficiency of the cardiovascular system. Subjects were placed into small groups, which represented the truest cross section of cardiovascular efficiency, as was determined by the pulse rate recovery. The rationale of grouping for the cardiovascular performance was to select an equal number of subjects from each gradation in the pulse rate recovery; thereby ensuring a realistic cross section, and a reduction of the psychological factors which influence performance in the event the top 33 1/3 in the pulse rate recovery would run together and/or, having the bottom 33 1/3 run together.

Prior to the cardiovascular test, a median was established of the pulse rate recovery data. The rationale involved in this is that after the cardiovascular test is completed, scores will be recorded with each respective pulse rate recovery, thereby enabling a comparative analysis of the cardiovascular scores of the upper fiftieth percentile, with the lower fiftieth percentile of the pulse rate recovery.

Prior to the start of the actual testing, all subjects were given a simplified explanation of the purpose of the research. Emphasis was placed on proper performance of the pulse rate recovery and the importance of relaxation during the taking of the recumbent pulse rate. All subjects were given two practice sessions of the Harvard Step Test. After all subjects took the Harvard Step Test, three heterogeneous groups were selected for the 600 yard run. Preliminary instructions were given to each group regarding the most efficient method of distance running, and remembering individual time after finishing the run. To insure accurate recording of times, each runner was given a partner who was responsible for remembering the time of a particular subject.

After each group was tested, the information on each subject was included with his or her pulse rate recovery data. At this point a comparative analysis was made by calculating the mean performance in the cardiovascular test in the upper and lower fiftieth percentile of the pulse rate recovery.

PHASE I

PULSE RATE RECOVERY

1. Subjects were selected at various times of the day for the pulse rate recovery test.
2. Commencement of the test began with the subject being asked to sit down at the area of the test and to remain seated for three minutes, before resting pulse was taken.
3. Upon being seated, the subject was asked to "sit down and relax."
4. During the subjects' resting time, the room temperature and time of day was recorded.
5. The recumbent pulse rate was taken by placing the tips of third and fourth fingers slightly compressed against the radial artery of the subject's left wrist. The subject's forearm was supinated and situated on top of the left thigh.

6. Immediately following the recording of the recumbent pulse rate, the subject was given a brief explanation and demonstration by the tester of the Harvard Step Test. Also, during the demonstration and explanation, the subject was shown the relationship of the metronome to the tempo of the cadence of the Harvard Step Test. (The metronome was started with the demonstration). For example, here is what the tester said: "You start with the right foot up first on UP, and immediately bring the left foot up on two and immediately lower the right foot down on three, and the left foot down on the number, which in this case it would be one, on the next it would be two, and so on. Just like the accumulative cadence, we use on our exercises in gym class. Now, here is what it is like with the metronome. Watch!" At this point, the writer demonstrated the entire technique, using the metronome and the verbal cadence aloud.

7. The subjects complete one step up cycle every four seconds, or thirty step up cycles every sixty seconds.

8. The Harvard Step Up Test was begun arbitrarily at numbers 12, 15, 30 or 45 on the tester's watch for one minute.

PHASE II

CARDIOVASCULAR EFFICIENCY TEST

The 600 yard run is a test which measures cardiovascular efficiency; therefore, it was chosen for this research.

1. There were six groups that ran in the cardiovascular efficiency test. Each group represented an equitable cross section of the pulse rate recovery test. The rationale for grouping heterogeneously was that it would eliminate better times in the 600 yard run in the event that all who performed well on the pulse rate recovery were to run together.
2. Each group was classified as I, II, III for girls and I, II, III for boys. In the girls' group there were two groups of eleven and one group of twelve subjects.
3. Arbitrary selection of the order in which groups would be tested was used.
4. Each group took the cardiovascular performance test at 3:00 or 3:10 P.M., depending upon the amount of discussion which preceded the run.
5. Each runner had assigned to him someone who was responsible for remembering the time of the subject as it was called out by the tester.

6. Two groups were tested each day for three consecutive days.
7. Data resulting for the cardiovascular performance test was recorded with each respective pulse rate recovery information.

TIME SCHEDULE

Throughout the pulse rate recovery and efficiency cardiovascular performance test, seventy boys and girls were tested. In the pulse rate recovery, approximately 4.7 subjects were tested every day for three school weeks. Pulse rate recovery testing began September 23, and continued until October 14.

In the cardiovascular efficiency testing, two group cross sections were selected to run each day. Since there were three group cross sections of boys and three group cross sections of girls of the pulse rate recovery, it took a period of one school week for the efficiency cardiovascular performance test. Actually, only three school days involved testing; however since it rained on October 13, the field was unfit to use on Monday, so actual testing was done on October 15, 16 and 17. Generally speaking, all of the testing was completed in one month's time.

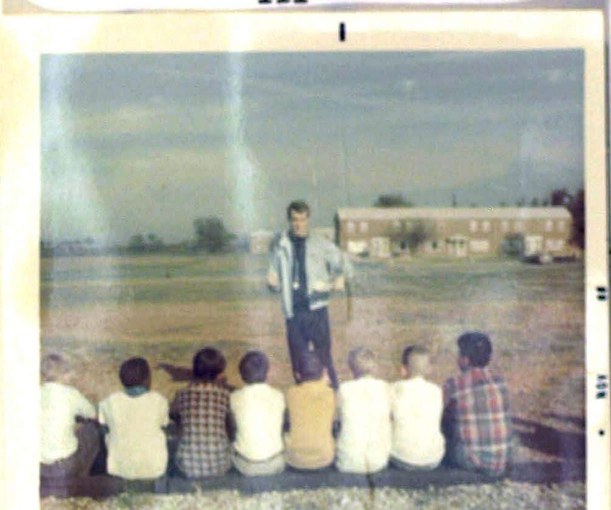
I

The Harvard Step Test

II

Pulse Rate Recovery

III



Preliminary instructions
for Cardiovascular Test
Group I.

IV

Cardiovascular Test Group II

TABLE I. Heart Rate Before and After Work, and Cardiovascular performance While Running of the Boys in the Upper 50th Percentile of the Pulse Recovery

SUBJECT	RECUMBENT HEART RATE Per minute	POST WORK (15 sec.) Per minute	POST WORK (90 sec.) Per minute	C. V. P. (600 yd.) Seconds
1	60	96	60	157
2	68	100	68	129
3	72	104	72	138
4	68	108	68	160
5	80	112	76	177
6	84	116	80	156
7	100	116	76	173
8	84	116	76	152
9	80	116	72	165
10	104	120	88	164
11	92	120	96	151
12	88	120	88	150
13	80	120	76	157
14	76	120	72	138
15	68	120	68	139
16	98	124	88	151
17	84	124	80	184
18	76	124	72	133
Means	80.8	108.6	76.4	154.1
Range	60-104	96-124	60-96	129-184

TABLE Ia — Chronological Age, Stature, Environmental Conditions and Time of Day of the Boys in the Upper 50th Percentile of the Pulse Recovery

SUBJECT	AGE (yrs)	HEIGHT (In)	WEIGHT (Lbs)	TIME	TEMPERATURE (Fahrenheit)
1	10	60	69	101 8:05AM	66°
2	10	53	60	107 8:11AM	66°
3	10	58	62	161 12:12PM	65°
4	10	54	61	167 12:18PM	65°
5	10	58	70	121 9:18AM	61°
6	10	56	63	162 10:42AM	62°
7	10	55	68	128 8:38AM	64°
8	10	57	72	125 8:35AM	64°
9	10	50	50	41 3:05PM	69°
10	10	57	85	47 3:11PM	69°
11	10	55	80	172 12:23PM	70°
12	10	53	60	158 10:38PM	65°
13	10	58	75	128 8:38AM	60°
14	10	57	85	134 8:44AM	60°
15	10	59	63	41 3:05PM	65°
16	10	56	69	101 8:05AM	68°
17	10	70	70	67 1:55PM	68°
18	10	65	80	105 8:09AM	69°
MEANS	10	62	68	2:21PM	65.3
RANGE		53-70	50-85	3:11-8:05	60-70

TABLE II Heart Rate Before and After Work and Cardiaovascular Performance While Running of the Boys in the Lower 50th Percentile of the Pulse Recovery

SUBJECT	RECUMBENT HEART RATE	POST WORK (15 sec.)	POST WORK (90 sec.)	C. V. P. (600 yrs.)
	Per minute	Per minute	Per minute	Seconds
19	72	124	72	144
20	100	128	116	142
21	76	132	76	146
22	64	132	72	151
23	96	136	92	145
24	100	136	112	140
25	96	136	116	156
26	92	136	112	158
27	88	140	88	186
28	96	144	96	186
29	80	144	100	183
30	104	148	100	145
31	96	148	92	169
32	76	148	84	151
33	80	152	80	163
34	68	152	68	141
35	96	156	96	191
36	112	168	120	195
MEANS	88.4	142.2	94.0	155.6
RANGE	64-112	168-124	72-120	140-195

TABLE IIa Chronological Age, Stature, Environmental Conditions and Time of Day of the Boys in the Lower 50th Percentile of the Pulse Recovery

SUBJECT	AGE (Yrs)	HEIGHT (In)	WEIGHT (Lbs)	TIME	TEMPERATURE (Fahrenhite)
19	10	53	66	101 8:05	65°
20	10	60n	89	121 9:18	69°
21	10	53	66	41 3:05	65°
22	10	57	90	96 8:00	67°
23	10	56	75	62 1:50	70°
24	10	60	85	157 9:44	70°
25	10	60	81	115 8:25	60°
26	10	53	64	121 9:18	65°
27	10	60	90	195 12:45	67°
28	10	57	90	46 3:10	62°
29	10	59	90	124 8:20	66°
30	10	55	63	139 8:35	59°
31	10	58	70	41 3:05	64°
32	10	57	85	48 3:12	64°
33	10	53	63	66 3:30	65°
34	10	56	75	167 12:18	70°
35	10	58	85	106 8:10	66°
36	10	60	121	133 8:43	60°
				1:44	
MEANS	10	56.9	80.4		
RANGE		53-60	63-121	8:00-3:30	

TABLE III Heart Rate Before and After Work and Cardiovascular Performance While Running of the Girls in the Upper 50th Percentile of the Pulse Recovery Test

SUBJECT	RECUMBENT HEART RATE Per Minute	POST WORK (15 sec) Per Minute	POST WORK (90 sec) Per Minute	C. V. P. (600 yds)
1	60	88	60	149
2	68	104	56	183
3	72	112	72	170
4	68	112	76	147
5	100	116	68	142
6	92	116	88	168
7	84	116	80	173
8	80	116	80	164
9	72	120	72	140
10	76	120	76	158
11	76	120	84	188
12	68	120	72	150
13	100	132	92	174
14	104	132	84	178
15	76	136	76	159
16	80	136	80	175
17	68	136	80	179
MEDIAN	79.0	119.5	76.2	164.6
RANGE	60-104	88-136	56-88	140-188

TABLE IIIa Chronological Age, Stature, Environmental Conditions, and Time of Day of The Girls in the Upper 50th Percentile of the Pulse Recovery

SUBJECT	AGE (Yrs)	HEIGHT (In)	WEIGHT (Lbs)	TIME	TEMPERATURE (Fahrenheit)
1	10	53	65	167 12:12	65°
2	10	60	72	87 8:51	60°
3	10	60	80	115 8:25	66°
4	10	55	66	120 9:17	66°
5	10	54	60	133 8:43	64°
6	10	55	70	26 2:02	62°
7	10	60	82	114 8:24	58°
8	10	57	70	86 8:50	68°
9	10	55	65	107 8:11	71°
10	10	57	70	36 3:00	75°
11	10	52	45	101 8:05	65°
12	10	60	80	173 12:24	65°
13	10	54	66	49 3:13	69°
14	10	54	71	50 3:14	63°
15	10	59	81	157 10:37	69°
16	10	58	85	136 8:46	59°
17	10	54	61	44 3:08	65°
MEDIAN		56.5	69.9	1:44	61.4
RANGE		52-60	45-85	8:05-3:14	58-75

TABLE IV Heart Rate Before and After Work and Cardiovascular Performance While Running of the Girls in the Lower 50th Percentile of the Pulse Recovery Test

SUBJECT	RECUMBENT PULSE RATE Per Minute	POST WORK (15 sec) Per Minute	POST WORK (90 sec) Per Minute	C. V. P. (in sec)
18	80	140	96	143
19	80	140	96	159
20	76	140	72	156
21	72	140	64	183
22	116	144	117	159
23	104	144	100	152
24	96	144	92	187
25	88	144	76	202
26	84	144	84	158
27	88	148	88	168
28	80	148	100	176
29	100	152	84	170
30	96	152	88	139
31	92	152	84	201
32	104	156	112	186
33	104	160	104	151
34	88	160	120	181
RANGE	72-116	147.5	64-120	139-201
MEANS	91.0	140-160	91.7	163.0

TABLE IVa Chronological Age, Stature, Environmental Conditions, and Time of Day of the Girls in the Lower 50th Percentile of the Pulse Recovery

SUBJECT	AGE (Yrs)	HEIGHT (In)	WEIGHT (Lbs)	TIME	TEMPERATURE (Fahrenheit)
18	10	57	60	137 8:47	65°
19	10	58	80	104 8:08	65°
20	10	55	55	39 3:03	69°
21	10	50	60	61 1:37	62°
22	10	59	67	43 3:57	75°
23	10	51	73	130 8:40	59°
24	10	53	80	158 10:38	68°
25	10	55	73	41 3:05	63°
26	10	55	73	48 3:12	64°
27	10	53	60	106 8:15	64°
28	10	55	85	109 8:18	58°
29	10	57	80	55 3:19	63°
30	10	56	85	67 1:55	62°
31	10	56	78	45 3:09	65°
32	10	55	85	112 8:18	60°
33	10	56	69	44 3:08	69°
34	10	54	84	109 8:15	63°
MEANS		54.8	73.3	1:38	64.4
RANGE		51-59	85-50	8:08-3:19	58-75

TABLE V Summary of the Heart Rate Before and After Work, and Cardiovascular Performance While Running of the Boys and Girls in the Lower and Upper 50th Percentile of the Pulse Recovery Test.

	RECUMBENT	POST WORK	POST WORK	C. V. P.
Upper 50th Percentile of Boys				
MEANS	80.8	108.6	76.4	154.1
Lower 50th Percentile of Boys				
MEANS	88.4	142.2	94.0	160.1
Upper 50th Percentile of Girls				
MEANS	79.0	119.5	76.2	164.6
Lower 50th Percentile of Girls				
MEANS	91.0	147.5	91.7	168.8

TABLE VI Overall Summary of the Heart Rate Before and After Work, and the Cardiovascular Performance While Running of the Boys and Girls in the Upper and Lower 50th Percentils, Computed Together of the Pulse Recovery Test

Upper Fiftieth Percentile

	RECUMBENT	POST WORK (15 sec)	POST WORK (90 sec)	E.C.V.P.
MEAN SCORE	78.4	114.0	76.3	159.3

Lower Fiftieth Percentile

	RECUMBENT	POST WORK (15 sec)	POST WORK (90 sec)	E.C.V.P.
MEAN SCORE	89.2	144.8	92.8	164.4

CONCLUSIONS AND RECOMMENDATIONS

As a result of this research, the summary of the heart rate before and after work and cardiovascular performance while running of the boys and girls in the lower and upper 50th percentile in Table V, and the overall summary of the heart rate before and after work, and the cardiovascular performance while running of the boys and girls of the lower and upper 50th percentile computed together of the pulse recovery test in Table VI, there is a tendency of the superior recovery on the pulse rate recovery test to have a definite positive relationship with superior performance of the cardiovascular efficiency in the 600 yard run. Thus, in this study, it has been shown that those subjects who were in the upper 50th percentile of the pulse rate recovery test were able to complete the 600 yard run in 5.1 seconds; faster than those in the lower 50th percentile of the pulse rate recovery test. Therefore, in this study the pulse rate recovery was a valid means in predicting the efficiency of cardiovascular performance.

The author recommends that this problem be researched further, using subjects at various levels of development to determine greater reliability of the positive results. Also, more testing of greater numbers of subjects under the same environmental conditions will increase the validity of the study.

BIBLIOGRAPHY

A. BOOKS

Beaman, Alice E., Physiology of Muscular Activity, Minneapolis, Minnesota: Burgess Publishing Company, 1936.

Davis, Elwood Craig., Muscular Activity, Dubuque, Iowa: W. C. Brown Company, 1961.

DeVries, Herbert A., Physiology of Exercise, Philadelphia, Pennsylvania: William C. Brown Company, 1966.

Dye, Joseph A., and Adrian Gordon Gould. Exercise and Its Physiology, Philadelphia, Pennsylvania: A. S. Barnes and Company, Inc., 1932.

Karpovich, Peter V., M.D., Physiology of Muscular Activity, Philadelphia and London: W. B. Saunders Company, 1953.

Lipovetz, Ferdinand John, Physiology of Exercise, Minneapolis, Minnesota: Burgess Publishing Company, 1938.

McCurdy, James Huff, The Physiology of Exercise, Philadelphia, Pennsylvania: Lea and Febiger, 1939.

Morehouse, Laurence E., and Augustus T. Miller. Physiology of Exercise, St. Louis, Illinois: The C. V. Mosby Company, 1953.

Schneider, Edward Christian, Physiology of Muscular Activity, Philadelphia, Pennsylvania: W. B. Saunders Company, 1948.

B. PERIODICALS

American Medical Association's Committee on Exercise and Physical Fitness, "Need for Varied Activities in Physical Education Programs." Journal of Health, (June, 1965)., p. 6. Physical Education, and Recreation,

Bigbee, Rollin and T. L. Doolittle, "The Twelve-Minute Run-Walk: A Test of Cardiovascular Fitness of Adolescent

Boys," Research Quarterly, (October, 1968) p. 491.

Dickinson, R. E., and W. W. Tuttle, "A Simplification of the Pulse Ratio Technique For Rating Physical Efficiency and Present Condition," The Research Quarterly, IX (August, 1938), p. 73.

Howard, Frank James, "Cardiovascular System Efficiency in Selected Physical Education Activities Courses," Peabody contribution to education. Second series, no. 288, (Nashville, 1965).

Franklin, Henry M. and Frank L. Kleeberger. "The Validity of the Pulse-Ratio Test of Cardiac Efficienty," The Research Quarterly IX (March, 1938), p. 32.

Morehouse, L. E. and W. W. Tuttle. "A Study of the Post-Exercise Heart Rate," The Research Quarterly, (March, 1942), p. 3.

Seltzer, Carl C. "Anthropometric Characteristics and Physical Fitness," Research Quarterly, 17:10, 1946.

Taylor, C. "Studies in Exercise Physiology," American Journal of Physiology, 135:25, 1941.

Tuttle, W. W. and R. E. Dickinson. "A Simplification of Pulse-Ratio Technique For Rating Physical Efficiency and Present Condition," Research Quarterly, (September, 1938), p. 9.

Tuttle, W. W. and E. P. Salit. "The Relation of Resting Heart Rate to the Increase in Rate Due to Exercise," American Heart Journal, (February, 1945), p. 594.