DEVELOPMENT OF A CARDIOVASCULAR FITNESS TEST FOR COLLEGE WOMEN BASED ON AN INDEX OF WORK EQUIVALENCY

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DISSERTATION

Presented to the Graduate Council of the
North Texas State University in Partial
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By

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CHAPTER I

INTRODUCTION

Lack of adequate physical fitness among young people has become a problem of national concern in recent years. Attention was focused on this problem as early as 1951 when almost half of the individuals called for induction into the armed forces failed their preinduction physical examinations. This concern was mirrored by President Eisenhower when he scheduled a conference to study the physical fitness of youth. In June, 1956, individuals of national reputation were invited to the conference, and the *President's Council On Youth Fitness* was formed. National attention was refocused on this problem in 1961 when President Kennedy reconvened the *President's Council On Youth Fitness*.

In the intervening years various aspects of physical fitness have been studied, tests of physical fitness have been devised, and nation-wide advertising programs have been launched. All these activities have been focused on the improvement of the physical fitness of Americans.

The Problem

The problem with which this study was concerned was that of developing a valid and reliable physical fitness test for college women which could be readily administered to large groups in a short period of time.

The problem was presented because the structure of physical fitness tests most widely used at the time of the study were used to support the thesis that the physical structure of the individual would affect the score attained on a physical fitness test. These data were also used in the development of a modified fitness test based on work equivalency.

Purposes of the Study

To further clarify the problem the following specific purposes are presented:

1. To establish the validity and reliability of a physical fitness test for college women which would include an index of work equivalency.

2. To develop charts for use in administering the Modified Fitness Test to women of various heights and weights.

3. To establish norms for use by instructors in the administration of the Modified Fitness Test.

Hypotheses

In order to accomplish the purposes of this study, the following hypotheses were tested:

1. There would be a significant difference between the results of the administration of the Skubic-Hodgkins Cardiovascular Efficiency Test and the results of the administration of the Modified Fitness Test relative to maximum heart rate attained in each of the following:

a. The Modified Fitness Test, Division I (15-inch step height) and the Skubic-Hodgkins Cardiovascular Efficiency Test;

b. The Modified Fitness Test, Division II (16-inch step height) and the Skubic-Hodgkins Cardiovascular Efficiency Test;

c. The Modified Fitness Test, Division III (17-inch step height) and the Skubic-Hodgkins Cardiovascular Efficiency Test;

d. The Modified Fitness Test, Division V, (19-inch step height) and the Skubic-Hodgkins Cardiovascular Efficiency Test.

2. There would be a significant difference between the recovery heart rate during the sixty-second recovery interval following the completion of the test in each of the following:

a. The Modified Fitness Test, Division I, and the Skubic-Hodgkins Cardiovascular Efficiency Test;

b. The Modified Fitness Test, Division II, and the Skubic-Hodgkins Cardiovascular Efficiency Test;

c. The Modified Fitness Test, Division III, and the Skubic-Hodgkins Cardiovascular Efficiency Test;

d. The Modified Fitness Test, Division V, and the Skubic-Hodgkins Cardiovascular Efficiency Test.

3. There would be a significant difference between the results obtained from the Skubic-Hodgkins Cardiovascular Efficiency Test and the Astrand-Ryhming Bicycle Ergometer Nomogram for determining physical fitness.

4. There would be no significant difference between the results of the administration of the Skubic-Hodgkins Cardiovascular Efficiency Test and the

heart rate attained during the time interval of the test.

5. There would be no significant difference between the recovery heart rate during sixty-second recovery interval following the completion of the Skubic-Hodgkins Cardiovascular Efficiency Test and the Modified Fitness Test, Division IV.

6. There would be no significant difference between the results obtained from the Modified Fitness Test and the Astrand-Ryhming Bicycle Ergometer Nomogram for determining physical fitness.

Definition of Terms

In order to insure consistency in this study the following terms were defined:

1. Modified Fitness Test -- The test of physical fitness for college women developed for this study utilizing an index of work equivalency. The mechanics of the test are as follows: (1) each woman will be assigned to s step height determined by her body stature. The step rate is twenty-four steps per minute for a time duration of three minutes. (2) the physical fitness of each subject will be determined by the heart rate at the completion of the test. (See Appendix D)

2. Cardiovascular Fitness -- The general condition and functioning ability of the heart, indicated by the speed of the heart beat during a specified amount of work.

3. Work Equivalency -- The theory whereby all individuals did a similar amount of work regardless of their stature.

4. Step Test -- A test of physical fitness employing the

technique of stepping up on a bench at a specified rate per minute for a designated time period.

5. Bicycle Ergometer -- A bicycle-like device used in physical fitness testing, containing a regulatory device for work leading as well as a speed indicator.

6. Ponderal Index -- A method of estimating body mass. The formula for Ponderal Index is: Ponderal Index =

7. Submaximal Work Rate -- The duration and amount of work established which would cause an increase in pulse rate without approaching the maximum pulse rate attainable by the individual being tested. The submaximal pulse rate was estimated by various authorities as a range from 120 beats per minute to 150 beats per minute. Heart rate obtained from submaximal work rates was also used to predict maximum oxygen uptake values for the individual being tested.

8. Oxygen Consumption -- The determination of the metabolic rate of the individual by measurement of the amount of oxygen consumed during a specified time period. Oxygen consumption and heart rate have been found to have a rectilinear relationship during work.

9. Aerobic -- Work done by the muscles in the absence of oxygen. Usually the limits of aerobic work were set at a pulse rate of 180 beats per minute.

10. Anaerobic -- Work done by the muscles in the absence of oxygen. When the oxygen required for work was greater than that being supplied by the cardiovascular system, oxygen debt was incurred. Glycogen was converted to pyruvic acid and

lactic acid appeared in the muscle as a by-product.

11. E. and M. Physiograph -- A device designed to make physiological measurements, particulary electrocardiograms.

12. Physical Fitness -- Physical fitness is the qualitative and quantitative assessment of the capacity of the individual to perform the activities of everyday life as well as to include a reservoir for emergency situations. Physical fitness includes elements of these five major components; (1) Motor Fitness, (2) Physical Work Capacity, (3) Body Weights, (4) Relaxation, and (5) Flexibility.

Background and Significance of the Study

The need for this study was indicated by R. V. Ganslen,[1] Professor of Physical Education at Texas Woman's University, in a lecture-critique of the physical fitness tests for woman. His suggestion was that an allowance for work equivalancy should be incorporated into the system or fitness testing.

One of the basic educational premises is that people are different and that differences should be considered in almost all aspects of educational research and instruction. This applies to the physical as well as the mental aspects of the individual.

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[1]R. V. Ganslen, Texas Women's University, Personal Communication, November 12, 1968.

A recent anthropometric study conducted by Pruitt[2] at Texas Woman's University involving 1049 students at that institution revealed a range in height from 52 to 72 inches. The weight range was even greater, from 75 pounds to 322 pounds. Earlier studies with various populations have indicated equal variety in the stature of the subjects. Yet the most widely used and accepted physical fitness test for college women has made no allowance for this obvious difference.

There has been research in the area of work equivalency. Astrand,[3] Asmussen,[4] and Davies[5] have done research related to this problem. However, in most cases, their work was conducted by use of a bicycle ergometer or a treadmill.

Research utilizing bicycle ergometers and treadmills, although highly valid and reliable, has had certain limitations when applied to large groups such as physical education classes. The first limitation is related to numerical considerations. The bicycle ergometer or the treadmill can be used to test only one subject at a time.

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[2]Joyce Pruitt, "Anthropometrical Data on 1049 College Women," unpublished Doctoral Dissertation, Texas Woman's University, Denton, Texas, 1968.

[3]P. O. Astrand and Kaare Rodahl, Textbook of Work Physiology, New York, McGraw-Hill Book Co., 1970.

[4]E. Asmussen and M. V. Nielsen, "Cardiac Output During Muscular Work and Its Regulation," Physiological Reveiw, XXXV (October, 1955), p. 778.

[5]C. T. N. Davies, "Maximum Heart Rate and Maximal Oxygen Uptake," Canadian Medical Association Journal, XCVI (March, 1967), p. 743.

This reduces their usefulness except for referral in specialized or adaptive physical education classes. The second limitation is related to time. Most physical fitness measures involving these two devices require an excessive amount of time. For example, the treadmill test is usually based on a twenty-minute work period. Clearly, such a test would be difficult to administer during a regular class period. The third limitation is the availability of the necessary equipment and therefore are not readily available to classroom teacher.

There are other varieties of physical fitness tests with reliable norms. However, time and administrative problems are often limiting factors when these tests are used with college women. A notable example of this type of test is the American Association for Health, Physical Education and Recreation Youth Fitness Test. This is an excellent test, with well established norms. However, it consists of six items, and the length of time required for its administration and number of administrative personnel required often make its use prohibitive. This is particularly true with college activity classes where students are numerous and class time is short.

The test which was most widely used at the time of this study was the Skubic-Hodgkins Cardiovascular Efficiency Test.[6] The test was devised in 1963 by the authors whose name it bears.

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[6]Vera Skubic and Jean Hodgkins, "Cardiovascular Efficiency Test for Girls and Women," Research Quarterly, XXXIV (July, 1963), p. 191.

The test required stepping up on an eighteen-inch bench for three minutes at the rate of twenty-four steps per minute. The fitness of the individual was assessed by application of a formula developed by the authors which involved pulse rate taken after one minute of rest following the completion of the test. Because of the test duration, ease of administration, and the time required, the test has gained wide acceptance.

Procedures for the Study

The _Skubic-Hodgkins Cardiovascular Efficiency Test_ was administered to 100 women students at North Texas State University during November and December of 1969. The participants were volunteers from five womens physical education activity classes at the University.

The same 100 women students at North Texas State University were given the Modified Fitness Test. This test was devised for this study to test work equivalency. In order to establish reliability, a retest was administered to each subject one week following the first administration of the Modified Fitness Test. During the retest, conditions identical to the origional test situation were maintained. The subjects taking the Modified Fitness Test were assigned to a step height according to the ponderal index relative to their height and weight. (See Appendix A) These assignments were made so that work equivalency indices could be established.

The same 100 subjects were administered the bicycle ergometer test developed by Astrand and Ryhming[7] using a workload ergometer test was used for comparative basis to establish norms for cardiovascular fitness. Since the height and weight of the subjects had no effect on the amount of work done by the subjects, the Astrand-Ryhming test was used as the control variable of the study. The Astrand-Ryhming test is recognized by leading physiologists as the best of the submaximal tests of cardiovascular fitness.

During all tests, the heart rate was monitored with an E. and M. Physiograph. Heart rate was recorded throughout the test period of each of the tests and during the recovery period.

At the completion of each test a comparison of the heart rate per minute was made between the Skubic-Hodgkins Cardiovascular Efficiency Test and the Modified Fitness Test for each individual involved in the testing program. The heart rate was also taken for thirty seconds at the end of the sixty-second recovery period. The heart rate at the completion of the Astrand-Ryhming Bicycle Ergometer Test and the Skubic-Hodgkins Cardiovascular Efficiency Test were compared for significant differences by use of the nomogram devised for each test. At the completion of the Astrand-Ryhming

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[7]P. O. Astrand and Irma Ryhming, "A Nomogram for Calculation of Aerobic Capacity from Pulse Rate During Submaximal Work," Journal of Applied Physiology, VII (January, 1954), p. 218.

Bicycle Ergometer Test and the Modified Fitness Test, the heart rates were compared for significant difference.

Hypothesis one and hypothesis two were treated in the null form for significant difference by the technique or analysis of covariance as discussed by McNemar.[8] Hypotheses three, four, five, and six were treated for significant difference between means by use of the Fisher t test.[9]

Limitations

This study was limited to 100 college women enrolled in the physical education activity classes at North Texas State University who volunteered to participate.

The results of the study were limited by the extent of the reliability and validity of the tests used for the collection of data.

The collection of the data included in this study was limited by time to the months of November and December of 1969.

Basic Assumptions

1. It was assumed that the subjects involved in the study would co-operate to the best of their ability and would respond with a total effort on all of the tests administered to them.

2. It was assumed that outside activities would have an equal effect on all participants in the study.

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[8]Quinn McNemar, Psychological Statistics, New York, Wiley and Sons, Inc., 1962, p. 362.

[9]McNemar, Ibid, p. 99.

Summary

It was the purpose of this study to develop a valid and reliable physical fitness test for use with college women which would include adjustments with respect to work equivalency. The adjustments were based on the ponderal index of the individual being tested.

Two established physical fitness tests, the *Skubic-Hodgkins Cardiovascular Efficiency Test* and the Astrand-Ryhming Bicycle Ergometer Test were used for comparative purposes and test validation. They were also used for the establishment of norms to be used with the Modified Fitness Test which was developed for this study. The test-retest procedure was utilized to establish an index of reliability for the Modified Fitness Test.

CHAPTER II

REVIEW OF THE RELATED RESEARCH

The review of the literature is divided into three areas. The first section deals with studies involving the determination of cardiovascular response to exercise, particularly those studies involving a submaximal test for the estimation of maximal physical capacity. The second section includes studies involving the comparative functional relationship between heart rate and oxygen consumption relative to exercise. The final section contains studies involving the three basic forms of exercise used for cardiovascular testing.

Studies Involving Cardiovascular Response to Exercise

Balke[1] used air force personnel to determine the correlation of static and physical endurance. He compared the effect of exercise on heart rate and oxygen consumption and determined that the maximum efficient heart rate was 180 per minute. Beyond this rate, any additional increase in heart rate is absorbed in increased requirements of the cardiovascular system. Firthermore, the oxygen consumption curve levels off (flattens out) at 180 beats per minute. At higher rates, anaerobic conditions exist and owygen debt is incurred.

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[1]Bruno Balke, "Correlation of Static and Physical Endurance," Report #1, Randolph Field, Texas: School of Aviation Medicine, April, 1952.

Lind[2] discussed the results of large muscle exercise on the heart and reported that dynamic exercise results in a large increase in cardiac output with an unchanged or slightly reduced mean arterial pressure. He further stated that prolonged heavy rhythmic exercise results in an inevitable demand for increased cutaneous blood flow. Continuing his discussion on cardiac response, Lind said that

> Whatever differences there are in cardio-vascular responses to different kinds of exercise, it remains clear that the primary aim of the changes in the cardio-vascular system during static and dynamic exercise is to supply the muscle with enough blood to allow continued unhampered activity.

Muller[3] believed that endurance in muscular work depends on the amount of oxygen that the cardio-vascular system is able to pump to the working muscles in a given period of time.

Montoye[4] studied the use of the treadmill to determine the interrelationship of pulse rate during moderate exercise, recovery pulse rate, and blood lactate level, and determined that post exercise pulse rate is sensitive to training. He further stated that of the various physiological measurements taken during and after moderate exercise, maximum exercise

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[2] A. R. Lind and G. W. McNicol, "Muscular Factors Which Determine the Cardio-vascular Responses to Sustained and Rhythmic Exercise," Canadian Medical Association Journal, XCVI (March, 1967), p. 712.

[3] E. A. Muller, Experimental Medical Surgery, XXI (January, 1964), p. 143, as cited by E. A. Muller, "Commentary," Canadian Medical Association Journal, XCVI (March, 1967), p. 715.

[4] Henry J. Montoye, "Inter-relation of Maximum Pulse Rate During Moderate Exercise, Recovery Pulse Rate, and Post-Exercise Blood Lactate," Research Quarterly, XXVI (December, 1953) p. 453.

pulse rate and post-exercise lactate level correlate highest with "all out" treadmill run times.

Morehouse and Miller[5] contended that during exercise the increased oxygen requirement of the contracting muscles is met by an increased flow of blood through the muscles. This is made possible by an increase in the amount of blood pumped by the heart.

Balke[6] reported that of all the physiologic functions measured, the pulse rate at any given workload reflected most closely the status of the work capacity of a person.

de Vries[7] stated that the ready availability of the pulse rate as a measure of what transpires internally has resulted in the accumulation of much interesting data that relate to various exercise conditions and heart rate. "Since the heart rate is easily obtained, it is indeed fortunate that research has shown that the heart rate is the more important variable in the response to the demands of exercise."

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[5]L. E. Morehouse and A. T. Miller, Physiology of Exercise, (5th edition) St. Louis, The C. V. Mosby Company, p. 105.

[6]Bruno Balke, "An Experimental Study of 'Physical Fitness' of Air Force Personnel," Department of Physiology-Biophysics, U. S. Air Force School of Aviation Medicine, Randolph Air Force Base, Texas, U. S. Armed Forces Medical Journal X (December, 1961), pp. 675-688.

[7]Herbert A. de Vries, Physiology of Exercise, Dubuque, Iowa, W. C. Brown Company, 1966, p. 72.

Bainbridge,[8] in some of his earliest studies, found that direct measurement of the amount of blood flow through skeletal muscle is very difficult. The change in the amount of blood flow varies not only with the type and intensity of the exercise, but also with the relative proportion of the total musculature involved.

Morehouse and Miller[9] related the following calculations of increased blood flow through the muscles during exercise. Under resting conditions the cardiac output may be five liters per minute, and it may rise to twenty liters per minute during exercise. At rest, about 0.8 liter of the cardiac output goes to the skeletal muscles, and since the net flow to non-muscular tissue probably changes little in exercise, perhaps as much as sixteen liters of the cardiac output may go to the muscles during exercise. Thus the total muscle bolld flow during exercise. Thus the total muscle blood flow during exercise would be about twenty times greater than the muscle blood flow at rest. The effects of training on the cardiovascular system were apparent. Cardiovascular training has long been an important part of nearly all forms of muscular endeavor.

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[8]F. A. Bainbridge, Physiology of Muscular Exercise, (3rd edition, rewritten by A. V. Boch and D. B. Dill) Longmans, Green and Company, 1939.

[9]Morehouse and Miller, *op. cit.*, p. 117.

Muller[10] stated that dynamic muscular training lowers the work pulse rate for a given oxygen consumption. This is due to a better utilization of oxygen by the trained muscle group.

In a study by Andres, Guzman and Becklake[11] it was reported that one of the results of athletic training was an increase in the cardiac output during submaximal exercise. The authors attribute this change to more effective shunting of blood to the muscles.

Another result of training was found to be an increase in the blood flow through working muscles involved in exercise. This was substantiated by Rohter, Rochelle, and Human[12] in research involving blood flow changes in the forearm during flexion and extension.

In order to examine the possible effect of strength training on cardiovascular condition, Nagle and Irwin[13] trained forty college men on a high and low resistance weight-lifting program for eight weeks. Using the bicycle ergometer

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[10]Muller, _op. cit._, p. 144.

[11]G. M. Andres, C. A. Guzman and M. R. Becklake, "Effect of Athletic Training on Exercise Cardiac Output," _Journal of Applied Physiology_, XXI (March, 1966), p. 603.

[12]F. D. Rohter, R. H. Rochelle, and C. Hyman, "Exercise Blood Flow Changes in the Human Forearm During Physical Training," _Journal of Applied Physiology_, XVIII (May, 1963), p. 789.

[13]R. E. Nagle and T. Irwin, "Effect on Circulorespiratory Endurance and Related Physiological Factors," _Research Quarterly_, XXXII (December, 1961), p. 607.

as a work-capacity test, they found no significant difference between the change which occurred relative to a control group who engaged in mild recreational activity.

Morehouse and Miller[14] stated that for a given work load the increase in heart rate is less in a physically fit subject than in a physically unfit subject. If both physically fit and unfit subjects work to the point of exhaustion, the maximal heart rates will be approximately the same in each, but the total work load performed will be much greater in the case of the more fit subject. In other words the greater stroke volume of a trained person enables him to achieve the necessary cardiac 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, or pause between beats, of the heart.

Andres *et al.*[15] found that during any particular training period, stroke volume changed little, but there was a fall in heart rate at a given work load that was associated with a drop in cardiac output. This applied not only to athletes tested before, during and after the season, but also to non-athletic students studied before and after the end of a gymnastic program.

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[14] Morehouse and Miller, *op.cit.*, p. 100.

[15] Andres, Guzman, and Becklake, *op. cit.*, p. 603.

Davies,[16] referring to submaximal tests used for the prediction of maximal endurance, indicated that the accuracy of the results was largely dependent on the subject's initial state of training. He further stated that submaximal data should be used to assess the exercise capacity of the individual.

Dejours[17] pointed out that "it is well known that ventilation and cardiac output increase immediately at the onset of contration of the larger muscle groups."

Asmussen and Nielsen,[18] who measured cardiac output in many subjects of both sexes and various ages, concluded that when the exercise is such that the heart rate rises above 120 beats per minute, then the stroke volume in most individuals reaches maximum and may decrease as heart rate rises with further effort. At high levels of work, cardiac output is dependent on the rise in heart rate.

Studies Involving the Comparative Functional Relationship Between Heart Rate and Oxygen Consumption Relative to Exercise

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[16] C. T. M. Davies, "Commentary," Canadian Medical Association Journal, XCVI (March, 1967), p. 744.

[17] P. Dejours, Journal Physiology. (Paris)51:164, 1969. As quoted by W. T. Josehans, "Commentaries," Canadian Medical Association Journal, XCVI (March, 1967), p. 713.

[18] E. Asmussen and M. Nielsen, "The Cardiac Output in Rest and Work Determined Simultaneously by the Acetylene and Dye Injection Methods," Acta Physiologica Scandinavica 35:73, 1955b as cited by Wyndham et al. Journal of Applied Physiology, XIV (November, 1959), p. 934.

In the evaluation of cardiovascular fitness, two basic measures are usually used. It should be noted in the evaluation of the literature that these two measures are closely related and highly interdependent.

Boothby,[19] in one of the earliest comparative studies of the relationship between oxygen consumption and heart rate, used himself as a subject and found that the pulse rate during work on a bicycle ergometer was a linear function of metabolism as measured by oxygen consumption.

Davies[20] reported that the accurate prediction of maximum oxygen intake from exercise heart rate and oxygen intake collected at submaximal work levels depends on (1) the linear relationship between the two variables, and (2) the ability of the subjects to reach a similar heart rate.

The study involved sixty healthy male and female subjects. Davies found that error existed in estimation of maximum oxygen intake. In sedentary subjects this error produced an underestimation of $-15 \pm 10\%$ of heart rate. He concluded that

> We should move away from the predicted maximum oxygen intake as a test criterion and seek alternate methods of using submaximal data to assess the exercise capacity of the individual, expecially when dealing with non-athletic populations.

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[19]W. M. Boothby, "Studies in Metabolism and Oxygen Consumption," American Journal of Physiology, XXXVI (June, 1915), p. 383.

[20]Davies, op. cit., p. 743.

Nagle and Bedicki[21] compared cardio-respiratory functions of fit and unfit individuals and also reported that oxygen consumption leveled off at 180 beats per minute. Furthermore, the rate of oxygen consumption and heart rate have a nearly straight line relationship throughout the test. This particularly true for those individuals exhibiting poor physical fitness characteristics. They concluded that untrained subjects should use a more gradually increased exercise routine for more precise measurement of cardio-respiratory capacity. Their findings were that the heart rate of 150 beats per minute at submaximal exercise correlated .69 with maximum heart rates attainable by the subjects tested.

Bates,[22] in a study at his laboratory at Montreal, Quebec, investigated cardiac output as a limiting factor to exercise in normal subjects exercising to maximal oxygen consumption. Up to 1500 kilogram/minutes (180-190 beats per minute) cardiac output, heart rate, and oxygen consumption showed a linear increase in relation to external workload. Above this load (about eighty per cent of maximum) subjects showed a tendency to level off.

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[21]Francis J. Nagle and Thomas G. Bedicki, "Response as a Measure of Circulatory Capacity," Research Quarterly, XXXIV (October, 1963), p. 361.

[22]D. V. Bates, "Commentary," Canadian Medical Association Journal, XCVI (March, 1967), p. 704.

The results ruggested that the limit of useful exercise capacity is reached when cardiac output no longer increases in relation to external workload, and are compatible with the suggestion by Balke[23] that any further increase in oxygen consumption above this level is required for the muscles of breathing and is not available for external work.

Shephard[24] pointed out that the maximum value of the effective cardiac output is determined by the working capacity of the cardiac muscle and the venous return. Cardiac output cannot usefully be increased beyond the point where oxygen consumption of cardiac muscle is making significant inroads upon the overall oxygen intake.

Andersen[25] contended that during exercise the heart rate increases as exercise progresses in order to achieve adequate cardiac output wheb stroke volume decreases. Moreover, heart rate at a steady state or taken at the end of a few minutes of exercise is closely related and linearly related to oxygen uptake. This characteristic changes with training.

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[23]Balke, op. cit., "Correlation of Static and Physical Endurance."

[24]R. J. Shephard, "Physiological Determinants of Cardiorespiratory Functions," Journal of Sports Medicine, VII (September, 1967), p. 111.

[25]K. Lange Andersen, "The Cardiovascular System in Exercise," Exercise Physiology, Harold B. Falls, editor, New York, Academic Press, 1968.

Alexander[26] stated that there are two ways in which changes in heart rate influence the efficiency of the circulation. First, heart rate alters the efficiency of the heart itself. The normal resting pulse rate of around 70 beats per minute does not represent the optimum rate in terms of mechanical efficiency of the heart muscle. This efficiency is increased by accelerating the rate of the heart up to about 120 beats per minute. Just where the optimum rate lies has been debated and certainly varies with different individuals. There is no doubt, however, that at rates above 150 beats per minute the mechanical efficiency of the heart seriously deteriorates.

Bergtsson[27] also investigated heart rate and reported that for subjects aged five to forty years, the heart rate increased linearly with exercise intensity. Oxygen consumption showed the same relationship with exercise intensity.

In assessing the effects of training on cardiac muscle, Andersen[28] found that heart rate decreased with training.

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[26]R. S. Alexander, "The General Physiology of Heart and Circulation," Speech at Western Reserve University School of Medicine, Cleveland, Ohio, October, 1964. (mimeograph)

[27]E. Bergtsson, "The Working Capacity in Normal Children Evaluated by Submaximal Exercise on a Bicycle Ergometer and Compared with Adults," _Acta Medica Scandinavica_, CLIV (March, 1954), p. 91-109.

[28]Andersen, "The Cardiovascular System in Exercise," _op. cit._, p. 122.

The well-known sports Brady-cardia may be as low as thirty beats per minute. During performance, the heart rate is much lowered for a given oxygen uptake for the athlete as compared to the non-athelete.

The effect of training on the heart rate may be summarized as follows:

1. The heart rate becomes lower at all metabolic rates.

2. A certain increase in metabolic rate brings about a smaller increase in heart rate after training.

3. Before training, the heart rate approaches its maximal value, asymptotic in most subjects. In a trained state this is changed to a closer linear relationship.

Research indicates that there is a defininte relationship between oxygen consumption and heart rate relative to exercise. The relationship is usually found to be of a progressively linear nature.

Astrand[29] found that oxygen uptake after five minutes of exercise increases linearly with work up to 1500 KPM/minute. A further increase in work load does not elevate the oxygen uptake nor heart rate, and the capacity for aerobic energy output above that provided by oxygen utilization falls on the anaerobic processes, with a steep increase in blood acid concentration as a consequence.

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[29]P. O. Astrand, "Measurement of Maximal Aerobic Capacity." Canadian Medical Association Journal, XCVI (March, 1967), p. 732.

Asumssen and Neilson[30] reported similar findings relative to the relationship between oxygen consumption and heart rate change during exercise.

Berggren and Christensen[31] found that oxygen uptake and pulse rate were linerly related over a wide range of values.

For 44 females age 20-65, Irma Astrand[32] found an approximate rectilinear relationship between heart rate and oxygen consumption. A. O. Astrand[33] plotting heart rate and oxygen consumption for male and female subjects found the two factors to be linearly progressional. This linear progression of oxygen consumption and heart rate was verified by the findings of Suggs.[34]

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[30]E. Asumssen and M. Neilson, "Cardiac Output during Muscular Work and Its Regulation," Physiological Reviews, XXXV (October, 1955), p. 778.

[31]G. Berggren and E. H. Christensen, "Heart Rate and Body Temperature as Indices of Metabolic Rate During Work," Arbeitsphysiol, XIV (1950), p. 225, as reported by L. B. Rowell, H. L. Taylor, and Yang Wang, Journal of Applied Physiology, XIX (November, 1964), p. 919.

[32]Irma Astrand, "Aerobic Work Capacity in Men and Women with Special Reference to Age," Acta Physiologica Scandinavica, XLIV, Supplement 169. 1960.

[33]P. O. Astrand, Experimental Studies of Physical Working Capacity in Relation to Sex and Age, Copenhagen Munksgaard, 1952.

[34]Charles W. Suggs, "An Analysis of Heart Rate in Response to Exercise," Research Quarterly, XXXIX (March, 1968), p. 195.

Le Blance and Kennedy,[35] stated that there was also a linear relation between heart rate and the amount of oxygen absorbed. Thus, maximum heart rate can be used as an index of work output.

There are two basic methods of determination of physical fitness. The first method involves working the subject to the point of total exhaustion and evaluating the heart rate and/or oxygen consumption. Although this is the more accurate of the two methods under consideration, obtaining subjects willing to perform to the point of exhaustion is difficult. This type test is also useless for classroom evaluation of subjects. The second method involves the prediction of the maximum values possible to be attained by the subject by use of a submaximal test of fitness and extrapolation of the data obtained to indicate the total predicted level attainable by the subject.

Irma Astrand[36] stated three prerequisites for the use of the predictive procedures: (1) The pulse rate during submaximal work increases approximately rectilinearly with oxygen intake, (2) Submaximal pulse rate of not lower than 125 beats per minute is used for predictors, (3) The pulse rate of the subjects can reach a masimum value of about 195 beats per minute.

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[35] J. Le Blance and R. A. Kennedy, "Use of Heart Rate as an Index of Work Performance," Journal of Applied Physiology, X (January, 1957), p. 276.

[36] Irma Astrand, op. cit. Supplement 169.

Wyndham[37] stated that

> The procedure is to measure the individual's heart rate and oxygen consumption, or to estimate the latter from a 'standard' oxygen consumption. A straight line is fitted to the plots and it is extrapolated to the maximum heart rate for the population. The oxygen consumption which is equivalent to the maximum heart rate on the straight line fitted to heart rate is matched against oxygen intake.

Sjostrand[38] based his estimates of maximum oxygen intake upon successive increments in work rate until a pre-determined heart rate was reached. In his study the subjects pedaled a bicycle ergometer at 300, 600, 900, and in some cases 1200 kilogram-meters/minute. At the first three loadings, the time of pedaling was ten minutes, but this was reduced to six minutes and even four minutes at the highest loads. The criterion for determining the maximum level was "when respiratory and circulatory organs can no longer adapt themselves to the energy consumption of the organism." The pulse level for adults was determined to be 180 beats per minute.

A method whereby maximum oxygen intake was predicted from the respiratory quotient was proposed by Issekutz, Birkhead and Rodahl.[39] According to their findings, the

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[37]C. H. Wyndham, "Submaximal Tests for Estimating Maximal Oxygen Intake," Canadian Medical Association Journal, XCVI (March, 1967), p. 737.

[38]T. Sjorstrand, "Changes in the Respiratory Organs of Workmen at an Ore Smelting Works," Acta Medica Scandinavica, CXLVII (Supplement 196, 1947), p. 687.

[39]B. Issekutz, N. C. Birkhead, and K. Rodahl, "Use of Respiratory Quotient in the Assessment of Aerobic Work Capacity," Journal of Applied Physiology, XVII (January, 1962), p. 47.

increase in carbon dioxide output relative to oxygen intake was the results of accumulation of lactic acid, with a decrease in the body bicarbonate pool. The method consisted of pedaling a bicycle ergometer at four submaximal work loads.

> The respiratory quotient was measured and plotted on a work-rate/respiratory quotient graph. A straight line was fitted to the points, and was extrapolated to, logarithmically. The maximum oxygen intake was then obtained from a standard work load-oxygen intake graph.

Allard and Goulet[40] tested employees of the city of Montreal, Canada, to evaluate their physical working capacity. The researchers used a varied load on the bicycle ergometer. The first load was 300 kpm/minute for six minutes. The second load was 450 kpm/minute for six minutes. The subject then remained idle for four minutes, during which time the "steady state" heart rates observed in the previous two loadings were plotted to extrapolate to HR_{150} and obtain a predicted kpm/minute. The authors in their findings indicated that

> Of the population investigated, 0.7% had a high PWC, 3.1% good, 14.2% average, 24.3% fair, and 57.3% had a low PWC. The subjects indulging in physical activity either on or off the job had a higher PWC than those who did not.

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[40] C. Allard and C. Goulet, "Symposium on Physical Working Capacity and Its Testing," Prevention of Ischmic Heart Disease, W. Raab, editor, Springfield, Ill., Charles C. Thomas, Publisher, 1966.

Maritz, Morrison, Peter, Strydon, and Wyndham[41] based their assessment of work on the measurement of heart rate oxygen consumption at four submaximal rates of work, the fitting of a straight line to the four pairs of plots, the extrapolation of the straight line to a maximum heart rate, and finally, reading from the graph, the oxygen consumption which is equivalent to the maximum heart rate. The oxygen consumption was an estimate of the individuals' maximum oxygen intake.

Margaria, Aghemo and Rovelli,[42] in assessing exercise and heart rate concluded that the work rate selected for submaximal testing should be chosen to give heart rates between 100 and 150 beats per minute.

Suggs[43] evaluate heart rate in response to stress in college men. He used three exercise intensities: (1) Light (<125 beats/minute), (2) Medium (125/150 beats/minute) and (3) Heavy (>150 beats/minute). He found that most heart response to exercise occurs during the first three to five minutes following the beginning of the exercise period.

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[41] J. S. Maritz, J. F. Morrison, J. Peter, N. B. Strydon and C. H. Wyndom, "A Practical Method of Estimating an Individuals' Maximum Oxygen Intake," Ergonomics, IV (April, 1961), p. 97.

[42] R. Margaria, P. Aghemo, and E. Rovelli, "Indirect Determination of Maximal Oxygen Consumption in Man," Journal of Applied Physiology, XX (September, 1965), p. 1070.

[43] Suggs, op. cit., p. 201.

According to Wyndham,[44] the inter-individual variation about the population mean heart rate is relatively small. The Astrands gave a coefficient of variation of about plus or minus one per cent at minimum heart rate. Wyndham's coefficient was plus or minus five per cent in population that was less homogeneous from the point of view of the men's physical fitness. This means that if the population mean heart rate is 190 beats per minute, only about five per cent of the sample will lie outside the range of 170-210 beats per minute.

Andersen[45] confirmed this lack of variation. He found that in a homogeneous group of sedentary subjects of the same sex, the relationship between both heart rate and oxygen consumption was remarkabley similar.

Astrand and Ryhming[46] introduced a nomogram based upon the measurement of heart rate at one rate of work, the estimation of oxygen consumption from the oxygen consumption against work-rate relationship given in the nomogram, and a straight line fitted between a common heart rate of 51 beats per minute at zero oxygen consumption and the measured heart

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[44]Wyndham, _op. cit._, p. 739.

[45]Andersen, _op. cit._, p. 96.

[46]P. O. Astrand and Irma Ryhming, "A Nomogram for Calculation of Aerobic Capacity (physical fitness) from Pulse Rate During Submaximal Work," _Journal of Applied Physiology_, VII (January, 1954), p. 218-222.

rate at the estimated oxygen consumption. The maximum oxygen intake was obtained from an extrapolation of a straight line to 195 beats per minute.

In 1965 Margaria[47] _et al._ divised another nomogram based on similar premise as that of the Astrands. This nomogram employed two rates of work which were chosen to give heart rates between 100 and 150 beats per minute. Adjustments were made in the work rate for very young and very old people. Three maximum heart rate lines were given in the nomogram so as to take into account the effect of age on maximum heart rate.

In the development of his nomogram, Maritz _et al._[48] used four submaximal rates of work.

Shephard[49] in development of the progressive step test, found a coefficient of validity of 0.872 when results were compared with the Astrand-Ryhming Nomogram. de Vires and Klafe[50] determined correlations and predictive errors in predicting maximal oxygen consumption for six submaximal tests of working capacity. Since the Astrand-Ryhming Nomogram

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[47]R. Margaria, P. Aghemo, and E. Rovelli, _op. cit._, p. 1072.

[48]J. S. Maritz, J. F. Morrison, J. Peter, N. B. Stydon, and C. H. Wyndom, _op. cit._, p. 98.

[49]Shephard, _op. cit._, p. 745.

[50]H. A. de Vries and C. E. Klafe, "Prediction of Maximal Oxygen Intake from Submaximal Tests," _Journal of Sports Medicine_, V (September, 1962), p. 207.

had a correlation coefficient of 0.735, they concluded that of the six tests compared, the test showing the highest predictive value was the Astrand-Ryhming Nomogram. A correlation coefficient between the Astrand-Ryhming Nomogram and the direct treadmill method was found by Glassford, Baycroft, Sedwick, and Macnab[51] to be 0.78.

Studied Involving the Bicycle Ergometer, the Step Test, and the Treadmill to Test Cardiovascular Efficiency

At the time of this study there were three basic forms of test commonly used for the evaluation of cardiovascular fitness: the step test, the bicycle ergometer, and the treadmill. The intra-test coefficients of correlation among the three basic test types were extremely high. This fact was important because all three types were widely used and any comparison of data is dependent upon test validity.

Wyndham[52] reported a 0.95 probability that the step test values would lie within ±0.96 of the observed treadmill test values. These findings agree with those of Irma Astrand.[53]

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[51]R. G. Glassford, G. H. V. Baycroft, A. W. Sedwick, and R. B. J. Macnab, "Comparison of Maximal Oxygen Uptake Values Determined by Predicted and Actual Methods," Journal of Applied Physiology, XX (May, 1965), p. 509.

[52]Wyndham, op. cit., p. 741.

[53]Irma Astrand, op. cit., Supplement 169.

Glassford *et al.*[54] reported related findings and also found a 0.95 probability that the ergometer value would lie within 0.4 leter/minute of the observed treadmill value. Kasch, Phillips, Ross, Carter and Boyer[55] showed a correlation coefficient of 0.95 between treadmill and steptest maximum oxygen intakes. Similarly, Shephard[56] found a coefficient correlation of 0.966 between the bicycle ertometer test and the step test.

Margaria[57] stated that

> The best exercise in my opinion is stepping up and down to the sound of a metronome. This procedure does not require costly apparatus needing calibration, the exercise is familiar enough to avoid the necessity of special training, and it is well accepted by the subjects because it does not lead to an unpleasant feeling of exhaustion. The test can be carried out by a technician, and calculations are avoided by using a nomogram. In my opinion the data obtained with this method are more uniform and therefore more indicative of the true values than those obtained from direct measurement, and a comparison with data from other subjects or from the same subject in different experimintal conditions is made possible.

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[54]Glassford *et al.*, *op. cit.*, p. 5169.

[55]F. W. Kasch, W. H. Phillips, W. D. Ross, J. L. Carter and J. L. Boyer, "A Comparison of Maximum Oxygen Uptake by Treadmill and Step Test Procedure," *Journal of Applied Physiology*, XXI (July, 1966), p. 1387.

[56]Shephard, *op. cit.*, p. 744.

[57]R. Margaria, "Commentary," *Canadian Medical Association Journal*, XCVI (March, 1967), p. 734.

Asmussen and Nielsen[58] indicated that the treadmill and step tests are more valid for American subjects because of their lack of familiarity and practice with bicycle riding as compared to subjects in the Scandinavian countries for whom the bicycle is a mojor means of transportation.

Shephard[59] compared bycycle ergometer and step test results and presented the following conclusions. He stated that

> Devotees of the bicycle ergometer have claimed that the rates of working on such a machine are known more precisely than the step test. However, the coefficient of variation in mechanical efficiency is closely similar for the two tests. Many subjects in North America also find difficulty in developing a high work rate during the unaccustomed exercise of cycling, whereas few, even today are completely unfamiliar with a step.

The Schneider Test[60] was devised to determine the fitness of aviators in World War I. The following six items comprised the test 1. Reclining Pulse Rate, 2. Reclining systolic pressure, 3. Standing pulse rate, 4. Increase in pulse rate on standing, 5. Blood pressure increase while standing, 6. Pulse rate immediately after exercise. The exercise consisted of having the subject step on a bench 18½ inches high 5 times in 15 seconds. Norms were established relative to the time required for the subjects' standing pulse rate to return to normal.

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[58] Asmussen and Nielsen, "Cardiac Output During Work and Its Regulation," *op. cit.*, p. 779.

[59] Shephard, *op. cit.*, p. 744.

[60] E. C. Schneider, "A Cardiovascular Rating as a Measure of Physical Ratigue and Efficiency," *Journal of the American Medical Association*, LXXIV (May, 1920), p. 1507.

Masters[61] devised the Two-Step Test to determine the Cardiovascular Fitness Index (CFI) of the subjects tested. The test consisted of ascending and descending two steps, nine inches high, at varying rates for ninety seconds. The blood pressure and heart rate two minutes following the completion of the exercise was compared with the pre-exercise blood pressure and heart rate to determine the Cardiovascular Fitness Index.

The Tuttle Pulse-Ratio Test[62] was administered as follows: 1. The resting pulse rate of the subject was taken. 2. The test consisted of stepping on a bench thirteen inches high. The male subject stepped twenty times and the female subject stepped fifteen times. The time duration was one minute. 3. Immediately upon completion of the period of exercise, the resting pulse rate was counted for two minutes. 4. After the pulse rate had returned to normal, the subject again stepped up and down for one minute. The rate of stepping was forty for the male subject and thirty five for the female. 5. Immediately following the exercise period, a resting pulse rate was taken for two minutes. This pulse rate was divided by the

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[61]Arthur M. Master and Enid T. Oppenheimer, "A Simple Exercise Tolerance Test for Circulatory Efficiency with Standard Tables for Normal Individuals," American Journal of Medical Science, XCVII (1929), p. 223. as reported by C. H. McCloy, Tests and Measurements in Physical Education, New York, Appleton-Century-Crofts, Inc., 1939, p. 250.

[62]W. W. Tuttle, and John Charlesworth, "The Use of the Pulse Ratio Test for Rating Physical Efficiency," Research Quarterly, X (March, 1939), p. 150.

resting pulse rate. 6. The number of steps to reach a pulse ratio of 2.5 was the index of fitness. The index of fitness was determined by use of a formula computation.

Gallagher and Bronha[63] developed a step test in the Harvard Fatigue Laboratory during World War II. From the Harvard Step Test came most of the step tests in use at the time of this study. There were two forms of the test. In the long form the subject stepped up and down on a twenty-inch bench at a rate of thirty steps per minute. The test continued for as long as the subject was able, up to the time limit of five minutes. A pulse count was taken from one to one and one-half, two to two and one-half, and three to three and one-half minutes following the completion of exercises. The physical fitness was computed from the following formula:

$$\text{Index} = \frac{\text{duration of exercise in seconds X 100}}{\text{2(sum of pulse counts in recovery)}}.$$

Norms were established for comparative purposes. In the short form of the test, the same procedure was used as for the long form; however, the pulse rate was taken for only one and one-half minutes after exercise. The score was

$$\text{Index} = \frac{\text{duration of exercise in seconds X 100}}{\text{5.5 X pulse count}}.$$

Norms were also established for this test.

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[63]L. Bronha and J. Gallagher, "The Step Test: A Simple Method of Measuring Physical Fitness for Muscular Work in Young Men," Research Quarterly, XIV (March, 1943), p. 31.

In 1943, Gallagher and Bronha introduced a modification of the Harvard Step Test for use with high school boys[64] and another modification for use with high school girls.[65] The tests were similar to the original with two exceptions, the step height is varied for boys and girls, and the time duration of the test has been reduced to four minutes for both groups.

Cureton[66] devised a Progressive Pulse Ratio Test to determine the physical fitness of adults males. This test was a modification of the Harvard Step Test. The step height was seventeen inches and to stepping was done as follows, The subject underwent five one-minute bouts, with an increasing step rate of 12, 18, 24, 30, and 36 steps per minute. After each one-minute bout, the heart rate was taken for a two-minute recovery period. The pulse rates were plotted on a chart.

Skubic and Hodgkins[67] proposed yet another revision of the Harvard Test, this time intended for college women. The test duration was three minutes on an 18-inch bench at a rate

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[64] J. R. Gallagher, and L. Bronha, "A Simple Method of Testing the Physical Fitness of Boys," Research Quarterly, XIV (March, 1943), p. 23.

[65] J. R. Gallagher and L. Bronha, "A Functional Fitness Test for High School Firls," Journal of Health, Physical Education and Recreation, XIV (December, 1943), p. 517.

[66] W. W. Waxman, "Physical Fitness Development for Adults in the Y. M. C. A.," Exercise and Fitness, The Athletic Institute, 1960, p. 183.

[67] Vera Skubic and Jean Hodgkins, "Cardiovascular Efficiency Tests for Girls and Women, Research Quarterly, XXV (May, 1963), p. 191.

of 24 steps per minute. The pulse rate was taken for 30 seconds after a rest period of one minute following the exercise. The authors developed national norms for their test.

The possibilities of a graduational step were investigated by Nagle, Balke and Naughton.[68] A device was constructed on which the level of the step could be raised as the subjects continued stepping at the prescribed rate.

Kurucz[69] devised the Ohio State University Cardiovascular Fitness Test which was a submaximal test of physical fitness. The test involved stepping on a dual-level bench with levels of fifteen and twenty inches. The test was comprised of eighteen fifty-second periods during which the subject alternated a thirty-second work period with a twenty-second rest period. During the rest period, the pulse rate was taken between the fifth and fifteenth seconds. The test was terminated when the subject's heart rate reached 150 beats per minute, or at the completion of the test, whichever came first. The work loadings were (1) six innings at 24 steps per minute of the 15-inch bench; (2) six innings at 30 steps per minute on the 15-inch bench; (3) six innings at 30 steps per minute on the 20-inch bench. Scoring was accomplished by determining the

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[68]F. J. Nagle, B. Balke, and J. P. Naughton, "Graduational Step for Assessing Work Capacity," <u>Journal of Applied Physiology</u>, XX (July, 1965), p. 745.

[69]R. L. Kurucz, "Construction of the Ohio State University Cardiovascular Fitness Test," unpublished Doctoral Dissertation, The Ohio State University, 1967.

number of innings completed, with a higher number indicating a better physical fitness.

Woods[70] established validation of the Ohio State University Cardiovascular Fitness Test. He found 0.538 coeffieient of correlation between the test and maximal oxygen consumption, with a reliability of 0.728.

Shephard[71] reported a progressive step test for predictions of aerobic work capacity. The subject was required to climb a flight of two nine-inch steps at a progressively increasing rate for eleven minutes. The speed was controlled by a metronome, and the pluse rate was recorded by telemetry or electrocardiogram.

A perusal of the related research appears to indicate conflicting evidence concerning the results of cardiovascular testing. Correlation between many of the tests were low, and in some cases,the tests themselves were suspect. Tests dealing specifically with the cardiovascular fitness of women were few. Research in this area was limited. There would appear to be a need for valid, reliable, conveniently administrated tests for evaluating the physical fitness of women.

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[70]Francis J. Woods, "The Validation of the Ohio State University Cardiovascular Fitness Test," unpublished Doctoral Dissertation, The Ohio State University, 1968.

[71]Shephard, op. cit., p. 744.

CHAPTER III

PROCEDURES OF THE STUDY

The subjects selected for this study included one hundred female students enrolled in five sections of the women's physical education service program at North Texas State University, Denton, Texas, during the Fall Semester, 1969. Their ages ranged from seventeen to twenty-one years, with the exception of two subjects. One of these subjects was twenty-two years of age and the other was twenty-four years of age. There were originally one hundred and six subjects who volunteered to be tested; however, six students did not complete the testing program, so their test results were omitted from the study.

The classes from which the subjects volunteered were selected for their similarity. The nature of the activity was considered, and classes selected to supply subjects for this study included activities which would be least likely to have an outside effect on the study. In order to lessen the effects of outside influences, classes which stressed conditioning exercises which would tend to contribute to physical conditioning, were avoided. All classes from which perticipants were selected met in the afternoon between two and five o'clock. Therefore, the effect of the time element was minimized.

Laboratory conditions during the testing program were uniform. The temperature of the laboratory was kept at seventy-five degrees Fahrenheit, plus or minus five degrees. Physical destractions which would affect the concentration of the participants during the testing period were eliminated.

The subjects from each class were assigned arbitrarily to groups consisting of six subjects in each group. It had been previously determined by preliminary testing that due to time limitations a maximum of six subjects could be tested during one class period.

Orientation Procedures

The subjects who volunteered to participate in this study were admitted, by class sections, to the research laboratory for an orientation session. During the orientation period, instructions were given as to the test precedures and purposes. Demonstrations of test equipment were presented, with particular emphasis on the operation of the E. and M. Physiograph, which was to be used to monitor heart rate during the testing. Participants were encouraged to ask questions during the orientation period to familiarize themselves with the equipment to be used. The procedure was followed so that any apprehensions regarding the physiograph and other unfamiliar equipment could be alleviated. Previous testing had revealed that often nervousness on the part of the subjects would have the effect of increasing the heart rate and thus affect the results of the tests.

Testing Procedure

Testing was done during physical education class time. Assignments of designated test times were made to each group of six students from each class. On the designated days each group reported directly to the laboratory to be tested before going to class. The subjects were requested to refrain from eating, smoking or engaging in any strenuous activity for one hour before their designated test time.

Before the initial testing session, each subject's heart rate was monitored on the E. and M. Physiograph. This was done in order to establish a "base line" of cardiac performance and a resting pulse rate. A second function was accomplished in that each subject was thus accustomed to having the heart rate monitored by the physiograph. In this and in subsequent testing sessions, all testing, physiological monitoring and evaluation of results was done by the researcher.

Electrode Placement. The E. and M. Physiograph used in the testing program required a three-electrode contact for the sending unit, one positive, one negative, and one ground contact. Electrode placement was as follows:

1. The positive electrode was placed on the manubrium section of the sternum.

2. The negative electrode was placed on the right side of the subject immediately below the eleventh rib.

3. The ground electrode was placed on the left side immediately below the eleventh rib.

Each subject was tested four times in the following order: first testing session, Skubic-Hodgkins Cardiovascular Efficiency Test; second session, Astrand-Ryhming Bicycle Ergometer Test; third session, Modified Fitness Test; fourth session, a repeat of the Modified Fitness Test.

Description of the Instruments

Three instruments were used in this study: the Skubic-Hodgkins Cardiovascular Efficiency Test, the Astrand-Ryhming Bicycle Ergometer Test, and the Modified Fitness Test.

Skubic-Hodgkins Cardiovascular Efficiency Test.[1] This test was developed in 1963 by the authors whose name it bears. The test, for which the authors developed national norms, was a modification of the Harvard Step Test and was intended for use in testing college women. The test, requiring three minutes for administration, involved stepping up on to an eighteen-inch step, at the rate of twenty-four steps per minute. Following the three-minute period of testing, the subject was allowed a one-minute rest period in a sitting position after which the pulse rate was taken for thirty seconds.

Astrand-Ryhming Bicycle Ergometer Test.[2] Developed in 1954, this test since its publication has become one of the

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[1]Vera Skubic and Jean Hodgkins, "Cardiovascular Efficiency Tests for Girls and Women," Research Quarterly, XXXV (July, 1965), p. 191.

[2]P. O. Astrand and Irma Ryhming, "A Nomogram for Calculation of Aerobic Capacity (physical fitness) from Pulse Rate During Submaximal Work," Journal of Applied Physiology, VII (January, 1954), p. 218.

most widely utilized of the tests for cardiovascular fitness. The test required the pedaling of a bicycle ergometer at the rate of 300, 600, or 900 kilogram/meters per minute for six minutes. Norms were established over a period of four years for each of the work loadings, and were international in scope.

Modified Fitness Test. This test was developed for use in this study. It was a modification of the Skubic-Hodgkins Cardiovascular Efficiency Test including provisions for work equivalency among individuals of varying stature. The time duration of the test was three minutes with a step rate of twenty-four steps per minute, the height of the step used by the individual being determined by the ponderal index. A chart showing the step height to be used for each subject is presented in Appendix A.

First Testing Session

1. During the first testing session, each subject was given the Skubic-Hodgkins Cardiovascular Efficiency Test.

2. The subject was commanded to "begin" the test. The step rate of twenty-four steps per minute was synchronized by use of an electronic notronome set at ninety-six beats per minute. This produced a "click" for each movement of the subjects' feet necessary to maintain the prescribed step rate.

3. Heart rate was monitored by use of an E. and M. Physiograph.

4. At the completion of the three-minute test duration,

the subject was commanded to "stop and sit down," so that the recovery period would begin immediately.

5. The heart rate was monitored for a recovery period of ninety seconds.

6. At the completion of the recovery period, the subject was dismissed and allowed to return to class.

Second Testing Session

1. During the second testing session the Astrand-Ryhming Ergometer Test was administered to each subject.

2. In order to maintain the work load of 600 kilogram/meters/minute, the Monarch Bicycle Ergometer was set at a loading of two Kilopods[3] and the speed maintained was fifty revolutions per minute. The revolution speed was established by an electronic nitronome set at one hundred beats per minute. The signal omitted was used to synchronize foot movement on the bicycle pedals.

3. The heart rate during the test was monitored by use of an E. and M. Physiograph.

4. At the completion of the six-minute test period the subject was commanded to "halt."

5. Heart rate was monitored for a ninety-second recovery period.

6. After the recovery period the subject was allowed to return to class.

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[3]Kilopod - One kilopod is the force acting on the mass of one kilogram at the normal acceleration of gravity.

Third Testing Session

1. During the third testing session, the Modified Fitness Test was administered to each subject.

2. Each subject was assigned to a predetermined step height relative to her ponderal index. (See Appendix A)

3. On command, the subject began stepping at the rate of twenty-four steps per minute. The rate was synchronized by the use of the electric metronome set at ninety-six beats per minute. The signal indicated each foot movement necessary to maintain the predetermined rate of stepping.

4. Heart rate was monitored by use of the E. and M. Physiograph.

5. At the completion of the three-minute test, the subject was allowed to stop.

6. Heart rate was monitored during the ninety second recovery period.

7. After completion of the recovery period the subject was allowed to return to class.

Fourth Testing Session

The fourth testing session consisted of a repetition of the conditions of test session three. This was done in order to establish reliability of the Modified Fitness Test. Since time duration was an element of consideration in the testing program, each subject was scheduled so that all tests were completed within three weeks.

Procedures for Treating Data

The heart rates for each subject on each of the four tests were recorded as follows: (1) heart rate at the completion of the test, (2) heart rate during the recovery period at intervals of thirty, sixty, and ninety seconds. The raw data were transferred to data processing punch cards for use in the I. B. M. Data Processing Center.

Hypotheses one and two were tested in the null form by the analysis of covariance technique. Hypotheses three, four, five, and six were tested in the null form by use of the Fisher's *t* test for significant difference between means. The .05 level of significance was used for acceptance or rejection of all hypotheses.

CHAPTER IV

RESULTS OF THE STUDY

The data for this study, collected and tested as indicated in Chapter III are presented in this Chapter.

Six basic hypotheses were tested in this study. Hypothesis one stated that there would be a significant difference between the results of the adminstration of the Skubic-Hodgkins Cardiovascular Efficiency Test and the results of the administraion of the Modified Fitness Test relative to maximum heart rate attained in each of the following:

a. The Modified Fitness Test, Division I (15-inch step height) and the _Skubic-Hodgkins Cardiovascular Efficiency Test_;

b. The Modified Fitness Test, Division II (16-inch step height) and the _Skubic-Hodgkins Cardiovascular Efficiency Test_;

c. The Modified Fitness Test, Division III (17-inch step height) and the _Skubic-Hodgkins Cardiovascular Efficiency Test_;

d. The Modified Fitness Test, Division V (19-inch step height) and the _Skubic-Hodgkins Cardiovascular Efficiency Test_.

The second hypothesis stated that there would be a significant difference between the recovery heart rate during the sixty-second recovery interval follwoing the completion of the test in each of the four divisions of the Modified Fitness Test shown in Hypothesis one and the _Skubic-Hodgkins Cardiovascular Efficiency Test_. Hypothesis three stated a significant difference between the results obtained from the *Skubic-Hodgkins Cardiovascular Efficiency Test* and those obtained from the *Astrand-Ryhming Bicycle Ergometer Test* for determining physical fitness. Hypothesis four said there would be no significant difference between the results of the administration of the *Skubic-Hodgkins Cardiovascular Efficiency Test* and the results of the administration of the Modified Fitness Test, Division IV, relative to maximum heart rate attained during the time interval of the test. Hypothesis five stated there would be no significant difference between the recovery heart rate during the sixty-second recovery interval following the completion of the *Skubic-Hodgkins Cardiovascular Efficiency Test* and the Modified Fitness Test, Division IV. Hypothesis six stated that there would be no significant difference between the results obtained from the Modified Fitness Test and the *Astrand-Ryhming Bicycle Ergometer Nomogram* for determining physical fitness.

Hypothesis one and hypothesis two were tested in the null form by use of analysis of covariance. Hypotheses three, four, five, and six were tested in the null form by use of the Fisher's *t* test for significant difference between means. The research hypotheses were accepted at the .05 level of significance.

In order to insure consistency of results, the order of testing for all subjects included in the study was as follows: (1) *Skubic-Hodgkins Cardiovascular Efficiency Test*, (2) *Astrand-*

Ryhming Bicycle Ergometer Test, and (3) Modified Fitness Test. A re-test of the Modified Fitness Test was administered to all subjects one week following the first adminstration of the Modified Fitness Test. Unless the subject completed all three tests and the re-test on the Modified Fitness Test, the results were omitted from the study.

Findings Related to the Hypotheses

Hypothesis One. Hypothesis one stated that there would be a significant difference between the results of the administration of the Skubic-Hodgkins Cardiovascular Efficiency Test and the results of the administration of the Modified Fitness Test relative to maximum heart rate attained in each of the following:

a. The Modified Fitness Test, Division I, and the Skubic-Hodgkins Cardiovascular Efficiency Test;

b. The Modified Fitness Test, Division II, and the Skubic-Hodgkins Cardiovascular Efficiency Test;

c. The Modified Fitness Test, Division III, and the Skubic-Hodgkins Cardiovascular Efficiency Test;

d. The Modified Fitness Test, Division V, and the Skubic-Hodgkins Cardiovascular Efficiency Test.

The data relative to the hypothesis one are presented in Table I according to the form suggested by Travers.[1]

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[1]Robert M. W. Travers, An Introduction to Educational Research (3rd Edition), New York, The MacMillian Company, 1969, p. 365-367.

TABLE I

ANALYSIS OF COVARIANCE OF THE MAXIMUM HEART RATE
ATTAINED ON THE
SKUBIC-HODGKINS CARDIOVASCULAR EFFICIENCY TEST
AND THE MODIFIED FITNESS TEST (N=55)

Source of Variation	Residuals			F Ratio
	Degrees of Freedom	Sum of Squares	Mean Squares	
Total	53	3743.19		6.17
Within	50	2731.78	54.63	
Difference	3	1011.40		

Adjusted Means:
Group
1. 170.51
2. 171.99
3. 173.46
4. 186.25

Analysis of covariance techniques were applied to the fifty-five subjects to whom hypothesis one was applicable. It should be noted that the remaining subjects involved in the study comprised Modified Fitness Test, Division IV, and these data were treated in hypothesis four.

The total mean heart rate of the Skubic-Hodgkins Cardiovascular Efficiency Test was 184.43 beats per minute with a standard deviation of 12.49. The total mean heart rate of the Modified Fitness Test was 174.30 beats per minute with a standard deviation of 9.53. The F ratio required for significance at the .05 level was 1.51. The F ratio for hypothesis one was found to be 6.19, which was highly significant beyond the .001 level. The research hypothesis of significant difference between the Skubic-Hodgkins Cardiovascular Efficiency Test and the Modified Fitness Test, Divisions I, II, III, and V was accepted. Since the F ratio for hypothesis one was found to be significant, the data were further analyzed by the application of the Fisher *t* test for significant difference between means. In each instance the *t* value between the Skubic-Hodgkins Cardiovascular Efficiency Test and the Modified Fitness Test was found to be significant beyond the .05 level of significance. The date pertaining to the application of the Fisher *t* test to the data on hypothesis one are found in Table II.

Hypothesis Two. Hypothesis two stated that there would be a significant difference between the recovery heart rate during the sixty-second recovery interval following the completion of the test in each of the following:

a. The Modified Fitness Test, Division I (15-inch step height) and the Skubic-Hodgkins Cardiovascular Efficiency Test;

b. The Modified Fitness Test, Division II, (16-inch step height) and the Skubic-Hodgkins Cardiovascular Efficiency Test;

c. The Modified Fitness Test, Division III, (17-inch step height) and the Skubic-Hodgkins Cardiovascular Efficiency Test;

d. The Modified Fitness Test, Division V, (19-inch step height) and the Skubic-Hodgkins Cardiovascular Efficiency Test.

The data relative to hypothesis two are presented in Table III.

TABLE II

MEANS, STANDARD DEVIATIONS, AND THE *t* VALUES BETWEEN THE SKUBIC-HODGKINS CARDIOVASCULAR EFFICIENCY TEST AND THE MODIFIED FITNESS TEST (N=55)

Tests	Means	Standard Deviations	*t*
Skubic-Hodgkins Cardiovascular Efficiency Test	188.45	10.84	6.63*
Modified Fitness Test, Division I	172.90	7.19	
Skubic-Hodgkins Cardiovascular Efficiency Test	186.12	5.67	6.81*
Modified Fitness Test, Division II	173.00	9.28	
Skubic-Hodgkins Cardiovascular Efficiency Test	187.35	11.55	5.70*
Modified Fitness Test, Division III	175.20	10.71	
Skubic-Hodgkins Cardiovascular Efficiency Test	168.25	14.13	-2.76**
Modified Fitness Test, Division V	176.62	8.97	

*Significant beyond the .001 level.
**Significant beyond the .02 level.

TABLE III

ANALYSIS OF COVARIANCE OF THE RECOVERY HEART RATE ATTAINED ON THE SKUBIC-HODGKINS CARDIOVASCULAR EFFICIENCY TEST AND THE MODIFIED FITNESS TEST (N=55)

Source of Variation	Residuals			F Ratio
	Degrees of Freedom	Sum of Squares	Mean Square	
Total	53	7176.21		4.56
Within	50	5632.82	112.65	
Difference	3	1546.39	514.46	

Adjusted Means:
Group
1. 120.76 3. 129.70
2. 131.89 4. 140.16

The total mean recovery heart rate of the *Skubic-Hodgkins Cardiovascular Efficiency Test* was 137.76 with a standard deviation of 14.34. The total mean recovery heart rate of the Modified Fitness Test was 130.07 with a standard deviation of 11.76. Analysis of covariance technique when applied to the data of hypothesis two yielded an F ratio of 4.56. The F ratio required for significance at the .05 level was 1.51.

The F ratio of 4.56 was highly significant beyond the .001 level, therefore on the basis of the high level of signivicance, the research form of hypothesis two indicating a significant difference between the recovery heart rate of individuals on the Skubic-Hodgkins Cardiovascular Efficiency Test and the Modified Fitness Test, Divisions I, II, III, and V was accepted. The F ratio was highly significant beyond the .001 level, therefore the Fisher t test was applied to the mean scores to determine the significant difference between means. The data are presented in Table IV.

Hypothesis Three. Hypothesis three stated there would be a significant difference between the results obtained from the Skubic-Hodgkins Cardiovascular Efficiency Test and those obtained from the Astrand-Ryhming Bicycle Ergometer Nomogram for determining physical fitness. For comparison purposes both instruments are based on a 0-100 scale with a higher index number indicating a higher level of fitness. The results of the data showed a mean index value of 47.66 for the Skubic-Hodgkins Cardiovascular Efficiency Test, with a standard deviation of 5.67. This indicated that approximately sixty-eight per cent of all subjects would score between 41.88 and 53.22 on the 0-100 scale. The mean index value on the Astrand-Ryhming Bicycle Ergometer Test was 49.30 with a standard deviation of 9.30. This indicated that approximately sixty-eight per cent of the individuals tested were in the range 40.00 to 58.60. These data when further analyzed yielded a t ratio of -1.45.

TABLE IV

MEANS, STANDARD DEVIATIONS, AND THE *t* VALUES
BETWEEN THE
SKUBIC-HODGKINS CARDIOVASCULAR EFFICIENCY TEST
AND THE
MODIFIED FITNESS TEST
REGARDING RECOVERY HEART RATE (N=55)

Tests	Means	Standard Deviations	*t*
Skubic-Hodgkins Cardiovascular Efficiency Test	141.81	12.63	
			5.24*
Modified Fitness Test, Division I	122.90	10.84	
Skubic-Hodgkins Cardiovascular Efficiency Test	135.25	12.67	
			1.55**
Modified Fitness Test, Division II	131.00	11.00	
Skubic-Hodgkins Cardiovascular Efficiency Test	141.70	12.16	
			5.58*
Modified Fitness Test, Division III	131.10	11.47	
Skubic-Hodgkins Cardiovascular Efficiency Test	124.62	15.17	
			-1.21**
Modified Fitness Test, Division V	135.50	10.72	

*Significant beyond the .001 level.
**No significant difference.

The t ratio of -1.45 is not significant to the reauired .05 level of significance; therefore, the research form of hypothesis four was rejected. A further analysis of these data is presented in Table V.

TABLE V

MEANS, STANDARD DEVIATIONS, AND THE t VALUE
BETWEEN THE
SKUBIC-HODGKINS CARDIOVASCULAR EFFICIENCY TEST
AND THE
ASTRAND-RYHMING BICYCLE ERGOMETER TEST
BASED ON 0-100 VALUE SCALE (N=100)

Tests	Means	Standard Deviations	t
Skubic-Hodgkins Cardiovascular Efficiency Test	47.66	5.67	-1.45*
Astrand-Ryhming Bicycle Ergometer Test	49.30	9.30	

*No significant difference.

Hypothesis Four. This hypothesis stated there would be no significant difference between the results of the administration of the Skubic-Hodgkins Cardiovascular Efficiency Test and the results of the administration of the Modified Fitness Test, Division IV, relative to heart rate attained during the time interval of the test. It should be noted that the step height on both tests was eighteen inches. Since the factors of step rate (24 per minute) and time (three minutes were the same for both tests, it follows that the two tests were identical. The results of the two thest were that the Skubic-Hodgkins Cardiovascular Efficiency Test mean maximum heart rate attained was 178.66 with a standard deviation of 11.27. The same forty-five subjects tested on the Modified Fitness Test, Division IV, showed a mean maximum heart rate of 178.28 with a standard deviation of 10.18. These data yielded a *t* value of 0.53. This was well below the level necessary for significance. The research hypothesis of no significant difference between the two tests was accepted. Further information concerning hypothesis four is presented in Table VI.

Hypothesis Five. This hypothesis also dealt with a negative relationship between the Skubic-Hodgkins Cardiovascular Efficiency Test and the Modified Fitness Test, Division IV, and stated that there was no significant difference between the recovery heart rate of the two tests. On the Skubic-Hodgkins Cardiovascular Efficiency Test the mean recovery heart rate was 134.60 with a standard deviation of 11.41. The same forty-five subjects showed a recovery heart rate mean of 135.86 on the Modified Fitness Test, Division IV. The standard deviation was 12.67. The *t* value of 0.69 was not significant to the required .05 level. It was therefore concluded that there was no significant difference between the recovery rate

TABLE VI

MEANS, STANDARD DEVIATIONS, AND THE *t* VALUE
BETWEEN THE
SKUBIC-HODGKINS CARDIOVASCULAR EFFICIENCY TEST
AND THE
MODIFIED FITNESS TEST, DIVISION IV
REGARDING MAXIMUM ATTAINED HEART RATE (N=45)

Tests	Means	Standard Deviations	*t*
Skubic-Hodgkins Cardiovascular Efficiency Test	178.66	11.27	0.53*
Modified Fitness Test, Division IV	178.28	10.18	

*No significant difference.

of the two tests. The research form of hypothesis five was accepted. The data from hypothesis five are found in Table VII.

Hypothesis Six. Hypothesis six stated that there would be no significant difference between the results obtained from the *Astrand-Ryhming Bicycle Ergometer Nomogram* for determining physical fitness. The 0-100 value scale was developed for the Modified Fitness Test in order to compare the results of the two tests. The results of the data showed a mean index value of 49.30 for the *Astrand-Ryhming Bicycle Ergometer Test* with

TABLE VII

MEANS, STANDARD DEVIATIONS, AND THE *t* VALUE
BETWEEN THE
SKUBIC-HODGKINS CARDIOVASCULAR EFFICIENCY TEST
AND THE
MODIFIED FITNESS TEST, DIVISION IV
REGARDING HEART RATE DURING RECOVERY (N=45)

Tests	Means	Standard Deviations	*t*
Skubic-Hodgkins Cardiovascular Efficiency Test	134.60	11.41	0.69*
Modified Fitness Test, Division IV	135.86	12.67	

*No significant difference.

Modified Fitness Test was 49.80 with a standard deviation of 4.68. The *t* value of -0.54 was not significant to the required .05 level. The research hypothesis of no significant difference between the results of the Astrand-Ryhming Bicycle Ergometer Nomogram and the results of the Modified Fitness was accepted. A further analysis of the data of hypothesis six is presented in Table VIII.

TABLE VIII

MEANS, STANDARD DEVIATIONS, AND THE *t* VALUE BETWEEN THE ASTRAND-RYHMING BICYCLE ERGOMETER TEST AND THE MODIFIED FITNESS TEST BASED ON THE 0-100 VALUE SCALE (N=100)

Tests	Means	Standard Deviations	*t*
Astrand-Ryhming *Bicycle Ergometer Test*	49.30	9.30	-0.54*
Modified Fitness Test	49.80	4.68	

*No significant difference.

In order to determine reliability of the Modified Fitness Test, each individual was subjected to a re-test one week following the original testing session. The results were as follows: Modified Fitness Test, first administration yielded a mean heart rate of 176.00 beats per minute. The re-test of the Modified Fitness Test showed a mean heart rate of 175.56. This gave a reliability factor in excess of .98. Further analysis of these data is presented in Table IX.

TABLE IX

RELIABILITY FACTOR OF THE MODIFIED FITNESS TEST
(N=100)

Tests	Means	Standard Deviations	r
Modified Fitness Test#1	175.33	8.33	.98
Modified Fitness Test #2	176.00		

Summary

Hypotheses one, two, four, five, and six were all found to be tenable, with a significance in excess of the .05 level. Hypothesis three was rejected when the data yielded no significant difference. The Modified Fitness Test was found to have a reliability coefficient of .98.

CHAPTER V

SUMMARY, FINDINGS CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to develop a cardiovascular fitness test for college women which would include an index of work equivalency. Specifically, the testing procedure sought to determine if the ponderal index of the individual, based on a formula involving height and weight, was a factor in testing cardiovascular fitness on a step test. The study sought also to establish the validity and reliability of a cardiovascular fitness test based on work equivalency. The study included the development of charts for use in administering the Modified Fitness Test and norms for determining the level of cardiovascular fitness of the subjects tested.

Subjects for this study included one hundred volunteers from the women's physical education activity classes at North Texas State University during the Fall Semester, 1969.

The instruments used were the Skubic-Hodgkins Cardiovascular Efficiency Test, the Astrand-Ryhming Bicycle Ergometer Test, and the Modified Fitness Test, a test involving the use of the theory of work equivalency which was developed for this study. (See Appendix A)

To achieve the basic purpose of this study, six hypotheses were developed and tested statistically. These hypotheses stated that

1. There would be a significant difference between the results of the administration of the Skubic-Hodgkins Cardiovascular Efficiency Test and the results of the administration of the Modified Fitness Test relative to maximum heart rate attained in each of the following:

a. The Modified Fitness Test, Division I, (15-inch step height) and the Skubic-Hodgkins Cardiovascular Efficiency Test;

b. The Modified Fitness Test, Division II (16-inch step height) and the Skubic-Hodgkins Cardiovascular Efficiency Test;

c. The Modified Fitness Test, Division III (17-inch step height) and the Skubic-Hodgkins Cardiovascular Efficiency Test;

d. The Modified Fitness Test, Division V (19-inch step height) and the Skubic-Hodgkins Cardiovascular Efficiency Test.

2. There would be no significant difference between the recovery heart rate during the sixty-second recovery interval following the completion of the test in each of the following:

a. The Modified Fitness Test, Division I, and the Skubic-Hodgkins Cardiovascular Efficiency Test;

b. The Modified Fitness Test, Division II, and the Skubic-Hodgkins Cardiovascular Efficiency Test;

c. The Modified Fitness Test, Division III, and the Skubic-Hodgkins Cardiovascular Efficiency Test;

d. The Modified Fitness Test, Division V, and the Skubic-Hodgkins Cardiovascular Efficiency Test.

3. There would be a significant difference between the results obtained from the Skubic-Hodgkins Cardiovascular Efficiency Test and in the results obtained from the Astrand-Ryhming Bicycle Ergometer Nomogram for determining physical fitness.

4. There would be no significant difference between the results of the administration of the Skubic-Hodgkins Cardiovascular Test and the results of the administration of the Modified Fitness Test, Division IV, relative to maximum heart rate attained during the time interval of the test.

5. There would be no significant difference between the recovery heart rate during the sixty-second recovery interval following the completion of the Skubic-Hodgkins Cardiovascular Efficiency Test and the Modified Fitness Test, Division IV.

6. There would be no significant difference between the results obtained from the Modified Fitness Test and those obtained from the Astrand-Ryhming Bicycle Ergometer Nomogram for determining physical fitness.

Through the use of data processing equipment, coefficients of F were developed for analysis of covariance to test hypotheses one and two. The Fisher t test for correlated samples was used to test for significance of difference between the mean scores of hypotheses three, four, five, and six. The .05 level of significance was used to accept or reject the research hypotheses. These data, with the necessary interpretations, were presented in tabular form.

Findings

In testing hypothesis one, it was found that there was a significant difference between the maximum heart rate attained on the Modified Fitness Test as compared to the maximum heart rate attained on the *Skubic-Hodgkins Cardiovascular Efficiency Test*. The mean difference was 6.85 beats per minute.

Of great importance is the distribution of the heart rate around the mean heart rate of the two tests. The data for the *Skubic-Hodgkins Cardiovascular Efficiency Test*, which has one step height of eighteen inches, and the data for the Modified Fitness Test, which has step heights of fifteen, sixteen, seventeen eighteen and nineteen inches are presented in Table X. The distribution of scores, by groups, indicates the equalizing effect on individual test scores provided by the Modified Fitness Test, which compensates for work equivalency by means of multiple step heights. On the basis of the F ratio of 6.17, which was highly significant beyond the .001 level, obtained when analysis of covariance techniques were applied to hypothesis one, the research form of hypothesis one was accepted as tenable.

In testing hypothesis two, it was found that the recovery heart rate on the Modified Fitness Test was significantly lower than the recovery rate on the *Skubic-Hodgkins Cardiovascular*

TABLE X

COMPARISON OF THE MEAN SCORES AND THE DEVIATIONS FROM THE MEAN SCORE FOR THE FIVE GROUPS TESTED ON THE SKUBIC-HODGKINS CARDIOVAXCULAR EFFICIENCY TEST AND THE MODIFIED FITNESS TEST (N=100)

	Skubic-Hodgkins Cardiovascular Efficiency Test			Modified Fitness Test		
Total Mean	182.05			175.20		
Group	Step Height	Group Mean	Dev. from Total Mean	Step Height	Group Mean	Dev. from Total Mean
1	18"	190.07	+8.31	15"	172.90	-2.30
2	18"	186.12	+4.36	16"	173.00	-2.20
3	18"	187.15	+5.39	17"	175.20	+/- 0
4	18"	178.66	-3.10	18"	178.28	+3.08
5	18"	168.25	-13.51	19"	176.62	+1.42

Efficiency Test. Application of the techniques of analysis of covariance yeilded an F ratio of 4.56. The F ratio of 4.56 was significant beyond the level necessary for the .001 level of significance, therefore, the research form of hypothesis two indicating a significant difference between the recovery rates attained by subjects on the two tests, was accepted.

In testing hypothesis three, it was found that there was no significant difference between the results of the *Skubic-Hodgkins Cardiovascular Efficiency Test* and those of the *Astrand-Ryhming Bicycle Ergometer Nomogram* for determining the physical fitness of the subjects tested. Hypothesis three was rejected on the basis of these data. It should be noted that 45% of the 100 subjects involved in hypothesis three were included in Division IV for who no significant difference was expected. The Fisher *t* test yeild was 1.45 compared to 1.96 required for significance.

It was found that there was no significant difference between the maximum heart rate attained on the *Skubic-Hodgkins Cardiovascular Efficiency Test* and the Modified Fitness Test, Division IV. As a result of these findings, the research form of hypothesis four was accepted.

When the Fisher *t* test was applied to the data for hypothesis five, it was found that there was no significant difference between the recovery rate of the *Skubic-Hodgkins Cardiovascular Efficiency Test* and the Modified Fitness Test, Division IV. On the basis of these data, the research form of hypothesis five was accepted as tenable.

In testing hypothesis six, it was found that there was no significant difference between the results of the *Astrand-*

Ryhming Bicycle Ergometer Nomogram and the Modified Fitness Test for determining physical fitness of the subjects tested. On the basis of these finding, hypothesis six was accepted as stated in the research form.

One further finding of interest was the comparison of the mean heart rate range for the Astrand-Ryhming Bicycle Ergometer Test and the Modified Fitness Test. The similarity of the distribution about the mean heart rate was further re-enforcement of the basic contention of study: that height and weight did have an effect on the performance of the individual on a test of cardiovascular fitness. These data are presented in Table XI.

TABLE XI

COMPARISON OF THE MEAN SCORES AND THE DEVIATIONS FROM THE MEAD SCORE FOR THE FIVE GROUPS TESTED ON THE ASTRAND-RYHMING BICYCLE ERGOMETER TEST AND THE MODIFIED FITNESS TEST (N=100)

	Astrand-Ryhming Bicycle Ergometer Test		Modified Fitness Test		
Total Mean Heart Rate	166.09		175.20		
Group	Group Mean	Dev. from Total Mean	Group Mean	Dev. from Group Mean	Step Height
1	164.63	-1.46	172.00	-3.20	15"
2	165.50	-1.59	173.00	-2.20	16"
3	169.20	+3.11	175.20	+/- 0	17"
4	168.88	+2.79	178.28	+3.08	18"
5	163.25	-2.84	176.62	+1.42	19"

Conclusion

Within the scope and limitations of this investigation, the following conclusions were drawn:

1. Results of the testing program revialed that the Modified Fitness Test was valid: that work equivalency does have influence on the subjects with respect to physical fitness.

2. Since there was a closely distributed intergroup mean heart rate found on the Modified Fitness Test, it was further illustrated that, within the limits of this study, the five step heights provided the necessary variation to produce work equivalency.

3. The purpose of the development of the Modified Fitness Test was to provide a step test which sould eliminate the effects of the height and weight of the individual in so far as was possible and still maintain practicality for use as a class room diagnostic tool. It would seem that this task has been successfully achieved, particularly when the intergroup scores of the Modified Fitness Test and the *Astrand-Ryhming Bicycle Ergometer Test* are compared. It should be noted with respect to the *Astrand-Ryhming Bicycle Ergometer Test* that the effect of the height and weight of the individual are nullified. The effect of height, and thus favorable anatomical angle of work, was eliminated because the bicycle seat was adjustable to the leg length of all subjects. Since all subjects were seated, the effect of weight was nullified. These same factors were considerations involved in the con-

struction of the Modified Fitness Test. It should be further noted that the Modified Fitness Test was not considered to be a panacea, but rather an improvement of existing step tests. The problem of work equivalency could only be solved completely by use of an infinite number of step heights. This would eliminate the usefullness of the test for the classroom and relegate it to use as a laboratory tool.

5. It was further concluded that one hundred subjects was an insufficient number of cases on which to develop reliable norms for the Modified Fitness Test. More subjects should be included in the development of norms in order to provide a greater diversity of individual stature combined with various levels of cardiovascular fitness.

Recommendations

Within the scope and limitations of this study, the following recommendations were made:

1. This study should be replicated, with a suitable number of subjects, in a laboratory equipped for gas analysis in order to study basal metabolism of subjects on the Modified Fitness Test. By gas analysis, the exact cost interms of oxygen consumption of each test could be determined.

2. This study was developed to apply only to college women. The stature variation among men is equal to, or possibly exceeds that found among women. Research should be done to develop a step test for men based on step height, using a variation in the height of the step relative to the ponderal

index of the individual man.

3. With reference to the Modified Fitness Test, further work should be done to develop norms for the test. The data on one hundred individuals is too limited to make prejections for norms for vast groups. It is suggested that women from more than one institution be tested in establishing the norms.

Implications for Future Use of the Findings

In order to provide praticality for the findings of this study, the following recommendations are made:

1. The Modified Fitness Test can be best utilized by the classroom teacher for indication of the cardiovascular fitness of the individual class members. The test results may be used for pupil placement or for structuring class activities as indicated by the cardiovascular fitness level of the students.

2. As a laboratory tool, the Modified Fitness Test can be used for diagnostic purposes. It could be used to indicate changes in the level of cardiovascular fitness in a test re-test application and to indicate the success of a particular fitness program being used in an attempt to improve the physical fitness of subjects. Because of the simplicity and ready availability of the equipment necessary for administration of the Modified Fitness Test, it would be useful in situations where funds were limited and laboratory equipment was sparse.

APPENDIX A

In determining step height for each individual to whom the Modified Fitness Test was administered, Sheldon's[1] formula for ponderal index was used. The formula is

$$\text{Ponderal Index} = \frac{\text{height}}{\sqrt[3]{\text{weight}}}.$$

The data compiled by Pruitt[2] was used to furnish heights and weights of college women. These data were the most recent collection of information concerning the anthropometry of college women available. The weight range for each one-inch deviation in height was used to plot the range of ponderal index for that particular height. From this range, the step height chart was developed. The range of ponderal index was 10.78 to 14.59. It should be noted that the ponderal index number designations decrease as the weight relative to the height of the individual increases, thereby aiding the subjects who are of a more compact build. The lower the ponderal index, the lower the step height for that individual on the Modified Fitness Test.

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[1]W. H. Sheldon, Atlas of Men, Harper and Brothers, (New York) 1954.

[2]Joyce Pruitt, "Anthropometrical Data on 1949 College Women," Unpublished doctoral dissertation, Texas Woman's University, Denton, Texas, 1968.

TABLE XII

Determination of Step Height for Administration of the Modified Fitness Test

Height in inches	Weight in Pounds/Step Height*
55	90 or below/B 91 or above/A
56	90 or below/D 91-105/B 106 and above/A
57	90 or below/D 91-95/C 96-100/B 101 and above/A
58	95 or below/D 96-100/C 101-105/B 106 and above/A
59	100 or below/D 100-105/C 106-115/B 116 and above/A
60	105 or below/D 106-115/C 116-120/B 121 and above/A
61	110 or below/D 111-115/C 116-125/B 126 and above/A
62	115 or below/C 116-125/C 126-135/B 136 and above/A
63	120 or below/D 121-130/C 131-140/B 141 and above/A
64	125 or below/D 126-135/C 136-140/B 141 and above/A

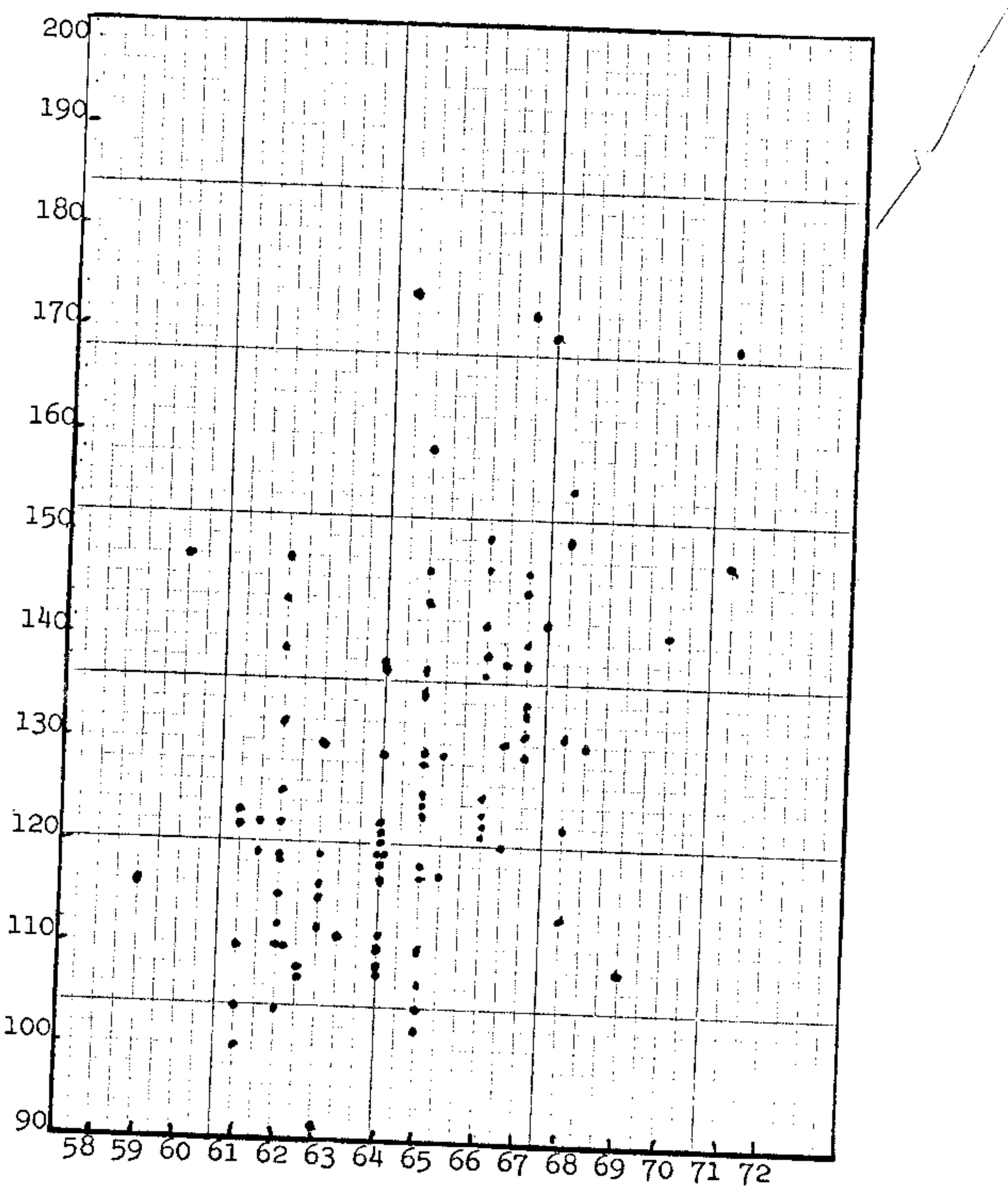
*Step height designations are as follows: Step A is 15 inches high, Step B is 16 inches high, Step C is 17 inches high, Step D is 18 inches high, and Step E is 19 inches high.

TABLE XII
continued

Height in Inches	Weight in Pounds/Step Height				
65	115 or below/E	116-135/D	136-145/C	146-155/B	156 and above/A
66	120 or below/E	121-135/D	136-150/C	151-160/B	161 and above/A
67	125 or below/E	126-145/D	146-160/C	161-165/B	166 and above/A
68	135 or below/E	136-150/D	151-165/C	166-165/B	176 and above/A
69	140 or below/E	139-160/D	161-175/C	176-185/B	186 and above/A
70	145 or below/E	144-170/D	171-190/C	191-195/B	196 and above/A
71	150 or below/E	151-180/D	181-195/C	196 and above B	
72	155 or below/E	156-180/D	and above/C		

APPENDIX B

Modified Fitness Test
Height/Weight Distribution of Subjects



N=100 Range 13" Height

APPENDIX C

SUBJECT	SKUBIC-HODGKINS TEST				ASTRAND-RYHMING BICYCLE ERGOMETER TEST				MODIFIED FITNESS TEST				GROUP
	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	
1	170	144	122	120	168	131	137	128	171	141	127	112	1
2	208	184	176	152	186	160	146	144	184	144	160	144	1
3	174	151	147	126	139	128	126	124	158	144	141	112	1
4	184	176	164	160	168	157	141	128	170	160	136	116	1
5	192	176	160	148	164	138	120	128	176	152	136	120	1
6	188	183	167	152	176	168	160	144	178	170	150	144	1
7	190	154	144	144	176	152	144	131	179	161	142	129	1
8	206	179	164	160	164	138	126	129	180	152	142	119	1
9	188	148	136	134	163	134	134	120	164	144	122	120	1
10	184	160	149	136	159	141	134	126	172	160	139	118	1
11	189	185	170	150	148	136	125	120	170	152	136	118	2
12	184	170	144	142	190	160	148	144	175	160	140	129	2
13	176	136	129	104	155	114	109	104	160	120	112	104	2
14	187	153	149	133	171	153	137	132	166	154	142	136	2

SUBJECT	SKUBIC-HODGKINS TEST				ASTRAND-RYHMING BICYCLE ERGOMETER TEST				MODIFIED FITNESS TEST				GROUP
	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	
15	190	174	150	140	155	138	131	123	180	160	139	136	2
16	176	144	136	128	126	129	119	113	160	152	128	121	2
17	196	176	160	144	168	160	144	144	161	160	144	127	2
18	186	176	150	124	154	144	123	120	173	168	136	128	2
19	190	169	151	128	167	136	138	138	181	164	160	141	2
20	176	144	138	120	162	132	125	114	160	155	131	120	2
21	189	178	160	144	166	136	120	118	173	168	139	128	2
22	190	169	151	128	167	136	128	128	181	164	160	141	2
23	182	168	144	160	168	144	144	144	171	144	140	136	2
24	191	171	159	143	168	158	131	128	182	164	146	139	2
25	186	164	148	138	155	131	112	108	171	158	134	120	2
26	188	168	144	141	179	160	128	120	184	160	144	138	2
27	191	176	159	147	145	144	131	136	190	167	160	152	2
28	160	144	152	136	156	152	144	128	160	128	144	128	3
29	189	162	160	152	190	160	151	144	177	160	158	144	3
30	178	162	160	152	190	136	128	120	184	168	152	136	3

SUBJECT	SKUBIC-HODGKINS TEST				ASTRAND-RYHMING BICYCLE ERGOMETER TEST				MODIFIED FITNESS TEST				GROUP
	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	
31	190	168	160	134	182	159	144	136	178	153	144	120	3
32	199	189	161	147	167	132	131	126	184	160	145	129	3
33	176	168	144	144	160	133	130	117	162	144	158	128	3
34	184	200	176	152	190	176	167	152	184	176	152	144	3
35	208	168	152	144	179	144	132	123	170	150	138	120	3
36	184	168	144	136	167	153	144	138	178	152	144	129	3
37	192	170	152	144	174	145	136	123	176	168	144	128	3
38	200	184	184	168	192	184	168	160	188	188	168	164	3
39	168	152	124	120	139	120	198	104	150	140	120	112	3
40	193	177	163	139	176	156	139	136	188	160	138	136	3
41	192	184	168	168	174	157	145	140	182	175	151	144	3
42	204	174	168	151	171	138	137	136	184	166	145	128	3
43	190	170	164	144	158	146	144	138	174	160	140	128	3
44	184	170	154	132	160	157	144	136	168	144	129	120	3
45	192	161	147	128	174	144	128	136	189	160	141	129	3
46	174	160	150	137	160	139	129	127	160	147	141	137	3

SUBJECT	SKUBIC-HODGKINS TEST				ASTRAND-RYHMING BICYCLE ERGOMETER TEST				MODIFIED FITNESS TEST				GROUP
	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	
47	190	168	150	129	154	152	140	120	168	148	133	118	3
48	175	164	160	159	152	136	104	088	180	160	136	136	4
49	183	176	147	137	160	128	114	096	180	175	148	131	4
50	190	165	160	154	177	139	125	124	197	168	160	152	4
51	184	168	144	136	184	161	144	136	184	168	160	152	4
52	160	149	135	128	140	111	103	096	163	144	128	120	4
53	183	163	152	136	187	176	174	160	184	168	162	159	4
54	184	192	160	144	176	168	150	138	189	181	168	150	4
55	162	136	132	132	176	160	152	135	158	149	139	125	4
56	180	174	150	140	167	146	136	123	181	174	148	142	4
57	184	168	148	140	164	152	138	136	185	171	149	140	4
58	174	166	138	130	162	144	144	128	180	145	131	121	4
59	189	159	149	141	184	168	160	160	186	160	154	154	4
60	177	156	142	136	174	176	160	160	170	161	136	112	4
61	184	160	144	136	183	159	144	136	184	159	146	133	4
62	192	192	152	152	181	156	147	136	184	169	160	144	4

SUBJECT	SKUBIC-HODGKINS TEST				ASTRAND-RYHMING BICYCLE ERGOMETER TEST				MODIFIED FITNESS TEST				GROUP
	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	
63	184	144	136	128	162	139	124	117	178	148	128	123	4
64	169	152	137	128	164	133	126	114	168	156	136	132	4
65	192	160	152	144	147	135	136	126	189	160	154	152	4
66	176	151	137	120	185	162	147	131	174	149	132	128	4
67	168	138	114	112	168	147	123	112	174	142	136	126	4
68	184	160	152	136	162	131	126	120	180	160	150	160	4
69	184	156	136	128	168	128	120	114	180	152	136	136	4
70	208	176	160	152	186	169	152	152	206	176	160	144	4
71	175	150	136	124	178	160	156	144	174	152	136	120	4
72	192	176	160	160	163	139	136	128	192	168	146	138	4
73	184	168	136	120	172	152	144	136	180	160	160	136	4
74	184	160	144	136	176	160	160	138	182	162	148	136	4
75	168	144	136	132	168	147	133	128	171	152	140	136	4
76	176	168	152	136	158	140	129	123	169	166	149	128	4
77	184	160	144	144	169	150	137	128	176	160	144	142	4
78	168	144	136	138	161	144	119	112	167	144	152	136	4

SUBJECT	SKUBIC-HODGKINS TEST				ASTRAND-RYHMING BICYCLE ERGOMETER TEST				MODIFIED FITNESS TEST				GROUP
	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	
79	160	154	136	132	144	126	120	120	168	152	130	128	4
80	168	160	136	120	168	160	146	144	168	160	128	128	4
81	160	160	134	120	170	169	144	144	162	158	144	144	4
82	176	172	154	144	166	133	132	117	176	160	144	128	4
83	200	178	163	149	187	162	157	128	192	176	160	144	4
84	162	150	128	118	176	160	144	144	170	160	150	136	4
85	184	150	132	124	171	144	140	128	179	146	137	128	4
86	192	184	164	148	160	144	128	134	190	172	154	143	4
87	168	160	128	118	158	131	129	128	164	161	128	194	4
88	192	190	154	136	176	168	168	152	198	160	160	160	4
89	178	157	139	123	162	164	144	128	172	160	138	136	4
90	163	144	133	124	168	136	126	117	168	144	123	117	4
91	160	144	132	128	171	160	137	128	169	150	136	124	4
92	180	176	158	144	179	178	162	136	182	176	160	150	4
93	184	176	152	128	176	144	123	108	191	178	168	152	5
94	168	152	148	128	168	136	126	120	174	160	144	139	5

SUBJECT	SKUBIC-HODGKINS TEST				ASTRAND-RYHMING BICYCLE ERGOMETER TEST				MODIFIED FITNESS TEST				GROUP
	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	Max H.R.	Recovery 30	60	90	
95	173	155	139	131	176	136	129	120	179	161	145	130	5
96	162	136	120	144	168	159	154	144	176	114	120	120	5
97	152	136	128	120	138	121	112	108	161	148	136	128	5
98	144	128	104	088	160	144	128	124	170	167	160	152	5
99	188	159	142	128	160	136	120	112	188	160	145	133	5
100	175	158	140	130	160	148	122	120	174	165	148	130	5

APPENDIX D

Procedures and Norms for the Administration of the Modified Fitness Test

1. Step height for the individual to be tested is determined by application of the height and weight of the subject to the ponderal index chart. (Appendix A)

2. The test consists of stepping up on the predetermined step height for three minutes at the rate of twenty-four steps per minute.

3. Pulse rate is taken by counting palpitations of the carotid artery for fifteen seconds immediately following completion of the test, and multiplying the total by four to get the maximum heart rate per minute.

4. The cardiovascular fitness of the subject is determined from the norms provided.

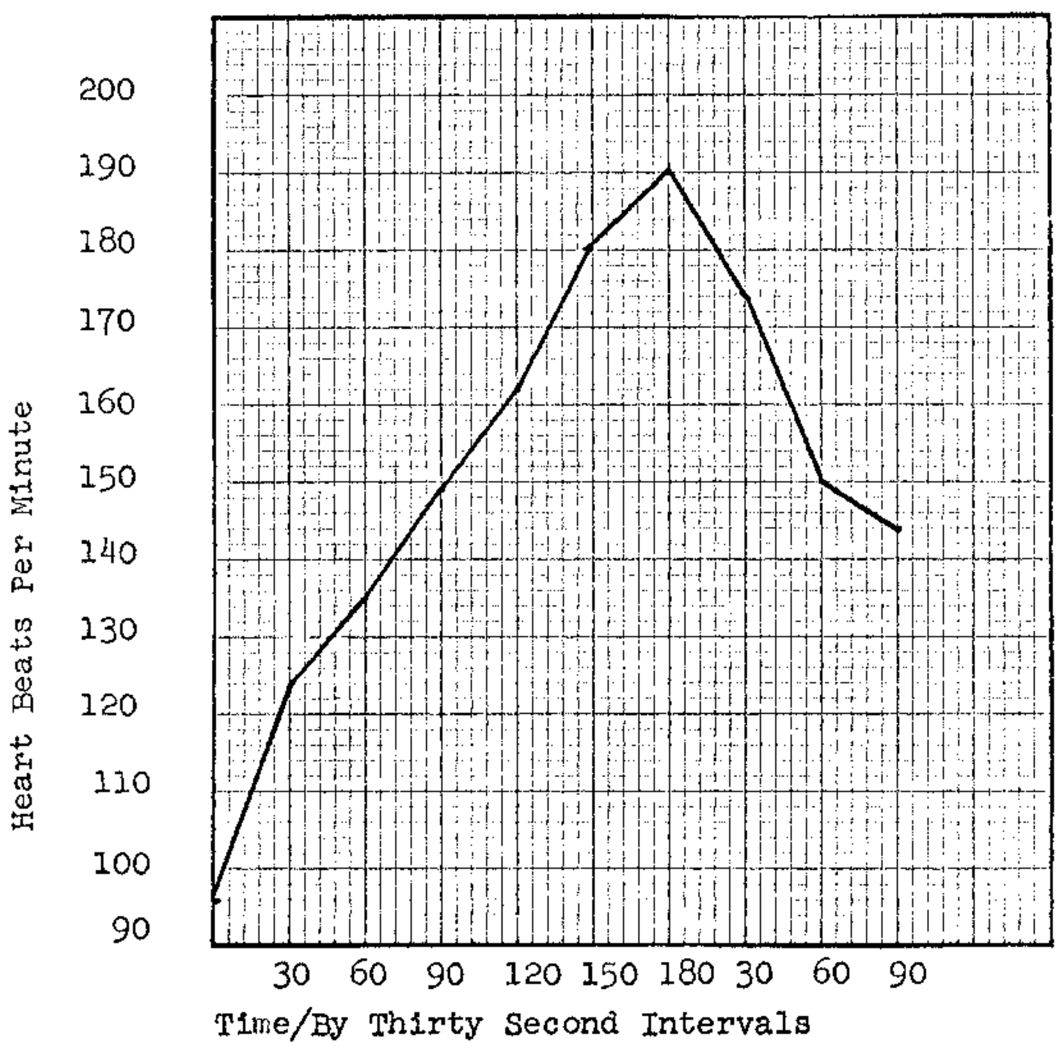
Norms for the Modified Fitness Test

Raw Score in Beats per Minute	Descriptive Term	Percentile of the Subjects	0-100 Scale
150 or less	Excellent	1	71+
151-160	Very Good	8	60-70
161-177	Good	43	49-70
178-188	Fair (Average)	34	39-48
189-199	Poor	12	28-38
200 or above	Very Poor	2	27 or less

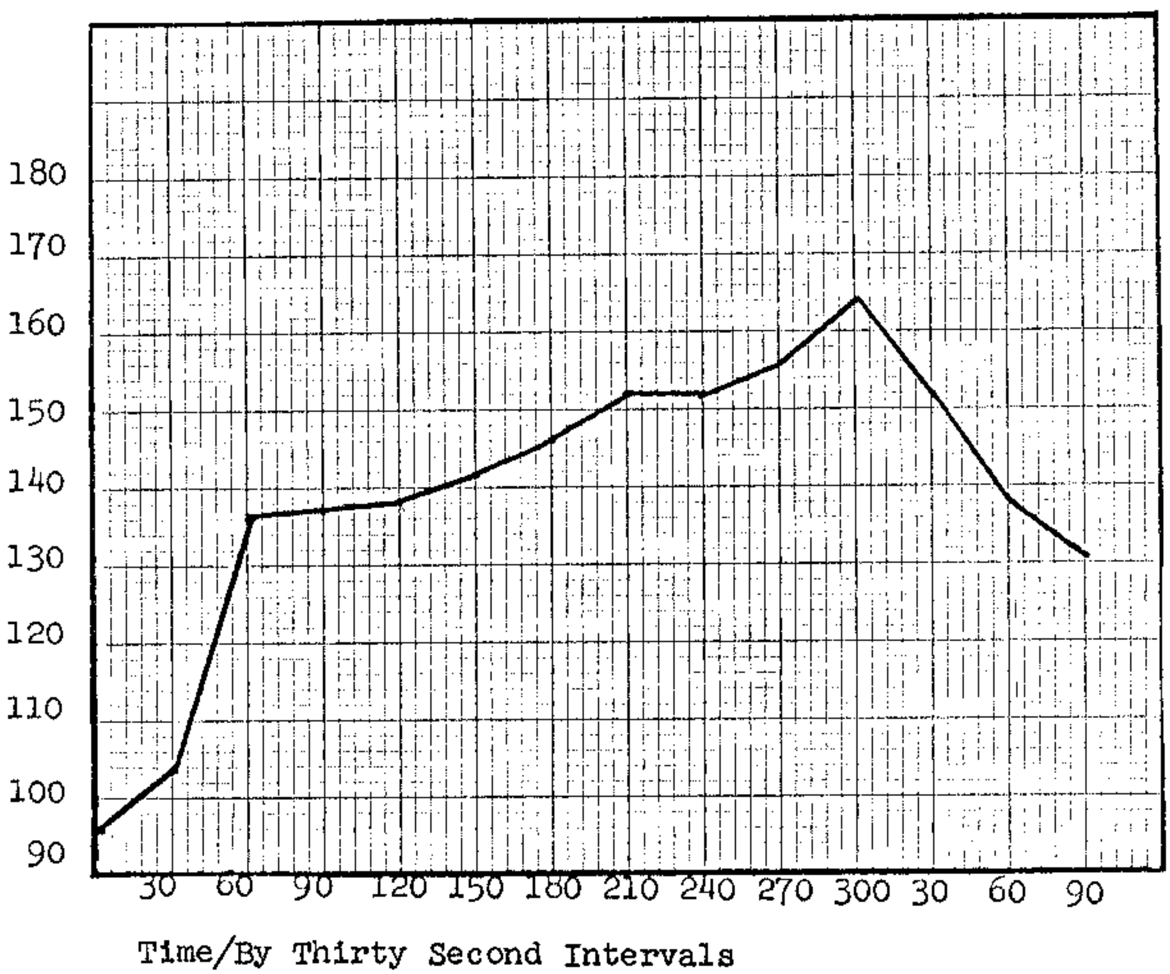
APPENDIX E

Graphs of Typical Heartrates

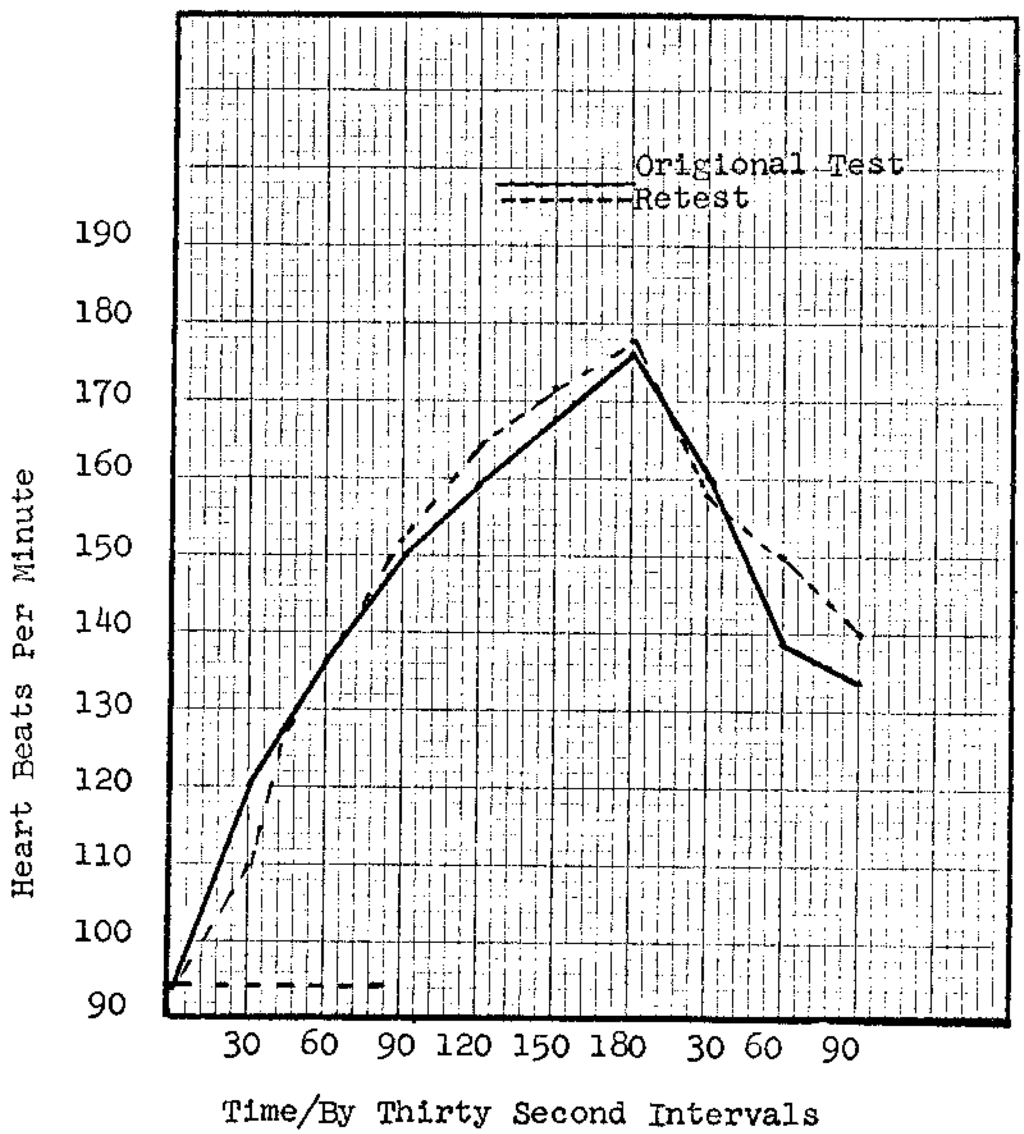
Typical Skubic-Hodgkins Cardiovascular Efficiency Test Heart Rate Patterns Throughout Test Duration and Recovery Period



Typical Astrand-Ryhming Bicycle Ergometer Test Heart Rate Pattern Throughout Test Duration and Recovery Period

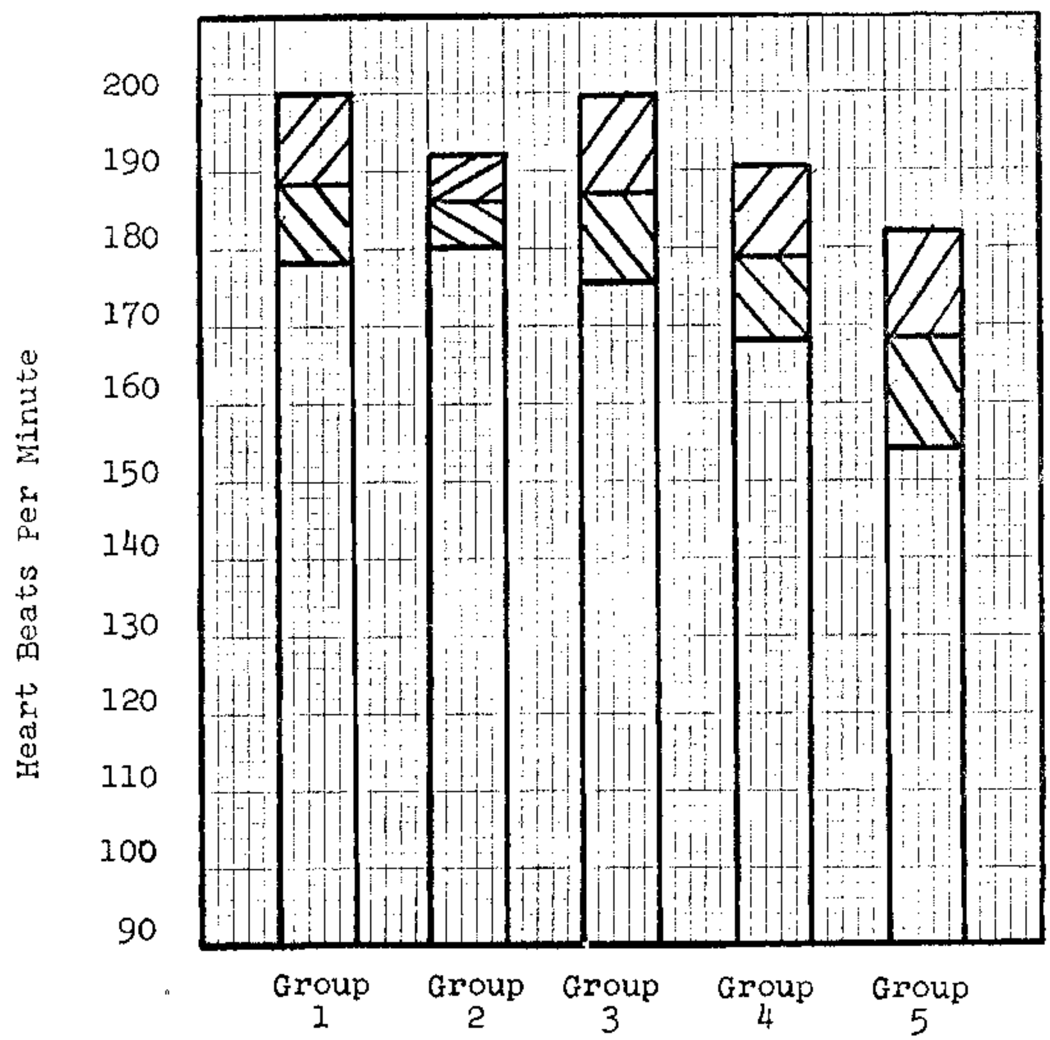


Typical Modified Fitness Test Heart Rate Pattern
Throughout Test Duration and Recovery Period for
Origional Test and Retest



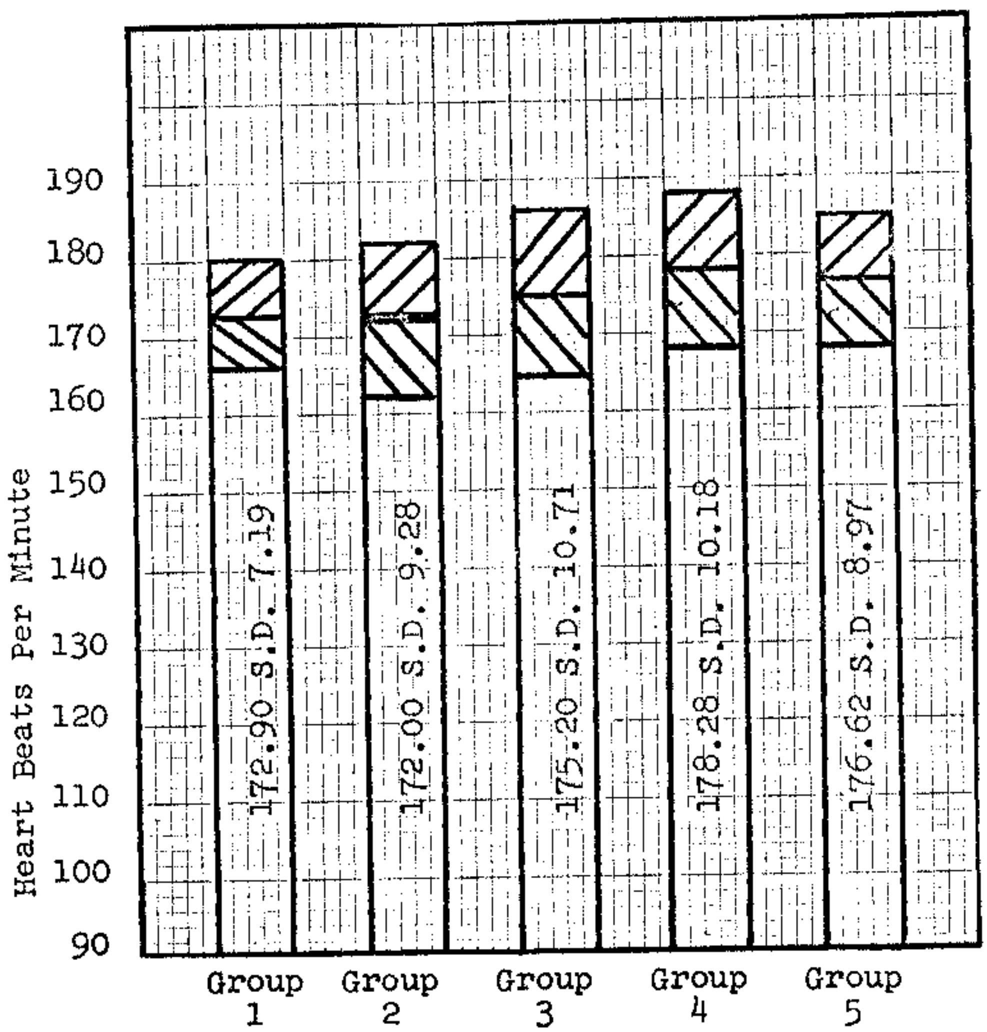
APPENDIX F

COMPARISON OF THE RESULTS OF THE ADMINISTRATION OF THE SKUBIC-HODGKINS CARDIOVASCULAR EFFICIENCY TEST TO THE FIVE GROUPS AS DETERMINED BY PONDERAL INDEX



APPENDIX G

COMPARISON OF THE RESULTS OF THE ADMINISTRATION OF THE MODIFIED FITNESS TEST TO THE FIVE GROUPS DETERMINED BY PONDERAL INDEX



APPENDIX H

DISTRIBUTION OF THE RESULTS OF THE MODIFIED FITNESS TEST ACCORDING TO HEIGHT

I - Division I, 15 inch step height
II - Division II, 16 inch step height
III- Division III, 17 inch step height
IV - Division IV, 18 inch step height
V - Division V, 19 inch step height

Height In Inches	Division/Number of Subjects
59	II/1
60	I/1
61	I/2, II/2, III/3
62	I/2, II/5, III/2, IV/5
63	III/3, IV/6
64	I/1, II/2, III/3, IV/9
65	I/1, II/3, III/5, IV/10
66	II/2, III/3, IV/6, V/2
67	I/3, II/1, III/2, IV/6,V/1
68	I/1, IV/3, V/2
69	V/1
70	V/1
71	IV/1, V/1

DISTRIBUTION OF THE RESULTS OF THE MODIFIED FITNESS TEST ACCORDING TO WEIGHT

Weight in Pounds	Division/Number of Subjects
92	III/1
99	II/1
104	IV/2
105	III/1
106	IV/1
108	IV/1, V/1
110	I/1, III/1, IV/3
111	I/1, IV/2
112	IV/2
113	IV/1
115	II/1, IV/4
116	IV/1
117	II/1, IV/1
118	IV/2
119	III/2, IV/2
120	II/1, III/1, IV/2
121	III/1, IV/1
122	II/1, III/2, IV/2

Weight in Pounds	Division/Number of Subjects
122	II/1, III/2, IV/2
123	II/1, III/1, IV/1, V/1
124	I/1, III/1, V/2
125	I/1, III/1, V/2
128	III/1, IV/3
129	II/2, III/1, IV/1
130	III/1, IV/1, V/1
131	II/1, IV/2, V/1
133	II/1, IV/2
134	IV/1
135	IV/1
136	II/1
137	III/1
138	IV/2
139	II/1, IV/1
140	I/1, II/2
141	V/1
142	III/1, IV/1
144	II/1
145	II/1, III/2
147	III/1
148	I/2
149	V/1
150	III/1, IV/1
155	I/1
157	I/1
169	IV/1
170	I/1
172	I/1
175	I/1

BIBLIOGRAPHY

Books

Allard, C. and Goulet, C. "Symposium on Physical Working Capacity and Its Testing," Prevention of Ischemic Heart Disease, Wilhelm Raab, editor, Springfield, Ill., Charles C. Thomas, Publisher, 1966.

Anderson, K. Lange, "The Cardiovascular System in Exercise," Exercise Physiology, Harold B. Falls, editor, New York, Academic Press, 1968.

Astrand, P. -O., Experimental Studies of Physical Working Capacity in Relation to Sex and Age, Copenhagen, Mundsgaard, 1952.

____________ and Rodahl, Kaare, Textbook of Work Physiology, New York, McGraw-Hill Book Company, 1970.

Bainbridge, F. A., Physiology of Muscular Exercise (3rd edition, rewritten by A. V. Bock and D. B. Dill) Longmans, Green and Company, 1966.

de Vries, Herbert A., Physiology of Exercise, Dubuque, Iowa, W. C. Brown Company, 1966.

Mathews, Donald K., Measurement in Physical Education, Philadelphia, W. B. Sounders Company, 1959.

____________, Stacy, R. W., and Hoover, G. N., Physiology of Muscular Activity and Exercise, New York, Ronald Press, 1964.

McCloy, Charles H., Tests and Measurements in Health and Physical Education, (3rd edition) New York, Appleton-Century-Crofts, Inc., 1954.

McNemar, Quinn, Psychological Statistics (3rd edition), New York, John Wiley and Sons, Inc., 1962.

Morehouse, Laurence E. and Mille, Augustus T., Physiology of Exercise (5th edition), St. Louis, The C. V. Mosby Company, 1967.

Travers, Robert M. W., *An Introduction to Educational Research*, New York, The MacMillan Company, 1969.

Waxman, W. W., "Physical Fitness Development for Adults in the Y. M. C. A.," *Exercise and Fitness*, New York, The Athletic Institute, 1960.

Articles

Andres, G. M., Buzman, C. A., and Becklake, M.R., "Effect of Athletic Training on Exercise Cardiac Output," *Journal of Applied Physiology*, XXI (March, 1966), 603.

Asmussen, E. and Nielsen, M., "The Cardiac Output in Rest and Work Determined Simultaneously by the Acetylene and Dye Injection Methods," *Acta Physiologica Scandinavica*, as quoted by Wyndham, et. al. *Journal of Applied Physiology*, XIV (November, 1959), 934.

______________________________, "Cardiac Output During Muscular Work and Its Regulation," *Physiological Reviews*, XXXV (October, 1955), 778.

Astrand, P. -O., and Ryhming, Irma, "A Nomogram for Calculation of Aerobic Capacity (physical fitness) from Pulse Rate During Submaximal Work," *Journal of Applied Physiology*, VII (January, 1954), 218-222.

_______________, "Breath Holding During and After Muscular Exercise," *Journal of Applied Physiology*, XV (March, 1960), 220.

_______________, Cuddy, T. E., Saltin, B., and Stenberg, J., "Cardiac Output During Submaximal and Maximal Work," *Journal of Applied Physiology*, XX (January, 1965), 253.

_______________, Ekblom, B., Messin, R., Saltin, B., and Stenberg, J., "Intra-arterial Blood Pressure during Exercise with Different Muscle Groups," *Journal of Applied Physiology*, XX (January, 1965), 253

________________, and Saltin, B., "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Exercise," *Journal of Applied Physiology*, XVI (November, 1961), 971.

________________, "Measurement of Maximal Aerobic Capacity," *Canadian Medical Association Journal*, XCVI (March, 1967), 732.

__________, and Saltin, B., "Oxygen Uptake diring the First Minutes of Heavy Muscular Exercise," Journal of Applied Physiology, XVI (July, 1961), 971.

Balke, Bruno, "An Experimental Study of 'Physical Fitness' of Air Force Personnel," Department of Physiology-Biophysics, U. S. Air Force School of Aviation Medicine, Rangolph Air Force Base, Texas, U. S. Armed Forces Medical Journal, X (July, 1961), 675.

__________, "Correlation of Static and Physical Endurance," Report #1, Randolph Field, Texas: School of Aviation Medicine, (April, 1952), Meographed.

Bates, D. V., "Commentary," Canadian Medical Association Journal, XCVI (March, 1967), 704.

Berggren, G., and Christensen, E. H., "Heart Rate and Body Temperature as Indices of Metabolic Rate During Work," Arbeitsphysiol, XIV (1950), 225 as reported from L. B. Rowell, H. L. Taylor, and Ynag Wang, Journal of Applied Physiology, XIX (November, 1964). 919.

Boothby, W. M., "Studies in Metabolism and Oxygen Consumption," American Journal of Physiology, XXXVII (June, 1915), 383.

Brouha, L. and Gallagher, J., "The Step Test: A Simple Method of Measuring Physical Fitness for Muscular Work in Young Men," Research Quarterly, XIV (March, 1943), 41.

Davies, C. T. M., "Commentary," Canadian Medical Association Journal, XCVI (March, 1967), 713.

Dejours, P., Journal Physiology, (Paris) LI (March, 1959), 163, as quoted by W. T. Josenhans, "Commentary," Canadian Medical Association Journal, XCVI (March, 1967), 713.

de Vries, H. A., and Klafs, C. E., "Prediction of Maximal Oxygen Intake from Submaximal Tests," Journal of Sports Medicine, V (September, 1962), 207.

Gallagher, J. R. and Brouha, L., "A Functional Fitness Test for High School Girls," Journal of Health, Physical Education and Recreation, XIV (December, 1943), 517.

__________, "A Simple Method of Testing the Physical Fitness of Boys," Research Quarterly, XIV (March, 1943), 23.

Glassford, R. G., Baydorft, B. H. V., Sedwick, A. W., and McNab, R. B. J., "Comparison of Maximal Oxygen Uptake Values Determined by Predicted and Actual Methods," Journal of Applied Physiology, XX (May, 1965), 20.

Hodgkins, Jean and Skubic, Vera, "Cardiovascular Efficiency Test Scores for College Women in the United States," Research Quarterly, XXXIV (December, 1963), 454.

Hodgkins Jean, and Skubic, Vera "Cardiovascular Efficiency Test Scores for Junior and Senior High School Girls in the United States," Research Quarterly, XXV (May, .964), 184.

Issekutz, B., Birkhead, N. C., andRodahl, K., "Use of Respiratory Quotient in the Assessment of Aerobic Work Capacity," Journal of Applied Physiology, XVII (January, 1962), 47.

Kasch, F. W., Phillips, W. H., Ross, W. D., Carter, J. L. and Boyer, J. L., "A Comparison of Maximum Oxygen Uptake by Treadmill and Step Test Procedures," Journal of Applied Physiology, XXI (July, 1966), 1387.

Le Blance, J. and Kennedy, R. A., "Use of Heart Rate as an Index of Work Performance, Journal of Applied Physiology, X (January, 1957), 276.

Lind, A. R. and McNicol, G. W., "Muscular Factors which Determine the Cardio-vascular Responses to Sustained and Rhythmic Exercise," Canadian Medical Association Journal, XCVI (March, 1967), 712.

Margaria, R., "Commentary," Canadian Medical Association Journal, XCVI (March, 1967), 734.

_______________, Aghemo, P., and Rovelli, E., "Indirect Determination of Maximal Oxygen Consumption is Man," Journal of Applied Physiology, XX (September, 1965) 1071.

Maritz, J. S., Morrison, J. F., Peter, J., Strydon, N. B., and Wyndom, C. H., "A Practical Method of Estimating an Individuals' Maximum Oxygen Intake," Ergonomics, IV (April, 1961), 97.

Master, Arthur M. and Oppenheimer, Enid T., "A Simple Exercise Tolerance Test for Circulatory Efficiency with Standard Tables for Normal Individuals," American Journal of Medical Science, CLXXVI (May, 1929), 223, as quoted by C. H. McCloy, Tests and Measurements in Physical Education, New York, Appleton-Century-Crofts, Inc., 1939.

Montoye, Henry J., "Inter-relation of Maximum Pulse Rate During Moderate Exercise, Recovery Pulse Rate Post-Exercise Blood Lactate," Research Quarterly, XXIV (December, 1953), 453.

Nagle, F. J., Balke, B., and Naughton, J. P., "Graduational Step Test for Assessing Work Capacity," Journal of Applied Physiology, XX (July, 1965), 745.

____________, and Bedicki, Thomas G., "Response as a Measure of Circulatory Capacity," Research Quarterly, XXXIV (October, 1963), 361.

Nagle, R. E. and Irwin, T., "Effects of Circulorespiratory Endurance and Related Physiological Factors," Research Quarterly, XXXII (December, 1961), 607.

Rohter, F. D., Rochelle, R. H., and Hyman, C., "Exercise Blood Flow Changes in the Human Forearm During Physical Training," Journal of Applied Physiology, XVIII (May, 1964), 789.

Schneider, E. C., "A Cardiovascular Rating as a Measure of Physical Fatique and Efficiency," Journal of the American Medical Association, LXXIV (May, 1920), 1504.

Shephard, R. J., "Physiological Determinants of Cardio-Respiratory Functions," Journal of Sports Medicine, Vii (September, 1967), 111.

Sjorstrand, T., "Changes in the Respiratory Organs of Workmen at an Ore Smelting Works," Acta Medica Scandinavica, (Supplement 196, 1947).

Skubic, Vera and Hodgkins, Jean, "Cardiovascular Efficiency Tests for Girls and Women," Research Quarterly, XXXV (May, 1963), 191.

Wyndham, C. H., "Submaximal Tests for Estimating Maximum Oxygen Intake," Canadian Medical Association Journal, XCVI (March, 1967), 737.

Unpublished Materials

Alexander, R. S., "The General Physiology of Heart and Circulation," Speech at Western Reserve University School of Medicine, Cleveland, Ohio, October, 1965 (Memeograph).

Ganslen, R. V., "Critique of Physical Fitness Tests," Personal Communication, Texas Woman's University, Novemver 12, 1968.

Kurucz, R. L. "Construction of the Ohio State Univeristy Cardiovascular Fitness Test," unpublished Doctoral Dissertation, The Ohio State University, 1967.

Pruitt, Joyce, "Anthropometrical Data on 1049 College Women," unpublished Doctoral Dissertation, Texas Women's University, Denton, Texas, 1968.

Woods, Francis J., "The Validation of the Ohio State University Cardiovascular Fitness Test," unpublished Doctoral Dissertation, The Ohio State University, 1967.