THE INFLUENCE OF INTERVAL TRAINING OF TWELVE MINUTES DURATION ON THE MAXIMAL AEROBIC OXYGEN INTAKE OF JUNIOR HIGH SCHOOL GIRLS

A THESIS

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CHAPTER I

INTRODUCTION

Rationale for the Study

A great deal of attention has been given by the American public in recent years to physical conditioning and physical fitness. National recognition was given when President-elect of the United States John F. Kennedy stated,

> . . . the physical fitness of our citizens is a vital prerequisite to American's realization of its full potential as a nation, and to the opportunity of each individual citizen to make full and fruitful use of his capacities. For the strength of our youth and the fitness of our adults are among our most important assets, and this growing decline is a matter of urgent concern to thoughtful Americans.[1]

Labor saving machinery and easy modes of transportation have changed modern man's mode of living. More and more persons tend to lead sedentary lives as a result of various modern conveniences and there is an increasingly large number of young Americans who are ignoring basic principles of health. Their physical fitness is not what it should be and as a result are getting soft.[2] The

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[1]John F. Kennedy, "The Soft American," Sports Illustrated, (December 26, 1960), 15.

[2]Ibid., 16.

increased leisure time that accompanies modern conveniences can be a continuation of a sedentary existence or it can be the opportunity for regular exercise.[1]

Physical fitness involves many aspects and functions of the human body. There have been numerous attempts to assess fitness objectively through measure of endurance, power, flexibility, speed, and strength.

During World War II, the United States Army, as well as the armies of foreign countries, devised numerous fitness tests,[2] most of which were designed strictly for boys or men. Several of these tests have been described in detail by Bookwalter.[3] Tests for high school girls, which, in general, have been designed to assess only one or two components of physical fitness, have been presented by O'Connor and Cureton.[4]

Astrand,[5] in a recent review concerning physical

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[1]Special Report by a Joint Committee of the American Medical Association and the American Association for Health, Physical Education and Recreation, "Exercise and Fitness," Journal of American Medical Association, CLXXXVIII No. 5 (May 4, 1964), 433.

[2]U. S. War Department, "Physical Training," Field Manual, War Department, (1946), 21-20.

[3]Karl W. Bookwalter, "Test Manual for Indiana University Motor Fitness Indices for High School and College Age Men," Research Quarterly, XIV (1943), 356-65.

[4]Mary E. O'Connor, and Thomas K. Cureton, Jr., "Motor Fitness Tests for High School Girls," Research Quarterly, XVI (1945), 302-14.

[5]P. O. Astrand, "Human Physical Fitness with Special Reference to Sex and Age," Physiological Review, XXXVI (1956), 307-35.

fitness with respect to sex and age, identifies major gaps in our knowledge of assessing the physical fitness of individual subjects. He states that heart rates and oxygen intake studies must be adjusted for sex and age difference, and in many instances related to kilograms of body weight.

The importance of the heart's response in meeting the demands of strenuous activity has given rise to numerous tests of cardiovascular function. Cardiovascular tests have been used to measure endurance, muscular activity fitness, or sometimes only to study the response of the heart to physical exercise. Tests such as the Schneider Test,[1] the Tuttle Pulse-Ratio Test,[2] the Brouha Step Test,[3] and more recently the Skubic and Hodgkins Test[4] have been administered to thousands of subjects. The last named tests have been used extensively with women or girls. All of these tests depend upon precise recording of heart rates before, during, or after vigorous exercise as the method for evaluating fitness.

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[1]Edward C. Schneider, "A Cardiovascular Rating as a Measure of Physical Fatigue and Efficiency," Journal of American Medical Association, LXXIV (1920), 1507-10.

[2]W. W. Tuttle and R. E. Dickinson, "A Simplification of the Pulse-Ratio Technique for Rating Physical Efficiency and Present Condition," Research Quarterly, IX (1938), 73-80.

[3]Lucien Brouha, "The Step Test: A Simple Method of Measuring Physical Fitness for Muscular Work in Young Men," Research Quarterly, XIV (1943), 31-36.

[4]Vera Skubic and Jean Hodgkins, "A Cardiovascular Efficiency Test for Girls and Women," Research Quarterly, XXXIV (May, 1963), 191-98.

A more objective method by which one can determine the physical fitness of an individual, as reflected by his cardiovascular system, is to determine the maximal oxygen consumption during exhausting work.[1] Maximal oxygen consumption is a laboratory measurement technique involving the utilization either of a motor driven treadmill or a bicycle ergometer. The treadmill testing is preferred in the United States because of the training and specific motor development needed for maximal oxygen intake achievement on a bicycle ergometer.

The volume of oxygen consumed during physical exercise is dependent upon the mass of muscles at work and the load on the muscles.[2] Once the maximal oxygen intake is determined, it may be expressed as milliliters per kilogram of total body weight per minute (ml/kg/min), or in liters or cubic centimeters per minute. This computation provides a measure of the immediately available oxidative energy which can be supplied to move a kilogram of body weight from one point to another.[3]

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[1]H. L. Taylor, E. Buskirk, and A. Henschel, "Maximal Oxygen Intake as an Objective Measure of Cardio-Respiratory Performance," Journal Applied Physiology. VLLL (July, 1955), 73-80.

[2]P. O. Astrand and Bengt Saltin, "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal Applied Physiology, XVI (1961), 977-81.

[3]E. Buskirk and H. L. Taylor, "Maximal Oxygen Uptake in Relation to Body Composition with Special Reference to Chemic Physical Activity and Obesity," Journal Applied Physiology, XI (1957), 72-78.

Statement of the Problem

This investigation entailed a study of one vitally important parameter of the cardiorespiratory system, the maximal aerobic oxygen intake. The study included fourteen junior high school girls enrolled in DeWitt Perry Junior High School in Carrollton, Texas during the academic year 1970-1971. Changes in cardiorespiratory fitness before and after a prescribed run/walk training program were noted in the investigation.

By measuring the maximum aerobic intake before the training was initiated and after the training program had been completed, the investigator was able to assess the value of this type of training to improve physical fitness. The investigator has thus been able to draw conclusions concerning the effectiveness of participation in a run/walk training program in altering cardiorespiratory fitness as evidenced by the aerobic oxygen intake as an index in this investigation.

Definitions and/or Explanations of Terms

For the purpose of clarification the following definitions and/or explanations of terms have been established for use in the study.

A. Run/Walk Program: The investigator accepts the explanation of Cooper for a run/walk program. Cooper states that the purpose of this program is for the subject to cover the longest possible distance in twelve minutes by running, or walking, whenever necessary to prevent becoming excessively exhausted.[1]

B. Maximum Aerobic Oxygen Intake: The investigator accepts the definition of Brouha and Radford who state:

> The maximum rate of exercise that can be performed with which the lungs and circulatory system provide the working muscles with oxygen . . . .[2]

C. Treadmill: The investigator accepts the explanation given by Consolazio, *et al*. The treadmill has a motor driven endless leather belt that can be operated at any speed up to twenty mph. The front end can be raised to vary the grade.[3]

D. Spirometer: The investigator accepts the explanation given by Consolazio, *et al*. A spirometer is a calibrated cylinder that is sealed from the outside by using a water seal in a second cylinder and is utilized in determining gas volume.[4]

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[1]K. H. Cooper, "Correlation between Field and Treadmill Testing as a Means of Assessing Maximal Oxygen Intake," *Journal Applied Medical Association*, CCIII, No. 3 (January, 1968), 45.

[2]Lucien Brouha and E. P. Radford, "Cardiovascular System in Muscular Activity," *Science and Medicine of Exercise and Sports*, ed. by Warren R. Johnson (New York: Warren Harper and Brothers, (1960), 181.

[3]C. Frank Consolazio, Robert E. Johnson, and Louis J. Pecora, *Physiological Measurements of Metabolic Functions in Man*, (New York: McGraw-Hill, 1963), 32.

[4]*Ibid*., 12.

E. Respiratory Gas Analysis: The investigator accepts the definition given by Consolazio, et al.

> A gas sample is introduced into a reaction chamber connected to a micrometer burette and is balanced by means of an indicator drop in a capillary against a compensating chamber. During the absorption of gas, mercury is delivered into the reaction chamber from the micrometer burette . . . . Volumes are read in terms of micrometer divisions. This amount permits the determination of carbon dioxide, oxygen, and nitrogen of respiratory gases.[1]

Purpose of the Study

The general purpose of the study was to determine the influence of a run/walk training program upon the maximal aerobic intake of junior high school girls. The study was unique in that heretofore, the technique of measuring oxygen intake had not been used to study junior high school girls before and after a training program.

Delimitations of the Study

The investigation was subject to the following delimitations:

A. Only fourteen girls enrolled in the required physical education classes at DeWitt Perry Junior High School in Carrollton, Texas during the academic year of 1970-1971 participated in the study.

B. The objectivity, reliability, and validity of the selected instruments for the measurement of maximum

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[1] *Ibid.*, 72.

oxygen intake.

C. The degree to which the students are representative of the population from which they are drawn.

Summary

A great deal of attention has been given by the American public in recent years to physical conditioning and physical fitness testing. Physical fitness involves many functions of the human body and numerous tests have been devised to measure the various components of physical fitness. Several of these tests have been enumerated in this chapter.

In this chapter a statement of the problem was given as well as definitions and explanations of terms relative to the study of the maximum aerobic intake as a fitness indices. The statement of the problem involved the principles underlying the measurement of the maximum aerobic intake of junior high school girls and its relationship upon cardiovascular fitness. A more detailed survey of the literature pertinent to this study will be presented in Chapter II.

CHAPTER II

RELATED LITERATURE

The review of literature pertinent to this study is presented to describe the techniques utilized by other investigators and to report the results that were obtained.

A. In 1942 Knehr, Dill, and Neufeld conducted a study pertaining to training and its effects on man at work and at rest.[1] The fourteen male subjects at Harvard University followed a training program for middle-distance running over a period of six months. The running was pursued three times weekly.

The men were studied before and during the training period, at rest, and while doing two grades of work on a motor driven treadmill. Bimonthly observations were made of the men at rest and biweekly studies of work performance in the Fatigue Laboratory were recorded.

It was found that a regimen of training did not alter, significantly, the decline of heart rate during a time range of three to four minutes. Thereafter,

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[1] C. A. Knehr, D. B. Dill, and William Neufeld, "Training and Its Effects on Man at Rest and at Work," American Journal of Physiology, CXXXVI No. 1, (March, 1962), 148-56.

following exhausitive exercise, the decrease in resting pulse rate was five beats per minute. The corrected data indicated that when complete exhaustion is reached in a given time period with varying rates of work, the pulse recovery curve was unaffected by training. In exhausting work there was an increased capacity for supplying oxygen to tissues and greater utilization of anaerobic reserves of energy.

B. In 1955 Taylor, Buskirk, and Henschel conducted a study to describe the technique of maximal oxygen intake, its limitations, and its usefulness in longitudinal experiments.[1] The subjects were male, ranging in age from eighteen to thirty-five, in good health, and all were conscientious objectors.

All work was done on a treadmill. The expired air was collected in balanced spirometers utilizing modified Towers respiratory valves.

Taylor, et al., determined it is more satisfactory to maintain a constant speed (seven miles per hour) when using a treadmill and increasing the grade in steps of two and one-half percent than to use a constant grade and changing the treadmill speed. Expired air was collected from the subjects one minute and forty-five seconds to two minutes and forty-five

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[1]Taylor, Buskirk, and Henschel, "Maximal Oxygen Intake," 73.

seconds of a three-minute run. The oxygen consumption had reached a steady state and was determined by examining the oxygen consumption for the final minute of the run. The investigators concluded if the oxygen intake at two different grades differs by less than 150cc per minute or 2.1cc per kilogram of body weight per minute, it can be assumed that a maximal oxygen intake has been attained.

C. Astrand[1] completed a study of 119 female subjects and 115 male subjects ranging in age of four years to thirty years. The study was concerned with physical fitness with special reference to sex and age.

The investigator determined that up to and including age thirteen, the maximal pulmonary ventilation of girls is of the same capacity as for boys. With the onset of puberty there is a relative decrease for the female's capacity for oxygen transport and it falls twenty-five to thirty percent lower than those of the male. In relation to body weight the difference becomes fifteen to twenty percent lower.

The average pulse rate during maximal physical work averaged 200 beats per minute for the total 227 subjects. It was determined that when well-trained subjects of both sexes in the same age group performed

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[1]Astrand, "Human Physical Fitness with Special Reference to Sex and Age," 307-35.

the same work on a bicycle ergometer, the males pulse rate was 128 beats per minute and the female pulse rate was 168 beats per minute with the oxygen intake at 2.1 L/min.

When undertaking muscular activity of such severity that the demand for oxygen intake was fifty percent of aerobic capacity, the heart rate averaged 138 beats per minute for female subjects. When working at a load which demanded an oxygen intake of seventy percent of aerobic capacity, female subjects had an average heart rate of 164 beats per minute.

Maximum pulmonary ventilation for boys age four to six was forty liters per minute. Boys twelve to thirteen years of age averaged seventy-five liters per minute. Female subjects older than twelve years had a maximum pulmonary ventilation between 46-48 ml/kg/min. The oxygen consumption was about seventeen percent lower than those of males of the same age group.

D. In 1957 Balke[1] discussed performance capacity in some detail. If physical work was to be performed on a motor driven treadmill, Balke recommended energy expenditure begin initially at a low level at the

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[1] Bruno Balke, "Performance Capacity," Symposium Department of the Army Research and Development Command Quartermaster Food and Container Institute for the Armed Services, Chicago, Illinois, April 12 and 13, 1957 (National Academy of Sciences, February, 1961), 13-19.

beginning of the test and then be increased gradually in small increments up to the maximal attainable level. That is best accomplished by elevating the treadmill angle in one-minute intervals by one percent while the speed is kept constant at 3.34 mph. The pulmonary gas exchange is measured continuously or at frequent intervals by collecting the expired air in Douglas bags with subsequent gas analyses.

With rising work intensities, the pulse rate and systolic pressure increase. The slope of the pulse rate curve varied not only from individual to individual but also within the same experimental subject. In men the systolic pressure usually reaches a peak at a workload when the pulse rate is close to 180 beats per minute. In most instances the systolic pressure drops off if this pulse rate is exceeded and as a result, the cardiac reserves become exhausted. In measuring oxygen consumption, an acceleration of the pulse rate beyond 180 beats per minute will tend to cause a plateau effect in oxygen intake.

The aerobic work capacity is further limited when the pulse rate exceeds 180 beats per minute from the respiratory gas viewpoint when the output of carbon dioxide overtakes the oxygen consumption. This incident indicates an insufficient oxygen supply to the working muscles.

E. In 1961 Astrand and Saltin[1] undertook a study to determine the maximal oxygen intake and heart rate in various types of exercises. The investigators utilized seven well-trained subjects in the experiments.

The experiments were conducted over a period of three to five months. The various exercises included: cycling using arms and legs; skiing; swimming; running on a treadmill; and, cranking-arm work.

The investigators demonstrated that some variations in methods for measurements of aerobic capacity might be without significance as far as the results are concerned. It was concluded in the study that the aerobic capacity and maximal heart rate are relatively the same in maximal running or cycling in well-trained subjects. In maximal work with arms, the heart rate was higher than predicted from the oxygen intake.

The investigators determined the maximum oxygen consumption for running to be 4.69 liters as compared to 4.47 liters for the same subjects while cycling. Determination of maximum oxygen consumption between 1:45 seconds and 2:45 seconds on the treadmill yielded 4.54 liters as compared to 4.47 liters on the bicycle ergometer.

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[1]Astrand and Saltin, "Maximal Oxygen Uptake and Heart Rate," 977.

The larger the participating mass of muscle, the greater the duration a high heart rate and cardiac output can be maintained. For this reason, the investigators concluded that cycling in a sitting position or running are types of exercises that are most convenient for conducting maximal oxygen consumption experiments.

F. Skubic and Hodgkins[1] undertook a study in 1963 to determine the heart rate in exercising female subjects. The subjects ranged from eleven years of age to twenty-three years of age and were divided into four groups. These groups were trained girls, untrained girls, active women, and sedentary women.

The subjects stepped up and down an eighteen-inch bench for three minutes at the rate of twenty-four steps per minute. The pulse rate was counted for thirty seconds following a one-minute rest period after completing the exercise. The recovery pulse count was taken only once either through palpation of the carotid artery or use of a radioelectrocardiograph.

The investigators found the heart rate for trained girls to be 133.78 beats per minute after one minute of exercise; and rise to 154.62 beats per minute upon

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[1]Skubic and Hodgkins, "A Cardiovascular Efficiency Test," 191-98.

completion of the second minute of exercise; and, 160.07 beats per minute after the third minute of exercise. The heart rates for the untrained girls ranged from 140.43 beats per minute for the first minute, to 163.71 beats per minute for the second minute, and 173.62 beats per minute for the third minute of exercise. No results pertaining to the heart rates during exercise for the active and sedentary women were presented by the investigators.

G. In 1963 Balke[1] reported a study designed to determine human working capacity employing a simple field test. The male subjects used in this study were accustomed to running as a non-competitive exercise for physical conditioning.

At the conclusion of a ten-week training period, which consisted of running and walking, the work capacity of eight male subjects was determined on the treadmill. The subjects then ran for the duration of one, five, twelve, twenty, and thirty minutes on different days, attempting to cover the greatest possible distance. The average velocity was calculated for each run and, in turn, expressed in the physiological term of oxygen intake obtained during the treadmill test and the oxygen consumption estimated

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[1]Bruno Balke, "A Simple Field Test for the Assessment of Physical Fitness," Report of the Civil Aeromedical Research Institute, Federal Aviation Agency (Oklahoma City, Oklahoma, April, 1963), 1-8.

from running.

The same procedure was employed with thirty-four high school boys with the duration for the running test set at fifteen minutes. The boys were instructed to cover the greatest possible distance within that time period.

The group of boys had an average maximum oxygen intake of 43.6 ml/kg/min in the treadmill test. During the fifteen-minute run the boys averaged a velocity which required an oxygen intake of 44.4 ml/kg/min.

The adult male subjects involved in the experiment to establish the duration or length of run which may yield a performance equivalent to the information obtained from the treadmill test had the following results. The treadmill test result yielded an average of 46.1 ml/kg/min oxygen consumption. The subjects running for a duration of twelve minutes consumed 46.7 ml/kg/min of oxygen, and the running of thirty minutes yielded a maximum oxygen consumption of 42.0 ml/kg/min.

Balke stated from the results obtained in this study:

> It can readily be seen that a very short effort, e.g., running 100 yards in 10 seconds, is accomplished almost entirely anaerobically; during a four-minute run the oxygen debt capacity covers about 20 percent; during an 8-minute effort still about 10 percent of the total oxygen requirements. However, in work periods exceeding 12 to 15 minutes, the anaerobic phase becomes less and less important for the accomplishment of the total work, accounting for not more than about 5 percent of the totally required amounts of oxygen.[1]

H. In 1968 Cooper[2] completed a study of the relationship between a twelve-minute field test and a treadmill maximum oxygen consumption test. Special emphasis was placed on the accuracy of estimating the maximum oxygen consumption from the results of a twelve-minute performance test.

The subjects were 115 U. S. Air Force male officers stationed at Lackland Air Force Base, Texas. The average age of the officers was twenty-two with a range from seventeen to fifty-two years.

The twelve-minute performance test was accomplished by all subjects utilizing an accurately measured 1.0 mile course. Each subject ran the twelve-minute test twice and the oxygen consumption data was compared with the nearest twelve-minute test. The interval between the field test and the treadmill

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[1] Ibid., 7.

[2] Cooper, "Correlation between Field and Treadmill Testing," 201-03.

test was no longer than three days.

Each test on the treadmill consisted of several three-minute runs separated by ten-minute rest periods. The subject was connected to either a Tissot gasometer or a two hundred-liter Douglas bag before beginning the treadmill test.

The investigator plotted the regression of distance in twelve minutes against the oxygen consumption and concluded that, "From the regression line, a good estimate of maximal oxygen consumption can be made on the basis of twelve-minute performance."[1]

After a period of training, several of the 115 officers were retested. It was demonstrated that with training, the subjects rapidly progressed up the regression line and when regular exercise ceased, performance decreased but still followed the regression line.

As a result of this study, levels of cardiovascular fitness have been established for the twelve-minute walk/run test. Since the majority of Cooper's subjects were less than twenty-five years of age, the levels of fitness pertain primarily to this age group.

The following results are predicted maximal oxygen consumption on the basis of the twelve-minute

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[1]*Ibid.*, 203.

performance. The distance of one mile would indicate an individual attained a maximal oxygen consumption of 25 ml/kg/min. An individual completing 1.5 miles in twelve minutes would have attained 42.6 ml/kg/min, and upon completion of 1.75 miles, 51.6 ml/kg/min.

I. Doolittle and Bigbee completed a study in 1968 to evaluate the distance covered in twelve minutes as an indicator of cardiorespiratory fitness.[1] The results from the twelve-minute test were compared with those from the more familiar 600-yard run/walk.

The subjects were 153 boys enrolled in the ninth grade. All the students were participating in the required physical education program at Luther Burbank Junior High School, Burbank, California.

The field test was performed on a quarter-mile grass track that had been divided into eighths. Each eighth was numbered consecutively for ease in determining the correct distance covered.

All subjects successfully completed a test-retest of the field performance test. The elasped

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[1]T. L. Doolittle and R. Bigbee, "Twelve-Minute Run-Walk: A Test of Cardiorespiratory Fitness of Adolescent Boys," Research Quarterly, XXXIX (October, 1968), 491-95.

time between the two field tests was five days. Nine subjects performed the 600- yard run/walk and the maximum oxygen consumption was later determined on a bicycle ergometer.

The results yielded a high correlation between the test-retest for the twelve-minute test and the maximum oxygen consumption. A low correlation was found for the 600-yard run/walk and maximum oxygen consumption.

J. Wilmore, et al., undertook a study in 1969 to evaluate the effectiveness of jogging for promoting significant increases in cardiorespiratory endurance in a large group of males of varying age.[1] The study was to further determine if the magnitude of the physiological changes is directly related to the duration of the exercise period.

The subjects consisted of volunteers from the male students, faculty, and staff at the University of California at Berkley. Fifty-five men ranging in age from seventeen through fifty-nine were divided into two exercise groups.

One exercise group performed a jogging program of twelve minutes/day, three days/week for a total of ten weeks. The second group performed the

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[1]Jack H. Wilmore, J. Royce, Robert N. Girandola, Frank Katch, and Victor L. Katch, "Physiological Alterations Resulting from a 10-Week Program of Jogging," Medicine and Science in Sports, II No. 1 (1970), 7-14.

jogging regimen twenty-four minutes/day, three days/week for a ten-week period.

A pretest/post test step-increment type of work was administered on a bicycle ergometer. Ventilation volumes, expired air aliquots, respiration rates, and electrocardiograms were monitored continuously at the end of each minute during the work capacity test.

The twelve-minute jogging group indicated change in the resting heart rate from 75.7 beats/min to 66.2 beats/min as compared to the twenty-four-minute group which had a resting heart rate of 70.7 beats/min pre-training and 62.5 beats/min post-training.

The maximum oxygen uptake for the twelve-minute group increased significantly from 41.56 ml/kg/min to 44.03 ml/kg/min (P = 0.05 level). The maximum oxygen uptake for the twenty-four-minute group increased from 42.96 ml/kg/min to 47.12 ml/kg/min (P = 0.05 level).

Both groups demonstrated significant increases in vital capacity, maximum oxygen intake, and oxygen pulse. Significant decreases were found in both resting heart rate and maximal heart rate. A decrease in residual lung volume was found only in twelve-minute group, while only the twenty-four-minute group showed significant decreases in weight and increases in total work and maximum tidal volume. The twenty-four-minute group generally demonstrated the greatest changes. The differences between the two groups were not statistically significant with exception of residual lung volume.

Summary

A review of the literature especially pertinent to this investigation has been presented in Chapter II. Chapter III will be concerned with the detailed procedures followed in the development of the study.

CHAPTER III

PROCEDURES FOLLOWED IN THE DEVELOPMENT OF THE STUDY

This chapter will encompass the development of the study under the following headings: Sources of Data, Preliminary Procedures, Selection and Description of Techniques of Measurements and Instruments, Procedures for Obtaining Subjects, Collection of the Data, and Summary.

Sources of Data

The sources of data for the development of this investigation are both documentary and human resources. The documentary sources were books, periodicals, pamphlets, and bulletins related to all aspects of the study. Pertinent theses and dissertations as well as microcards and microfilms were examined in preparing the study.

The human sources consisted of selected authorities in the fields of physiology and physical education. Special assistance was procured with the cooperation of Gunnar Blomqvist, M. D. and Staff from the Pauline and Adolph Weinberger Laboratory in the Cardiopulmonary Research Department of Internal Medicine, at the University of Texas Southwestern Medical School in Dallas, Texas.

Further assistance was received from Bruno Balke, M. D. from the University of Wisconsin, and Lt. Col. Kenneth Cooper, MC, USAF, Aerospace Medical Laboratory, Lackland Air Force Base, Texas. The human sources who participated in the study were fourteen girls enrolled in the required physical education program at DeWitt Perry Junior High School in Carrollton, Texas.

Preliminary Procedures

The investigator outlined and adhered to several preliminary procedures in the development of the study. A review of the literature relevant to the study was conducted. The review included the techniques utilized by other investigators to measure oxygen intake, and the results obtained by these investigators.

Permission was obtained from Dr. Gunnar Blomqvist and the Human Research Committee of the University of Texas Southwestern Medical School in Dallas, Texas to use the Human Research Laboratory and equipment in the Cardio-pulmonary Research Department at the medical school. The services of a qualified laboratory technician to make the Scholander gas analysis was also secured.

A Tentative Outline of the study was prepared and presented on January 28, 1971 in a Graduate Seminar of the College of Health, Physical Education, and Recreation at the Texas Woman's University. In accordance with suggestions and recommendations accrued from the seminar, the outline was revised and approved by the members of the thesis committee. The approved outline was then filed in the form of a prospectus in the Office of the Dean of Graduate Studies at the Texas Woman's University.

Selection and Description of Techniques of Measurements and Instruments

The exercise performed in the laboratory for testing purposes was executed on an A. R. Young treadmill. No particular level of skill is required for walking on a treadmill when compared to a level of skill required for exercising on a bicycle ergometer. A Hewlett-Packard EKG recorder was used in determining the heart rate of each subject during the laboratory testing.

The oxygen intake was determined by the Douglas bag technique, using a Collins triple J valve. The volume of expired air was measured in a Tissot spirometer. Samples of expired air were stored in Mercury gas tonometers and were then analyzed by the Scholander technique. An experienced laboratory technician in the employ of the medical school analyzed the gas samples to determine the relative concentrations of oxygen and carbon dioxide.

A pilot study was conducted to determine the initial grade and speed the treadmill would be set to initiate testing. It was determined, from the pilot study, that the treadmill should be set at an initial grade of five degrees as suggested by Balke.[1] The grade of the treadmill was subsequently increased two and one-half percent every two and one-half minutes[2] until the pulse rate was approximately 170 beats per minute as suggested by Astrand.[3]

The speed of the treadmill was maintained at a constant rate of three mph. Information received from the pilot study demonstrated this particular speed to be the best in order for each subject not to break her walking stride and begin to run.

Procedures for Obtaining Subjects

Subjects for the study were selected from the female students enrolled in the required physical education program at DeWitt Perry Junior High School in Carrollton, Texas. The details of the proposed study were carefully explained to each prospective subject and to her parents. A total of fourteen girls participated in the study.

The medical school and the Public Health Service regulations required written consents be obtained from all human subjects. A copy of the parental consents may be found in the Appendix. The Carrollton-Farmers Branch Independent School District required written parental

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[1]Balke, "Performance Capacity," 13-19.

[2]Taylor, Buskirk, and Henschel, "Maximal Oxygen Intake," 73-80.

[3]Astrand, "Human Physical Fitness," 307-35.

consents and a copy may be found in the Appendix.

Collection of the Data

The regimen to be followed in the run/walk training was established as suggested by Balke.[1] The subjects participated in the training program continuously for eight weeks. The exercise involved running twelve minutes a day, three days per week for a total of eight weeks. The girls were instructed to cover the greatest distance possible within the alloted time. The exercise was performed on an accurately measured 440-yard track which was further divided into eighths for convenience in measuring purposes.

The subjects were provided with proper clothing and shoes. The exercise was conducted at the same time each day and the entire group completed the training program.

Prior to the actual pretesting, the subjects were transported to the Southwestern Medical School and familiarized with the equipment to be used in the laboratory testing. An assessment of the approximate work level at which the subjects would reach a pulse rate of 150-170 beats per minute was made at this time.

The pretesting was conducted with two subjects each day. Each subject was connected with three electrodes.

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[1]Balke, "A Simple Field Test," 7.

The resting heart rate was monitored prior to the warmup period. The warmup period consisted of each subject walking on the treadmill set at zero grade level at a rate of three mph for three minutes. The subject's nose was then clamped shut and the mouthpiece inserted in order for a small gas sample to enter two Douglas bags. This made it possible to flush the Douglas bags with the subject's air. After the warmup was completed, the subject was allowed to sit and the bags were then evacuated and all equipment checked before the actual test.

The actual test began with the subject walking at three mph at an initial grade of five degrees. Every two and one-half minutes the grade was raised two and one-half percent until the heart rate reached 150 beats per minute at which time the first gas sample was taken. The subject continued walking until the heart rate reached 170 beats per minute at which time the second gas sample was collected. Each sample was taken for a one-minute period.

At the conclusion of the treadmill test, the subject was seated and the heart rate monitored continuously. The bags were removed and the gas volume was measured individually in a Tissot spirometer and a small sample stored in a mercury tonometer for analyzation of the percentage of oxygen and carbon dioxide concentrations via the Scholander technique. The treadmill was operated by a trained student assistant. The investigator monitored the EKG recorder and sampled and stored all gas samples for analysis.

The training period was initiated upon completion of the laboratory pretest of the fourteen subjects. At the conclusion of the eight weeks run/walk program, each subject underwent a post test in the laboratory identical to the pretest previously described.

Summary

The procedures followed in the course of the study have been described. Information concerning the source of the subjects and technical procedures used in obtaining gas samples were presented. The actual laboratory testing method was described in detail. The data obtained from the laboratory tests and the training program will be presented and interpreted by the appropriate tables and diagrams in Chapter IV.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF DATA

The present chapter contains an analysis and interpretation of the data collected during this investigation. The raw data appear in Appendix B of this thesis. The data processing services of the University of Texas Southwestern Medical School were utilized for the computation of the data. An Olivetti-Underwood Programma 101 Electronic Desk Computer was used for the analysis of the data.

The means, standard deviations, and standard errors of the means for the oxygen intake, minute ventilation, respiratory quotient, heart rate, and treadmill grade have been summarized in Tables 1, 2, 3, and 4 for the fourteen subjects. Table 1 has been presented on page 32.

The $\dot{V}O_2$ (oxygen uptake) is expressed in liters per minute (L/min). There was a significant increase in the $\dot{V}O_2$ in L/min between the two gas samples taken when the pulse was approximately 150 beats/min and 170 beats/min.

The respiratory quotient (RQ) between the two gas samples did not differ significantly ($P = .20$). This measure indicates the subjects were tested aerobically. An RQ of 1.00 or above would have been indicative of anaerobic work.

TABLE 1

GROUP MEAN DATA FOR TWO EXPIRED GAS SAMPLES PRIOR TO TRAINING

N = 14	Gas Sample 1			Gas Sample 2		
	Mean	SD	SE	Mean	SD	SE
$\dot{V}O_2$ L/min	1.24[a]	0.15	0.04	1.40[a]	0.19	0.05
$\dot{V}E$ L/min	43.11	7.80	2.08	47.42	8.26	2.21
RQ	.88[b]	.05	.01	.89[b]	.46	.02
HR	156.40[c]	5.20	1.40	170.60[c]	4.72	1.26
GT	8.75[d]	2.55	0.68	10.71[d]	2.28	0.61

Key to symbols: $\dot{V}O_2$ = oxygen Uptake, $\dot{V}E$ = Minute Ventilation BTPS, RQ = Respiratory Quotient, HR = Heart Rate, GT = Grade of Treadmill.

a = $P < .0005$
b = $P = .20$
c = $P < .001$
d = $P < .0005$

The first gas sample was taken when the heart rate of the subjects approximated 150 beats/min and the second sample was taken when the heart rate had reached approximately 170 beats/min. Table 1 illustrates the increase in the heart rates between samples and the difference was significant ($P < .001$). The heart rates increased as the level of the grade on the treadmill was increased.

The means differed significantly for the measures of oxygen uptake, respiratory quotient, heart rate, and the grade of the treadmill only illustrates that the samples were taken at two different time intervals. The data presented in Table 1 and Table 2 reaffirms the testing procedures described previously in Chapter II.

The means, standard deviations, and standard errors of the means for two expired respiratory gas samples after training are presented in Table 2. The data illustrated in the table are for the group of fourteen subjects.

The $\dot{V}O_2$ obtained from the first expired gas sample was 1.32 L/min and the $\dot{V}O_2$ from the second sample averaged 1.49 L/min. The difference was significant ($P < .0005$), since the samples were taken deliberately at different time intervals. The respiratory quotients did not differ significantly ($P = .0125$) and were .88 and .85 respectively for the first and second samples.

The heart rates averaged 153.86 beats/min for the first sample and 168.21 beats/min for the second expired gas sample. There was a significant difference in the heart rate at the time the two respiratory gas samples were collected ($P < .0005$).

The significant difference in the means for the measures of oxygen uptake, respiratory quotient, heart rate, and the grade of the treadmill illustrated that the gas samples were taken at two different time intervals. The procedures described earlier in Chapter II for observing the metabolic changes at different pulse rates were confirmed by the analysis of expired gas samples obtained upon the completion of the training program and were similar to the pattern observed in the pretest.

TABLE 2

GROUP MEAN DATA FOR TWO EXPIRED GAS SAMPLES AFTER TRAINING

N = 14	Gas Sample 1			Gas Sample 2		
	Mean	SD	SE	Mean	SD	SE
$\dot{V}O_2$ L/min	1.32[a]	0.15	0.04	1.49[a]	0.21	0.06
$\dot{V}E$ L/min	38.71	9.95	2.66	46.34	10.52	2.81
RQ	.88[b]	.08	.02	.85[b]	.25	.07
HR	153.86[c]	3.92	1.05	168.21[c]	3.91	1.04
GT	9.46[d]	2.23	0.60	11.96[d]	2.73	0.60

Note: Symbols are the same used in Table 1.

a = $P < .0005$
b = $P = .0125$
c = $P < .0005$
d = $P < .0005$

The group mean data for expired gas samples before and after the training period are presented in Table 3 on the following page.

The mean oxygen uptake for sample one before training was 1.24 L/min at a mean heart rate of 156.40 beats/min and increased to 1.32 L/min at a slightly lower heart rate of 153.86 beats/min for sample one after training. The respiratory quotient was identical in samples one before and after training.

TABLE 3

GROUP MEAN DATA FOR EXPIRED GAS SAMPLES 1
BEFORE AND AFTER TRAINING

N = 14	Sample 1 Before			Sample 1 After		
	Mean	SD	SE	Mean	SD	SE
$\dot{V}O_2$	1.24	0.15	0.04	1.32	0.15	0.04
$\dot{V}E$ L/min	24.48	3.47	0.93	25.45	2.99	0.86
RQ	.88	.05	.01	.88	.08	.02
HR	150.40	5.20	1.40	153.86	3.92	1.05
GT	8.75	2.55	0.68	9.46	2.23	0.60

The group mean data for expired gas samples two before and after the training period are presented in Table 4.

TABLE 4

GROUP MEAN DATA FOR EXPIRED GAS SAMPLES 2
BEFORE AND AFTER TRAINING

N = 14	Sample 2 Before			Sample 2 After		
	Mean	SD	SE	Mean	SD	SE
$\dot{V}O_2$ L/min	1.40	0.19	0.05	1.49	0.21	0.06
$\dot{V}E$ L/min	27.73	4.30	1.15	28.65	3.21	0.86
RQ	.89	.46	.01	.85	.25	.07
HR	170.60	4.72	1.26	168.21	3.91	1.04
GT	10.71	2.28	0.61	11.96	2.23	0.60

The mean oxygen uptake of 1.40 L/min for sample two before the training period increased to a mean of 1.49 L/min in the second sample after the training period. The respiratory quotient remained relatively constant in both instances and illustrated, once again, that the oxygen intake of the subjects was measured in the aerobic stage of work.

The heart rate was slightly lower during the post training test second gas sample. The grade of the treadmill was increased during testing but again, as Table 3 indicates, the heart rate was slightly lower despite the increase in grade of the treadmill.

Pearson Product-Moment correlation coefficients were applied to the combination of variables listed in Table 5. The coefficient of correlation is presented for the means of expired gas samples one and two before and after the training program.

TABLE 5

CORRELATION OF THE HEART RATE WITH OXYGEN UPTAKE, MINUTE VENTILATION WITH OXYGEN UPTAKE, AND RESPIRATORY QUOTIENT WITH OXYGEN UPTAKE

N = 14	Mean Samples 1 & 2 Before Training		Mean Samples 1 & 2 After Training	
	r	SEE	r	SEE
HR VS $\dot{V}O_2$	0.08	4.03	0.33	3.00
$\dot{V}E$ VS $\dot{V}O_2$	0.52	6.34	0.44	8.65
RQ VS $\dot{V}O_2$	0.41	0.04	0.38	0.05

The coefficients of correlation between heart rate and $\dot{V}O_2$ ml/kg/min before and after training are positive. According to Koenker,[1] correlation coefficients ranging from 0.20 to 0.59 show only a slight to fair degree of relationship.

A line of regression and individual plots of the heart rate correlated with oxygen uptake expressed in ml/kg/min are presented in Figure 1. The graph illustrates a linear decrease in $\dot{V}O_2$ with a high heart rate in samples one and two before the training program. After training the slope of the line of regression increases with a higher $\dot{V}O_2$.

There is a slight increase in oxygen uptake with an increase in heart rate after the training period. In Figure 1, a lower heart rate yields an increase in oxygen uptake after training. This is in agreement with Astrand and Rodahl[2] who have explored this area of work physiology in great detail.

The correlation coefficients between minute ventilation ($\dot{V}_E$) and oxygen uptake ($\dot{V}O_2$) showed a fair degree of relationship. According to Astrand and Rodahl,[3] a

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[1]Robert H. Koenker, Simplified Statistics, (Bloomington, Illinois: McKnight and McKnight, 1961), 52.

[2]Per-Olof Astrand and Kaare Rodahl, Textbook of Work Physiology, (New York: McGraw-Hill, 1970), 350.

[3]*Ibid.*, 207.

positive correlation always exists between the two variables but ventilation has very poor predictive value with respect to oxygen utilization, because it does not reflect the transfer of oxygen to the blood and muscles. The correlation between minute ventilation and oxygen uptake has been presented in Figure 2 by a line of regression.

The respiratory quotient (RQ), is the ratio CO_2 produced divided by O_2 utilized (CO_2/O_2), was correlated, experimentally, with oxygen uptake. There was only a slight correlation between the two variables and in Figure 3 the lines of regression for before and after training illustrate an almost identical pattern. The individual plots in Figure 3 confirm the fact that the subjects were in the aerobic stage of work.

The mean data for an extrapolation of the heart rate before and after the training program at an oxygen uptake of 25 ml/kg/min have been presented in Table 6.

TABLE 6

MEAN HEART RATE B/MIN AT
$\dot{V}O_2$ 25 ML/KG/MIN

N = 14	HR Before	HR After	ΔHR	%Δ HR
$\bar{X}$	156.1*	152.4*	-3.71	-1.52
SD	20.1	22.2	21.79	13.83
SE	5.5	5.9	5.82	3.70

*$P > 0.25$

An extrapolation was made from an assumed mean oxygen uptake of 25 ml/kg/min before and after the training period. The mean heart rate was 156.1 beats/min before the training period and decreased to 152.4 beats/min after the training period. The training program did not result in a significant change ($P > 0.25$) in the heart rate of the subjects. A graphic illustration of the heart rate is presented in Figure 4.

The mean data for an extrapolation of the oxygen uptake before and after the training period at a heart rate of 170 beats/min has been presented in Table 7.

TABLE 7

MEAN $\dot{V}O_2$ IN ML/KG/MIN AT HEART RATE 170 B/MIN

N = 14	$\dot{V}O_2$ Before	$\dot{V}O_2$ After	$\Delta\dot{V}O_2$	%Δ VO_2
$\bar{X}$	27.7*	29.2*	1.54	6.60
SD	4.8	3.8	2.88	11.41
SE	1.3	1.0	0.77	3.05

*$P < 0.05$

An average heart rate of 170 beats/min was utilized to determine the subjects oxygen uptake before and after training. The heart rate of 170 beats/min indicated that the subjects were working aerobically. The extrapolation of $\dot{V}O_2$ before the training period was 27.7 ml/kg/min and increased to 29.2 ml/kg/min after the training period ($P > 0.05$). There was an increase of 6.6% in oxygen uptake for the subjects. A graphic description of the extrapolated oxygen uptake is presented in Figure 4.

The heart rate of the subjects before the training program did not change significantly as a result of training. However, the oxygen uptake increased significantly after the training program even though the heart rate remained relatively unchanged.

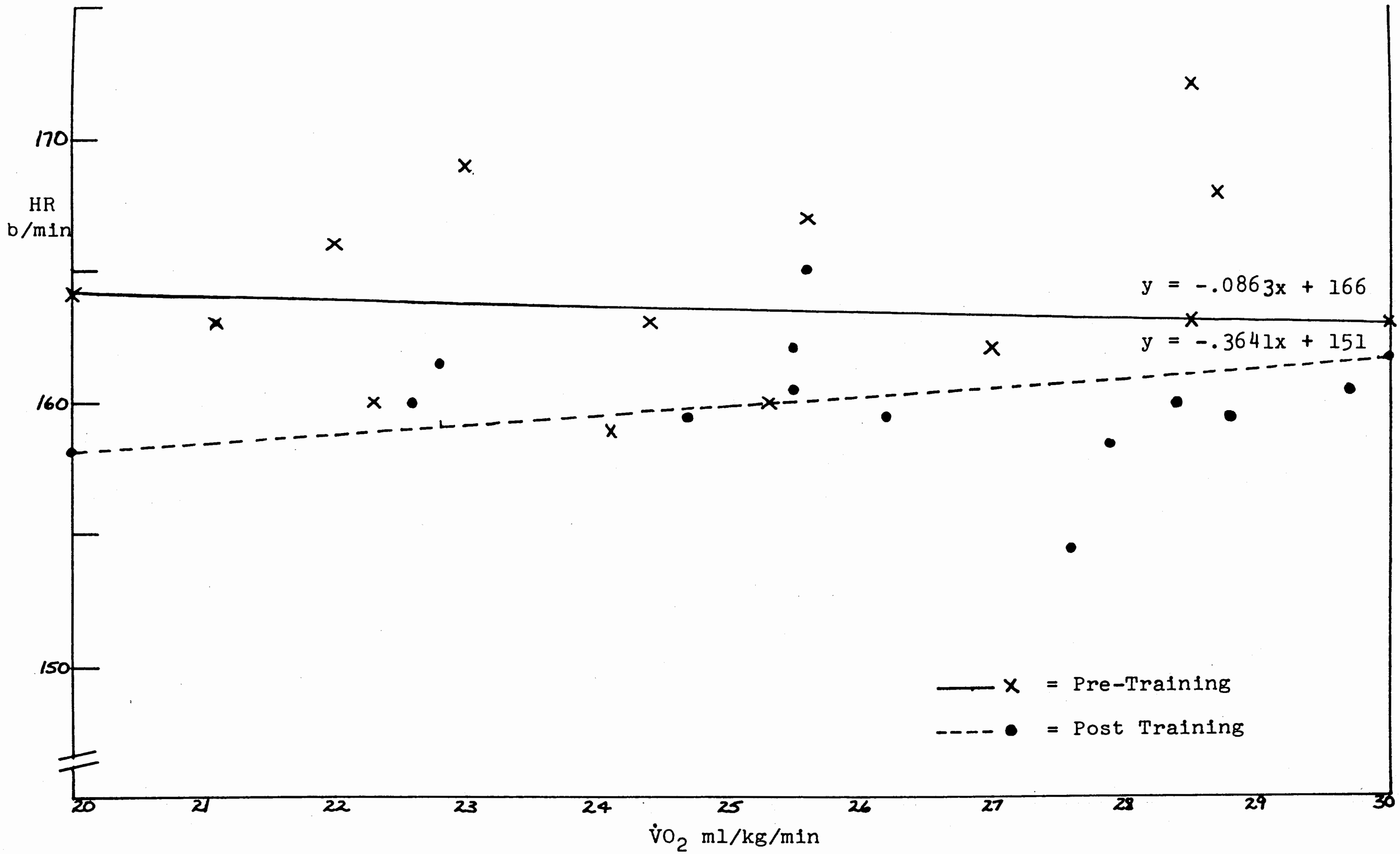

Figure 1.--Line of regression HR vs $\dot{V}O_2$. Expired gas samples 1 and 2 pre and post training.

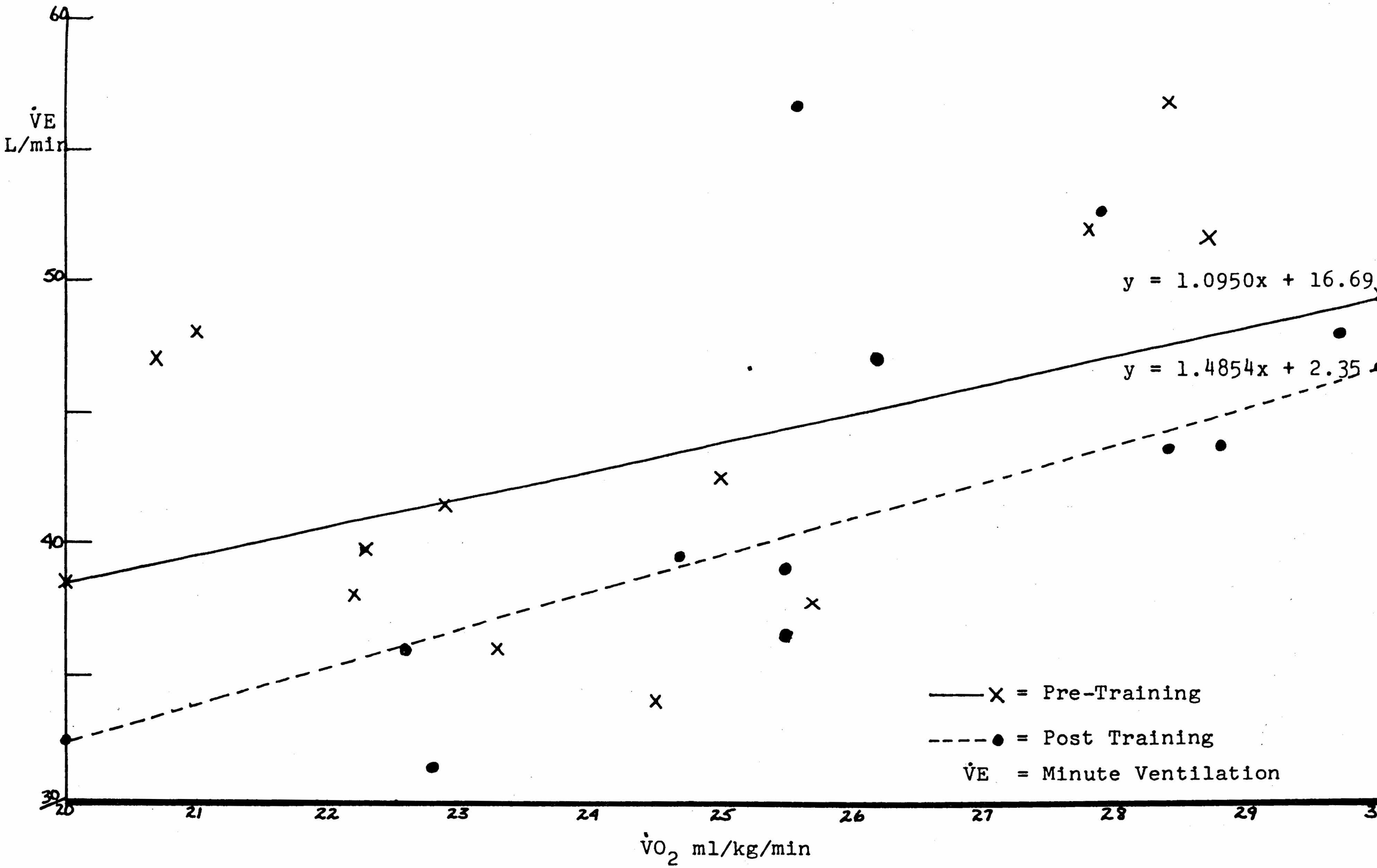

Figure 2.--Line of regression $\dot{V}E$ vs $\dot{V}O_2$. Expired gas samples 1 and 2 pre and post training.

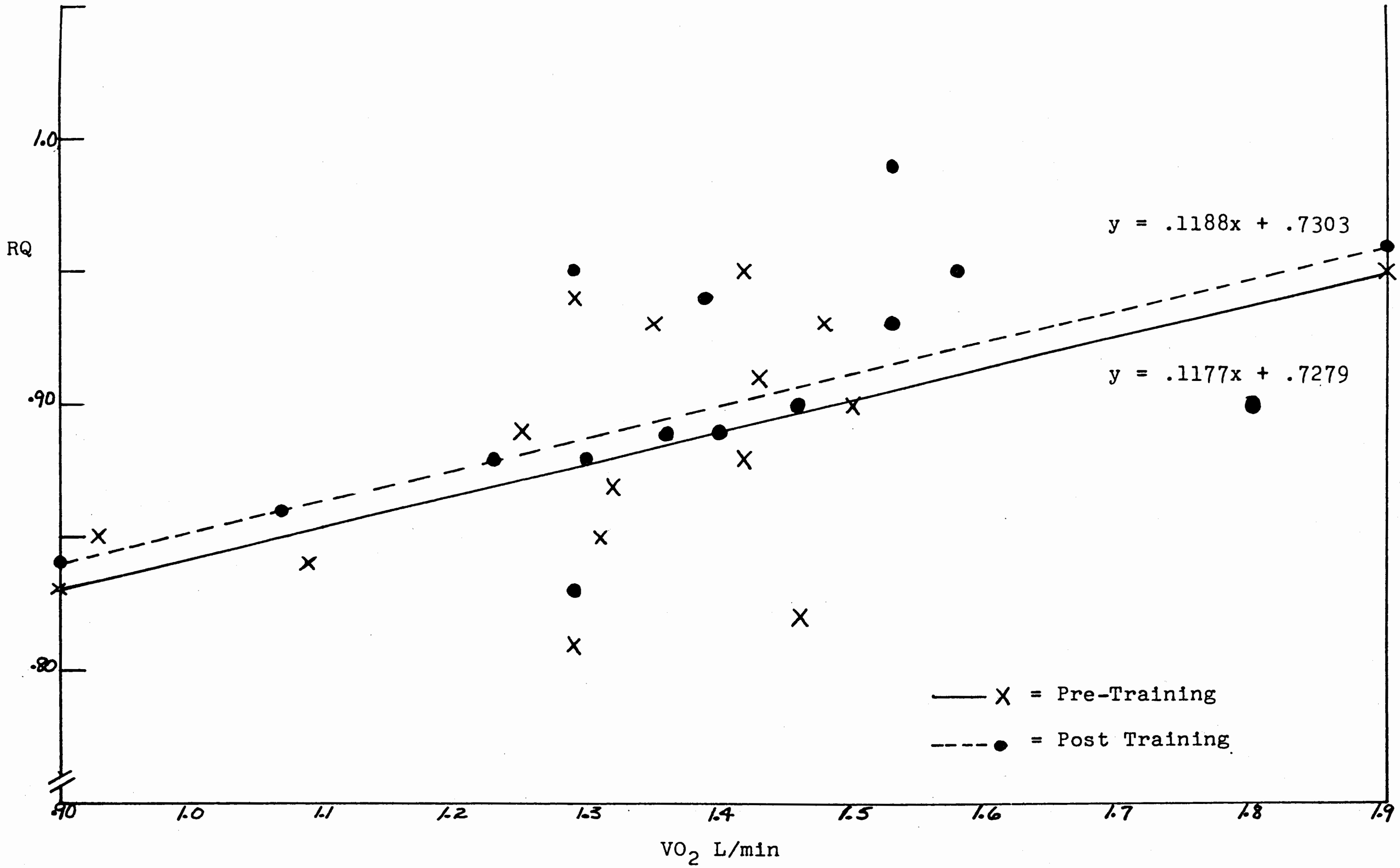

Figure 3.--Line of regression RQ vs VO_2. Expired gas samples 1 and 2 pre and post training.

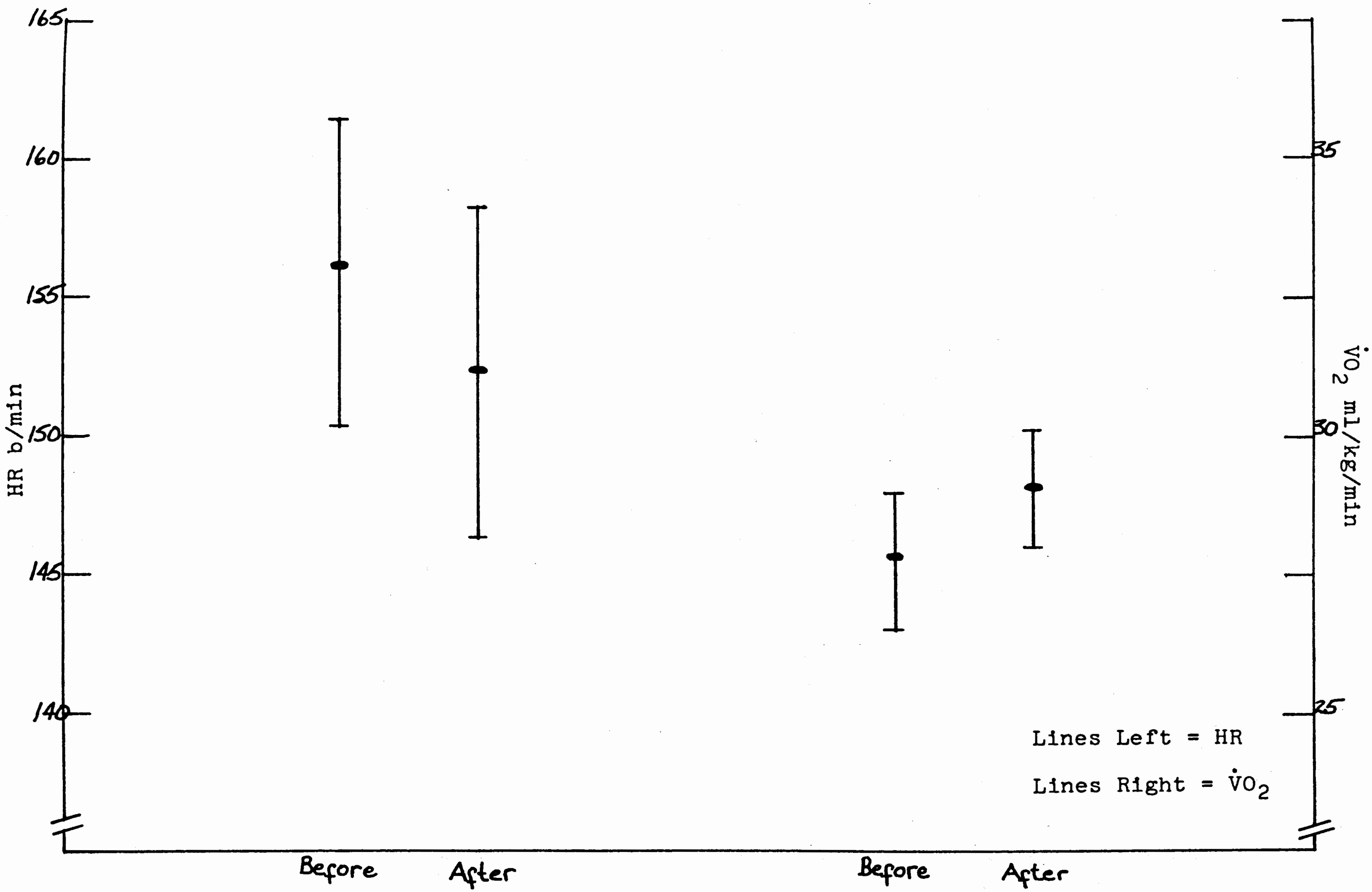

Figure 4.--Extrapolated Heart Rate at $\dot{V}O_2$ 25 ml/kg/min. $\dot{V}O_2$ at Heart Rate of 170 b/min.

Summary

This chapter was devoted to an analysis and interpretation of the data. The group mean data was presented for the two expired gas samples obtained from each subject before the training program was begun and after the training program was completed.

The means, standard deviations, and standard errors of the means were calculated for each expired gas sample collected. The data procured from the samples obtained before the subjects initiated the run/walk program were statistically significant from one another. The expired gas samples secured from each subject after the training period were also significantly different from one another.

Correlation coefficients have been presented between heart rate and oxygen uptake; minute ventilation and oxygen uptake; and, respiratory quotient and oxygen uptake. The correlation coefficients were low, indicating at best only a slight to fair, positive relationship.

An extrapolation of the heart rate at an oxygen uptake of 25 ml/kg/min was made. The change in the heart rate noted was not significant. An extrapolation of the oxygen uptake at a heart rate of 170 beats/min has also been presented. There was a significant increase in the oxygen uptake of the subjects at the given heart rate.

Chapter V contains the summary, conclusions, and recommendations for further studies.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDIES

Statement of the Problem

This investigation entailed a study of one vitally important parameter of the cardiorespiratory system, the maximal aerobic oxygen intake. The subjects were fourteen junior high school girls enrolled in DeWitt Perry Junior High School in Carrollton, Texas.

Changes in cardiorespiratory fitness before and after a prescribed run/walk training program were noted in the study. By measuring the maximum aerobic intake before the training program was initiated and after the training program had been completed, conclusions concerning the effectiveness of participation in the training program could be assessed. The aerobic oxygen intake was used as the principal indices utilized in determining alterations of cardiorespiratory fitness of the subjects in this investigation.

Procedures

The exercise performed in the laboratory for testing purposes was executed on a motor driven A. R. Young treadmill. An EKG recorder was used in determining the heart rate of each subject during the laboratory testing.

The oxygen intake was determined by the Douglas bag technique, using a Collins triple J respiratory valve. The volume of expired air was measured in a Tissot spirometer. Samples of expired air were stored over mercury in gas tonometers and were then analyzed by the Scholander technique for concentrations of carbon dioxide and oxygen.

The speed of the treadmill was maintained at a constant rate of three mph and set at an initial grade of five degrees. The grade was increased two and one-half percent every two and one-half minutes until the heart rate of each subject was approximately 170 beats/min.

The subjects were tested prior to the prescribed exercise program and after the program. The subjects participated in the twelve-minute exercise program continuously for an eight-week period. The exercise involved running, walking, or jogging twelve minutes a day, three days per week.

Discussion

The accurate assessment of the effects of training on individuals as well as groups has been given great impetus by the publication of the popular "paperback" edition of the book Aerobics[1] by Kenneth Cooper. Many

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[1]Kenneth H. Cooper, M.D., Aerobics, (New York: M. Evans and Company, Inc., 1968).

years before this publication reached the newsstands investigators in Europe and the United States had been conducting many investigations of "training effects".

One of the great difficulties involved in assessing the changes in performance capacity of subjects has been the trend of investigators to attempt to determine the "maximum" working capacity of the subjects before and after training. All out tests on the treadmill or bicycle ergometer fill the literature of work physiology.

The use of "all out" performance test results in the production of a substantial oxygen debt and a ten-twenty fold increase in the lactic acid content of the blood which according to the worlds foremost authority, Margaria,[1] is most difficult to evaluate.

The difficulties associated with evaluating training effects when the test procedures result in anaerobic metabolic changes, are compounded by the fact that trained subjects can always work for a longer period of time on the treadmill or ergometer.

In recent years interest has been concentrated on the development of aerobic tests in which the investigator controls the duration of the work by continuously monitoring the pulse rate to prevent the subject from "gutting it out", or voluntarily pushing himself into an anaerobic work stage

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[1]R. Margaria, "Exercise at Altitude," Excerpts Medical Foundation, (Milan, Italy: 1967), 22.

during the test. Numerous investigations have demonstrated that most male subjects shift over into anaerobic work when the pulse rate reaches 180 beats/min, while female subjects tend to show the same change-over about 10 beats/min lower, 170 beats/min. A second and very accurate check on the subject's metabolism is any unusual variation in the respiratory quotient CO_2/O_2, past unity 1.000.

The heart rate and oxygen intake has been demonstrated, by many investigators; Balke,[1] Astrand,[2] Shepherd,[3] and Ganslen,[4] to be linearly related until anaerobic processes intervene; thus, one can use a cutoff pulse rate to stop the test. A double check on this assessment procedure is the respiratory quotient previously mentioned.

The aerobic working capacity of the subject assessed by utilizing the VO_2 is considered, by most investigators, to be the most valuable tool to assess the effects of changes in the performance capacity of subjects. However, even at this late date, some investigators

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[1]Bruno Balke and R. W. Ware, "An Experimental Study of Physical Fitness of Air Force Personnel," USAF Medical Journal, X, (1959), 675-688.

[2]I. Astrand, "Aerobic Work Capacity in Men and Women with Special Reference to Age," Acta Physiologica Scandinavia, IXL Supp. 169, (1960).

[3]R. J. Shepherd, Endurance Fitness, (Toronto, Ontario: University of Toronto Press, 1969).

[4]R. V. Ganslen, B. Balke, F. J. Nagle, and E. E. Phillips, "Drug Effects on Work Capacity and Orthostatic Tolerance," Journal of Aerospace Medicine, XXXV No. 7, (July, 1964).

Wilmore, et al.,[1] have persisted in using essentially "all out" tests to evaluate training effects.

The fact that the pulmonary ventilation, heart rate, oxygen intake increases steadily with an increasingly intensity of exercise has been known for a very long time, Smith.[2] The influence of specific training programs on these physiological indices is less well documented and has suffered largely from inaccuracies introduced by the design of various experiments intended to assess training effects.

The present investigation was designed to evaluate the effects of a twelve-minute jogging program, suggested by Dr. Cooper,[3] on the oxygen intake and heart rate of young teenage junior high school girls, on which there is a great paucity of information. Wilmore, et al.,[4] used a twelve-minute jogging program with twenty adult male subjects, however, the testing procedures involved all out bicycle ergometer rides and therefore the data is of little practical comparative value to assess training effects on a specific physiological variable.

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[1]Wilmore, et al., "Physiological Alteration," 8.

[2]Henry Monmouth Smith, Gaseous Exchange and Physiological Requirements for Level and Grade Walking, Carnegie Institution of Washington, (Washington, D. C., April, 1922), 322.

[3]Cooper, Aerobics.

[4]Wilmore, et al., "Physiological Alteration," 8.

In the present investigation, the subjects were first acquainted with the treadmill and respiratory gas analysis apparatus via a pilot study which was really a familiarization program. The testing procedure was then refined, as described in Chapter II, and the pre-training tests conducted on all subjects.

The subjects carried out a run/walk training program three times per week in which the general objective of the subjects was to cover as much distance in twelve minutes as possible commensurate with their performance capacity at any given stage in the program. Upon the completion of the three day per week training program, the subjects returned to the Southwestern Medical School for the post training test which was completed by approximately April 1, 1971.

The data collected during the course of the investigation was analyzed on an Olivetti-Underwood Programma 101 Electronic Desk Computer at the Southwestern Medical School. Conventional statistical procedures were utilized and have been presented in tabular and graphic form in Chapter IV of the thesis.

The data clearly indicates a significant increase in the aerobic oxygen intake between the pre-training and post training period of 90 ml/min which translates into .069 cc/min/kgs. This increase in oxygen intake is attributed to the effect of training. Conversely, there was a slight decrease in the post training pulse rates and ventilation during the treadmill testing suggesting an increase in the utilization of oxygen which may be attributed to several different factors; an increased stroke volume of the heart; improved peripheral circulation deep in the muscles or, changes in red blood cells and total hemoglobin content of the blood.

Since this investigation did not involve training programs of varying intensity or duration in excess of eight weeks, it is impossible to speculate as to what metabolic or physiological changes may have resulted by a more intensive training program or a more extended program.

It is of particular interest to note that the subjects were tested at or very close to what is considered their maximum aerobic capacity of 170 beats/min. The fact that the subjects were working aerobically at this high pulse rate level, was confirmed by the fact that the RQ did not vary significantly during the exercise and did not exceed unity, with the exception of one subject, during either the pre-training or post training tests. A regression line for the RQ has been plotted for informational purposes in Figure 3, Chapter IV.

A plot and correlation of the heart rate and VO_2 shows only a low significant relationship which improved slightly in the post training test phase of the investigation (Figure 1, Chapter IV). As has been mentioned previously, the minute volume, improved muscle circulation, lower ventilation rate and more efficient transport of oxygen are factors which must be considered here with respect to this relationship. One may speculate that, because of the frequent running and jogging training, the subjects may actually have improved their efficiency in walking on the treadmill. During long intensive training programs one would need to consider changes in body composition and muscular girths in evaluating the significance of all of the above mentioned factors.

Since the ventilation decreased about 2.5 L/min in the post training tests, plots of the ventilation vs heart rate or VO_2 tend to be less meaningful. This is understandable, in view of the fact that the ventilation only represents the exercise tidal air flow in and out of the lungs, but does not indicate the oxygen absorption rate by the blood stream as the blood passes through the lung capillaries.

Conclusions

The aerobic oxygen intake can be significantly improved by a training program of three days weekly which does not exceed twelve minutes of alternate walking and running. There is a trend for the pulse rate and gross ventilation to decrease even with moderate training program, but the results are not nearly as definitive as is the aerobic oxygen indices chosen in this investigation. A more intensive training program could conceivably improve these measures which, with a more complete battery of tests, would provide more definitive results. There is a great need for additional investigations of "training effects" on people of all ages using acceptable aerobic laboratory testing procedures. This pioneer study of young girls tested before and after a controlled training program is a step in the direction of better exercise program development, programs which are economical in terms of time yet adequate to improve the physical fitness of American youth to acceptable limits.

Recommendations for Further Studies

It is imperative that all future investigators of training effects restrict their testing procedures to aerobic procedures otherwise, the comparison of data from different investigators using all out performance tests which depend upon will power, fortitude, etc., is useless.

It would be most desirable to determine the cardiac output (minute volume) before and after a twelve-minute training program in an attempt to explain the significant changes in the aerobic oxygen intake in this investigation.

It would be desirable to investigate the effects of run/walk jogging programs in which the subjects had a mandatory distance to cover or, ran, jogged, and walked at specific time intervals for twelve minutes per day.

It would be desirable to examine the effects of doubling the exercise period, but still allow the subjects to "go as they please" for twenty-four minutes.

It would be of interest to assess the red blood cell and hemoglobin content before and after a twelve-minute training program to see if the oxygen intake improvements noted in this investigation can be correlated with other physiological parameters.

APPENDICES

APPENDIX A

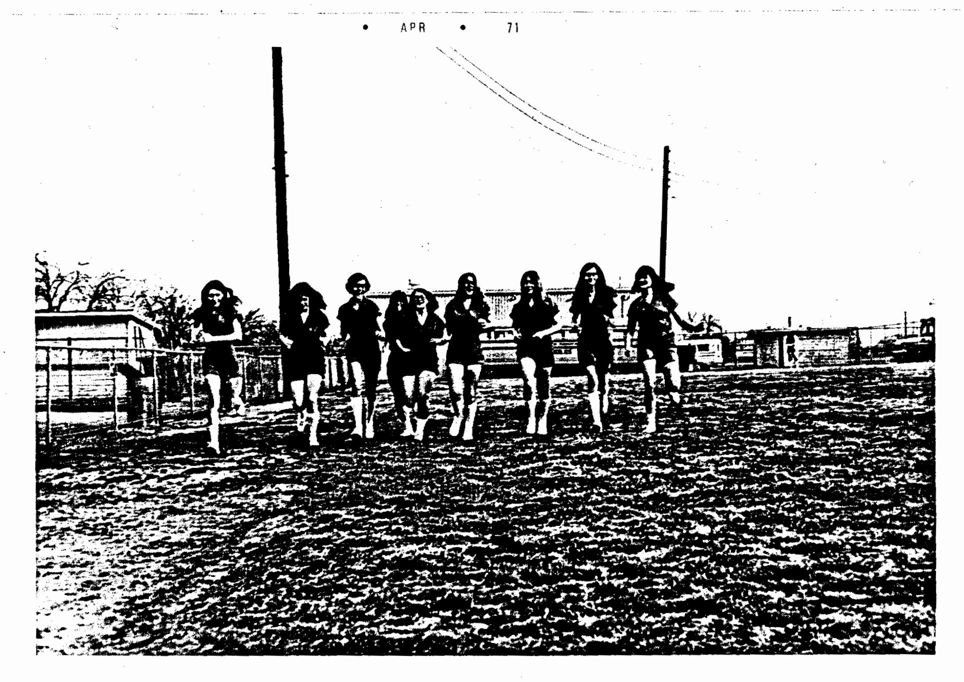

Figure 5.--Subjects participating in the training program.

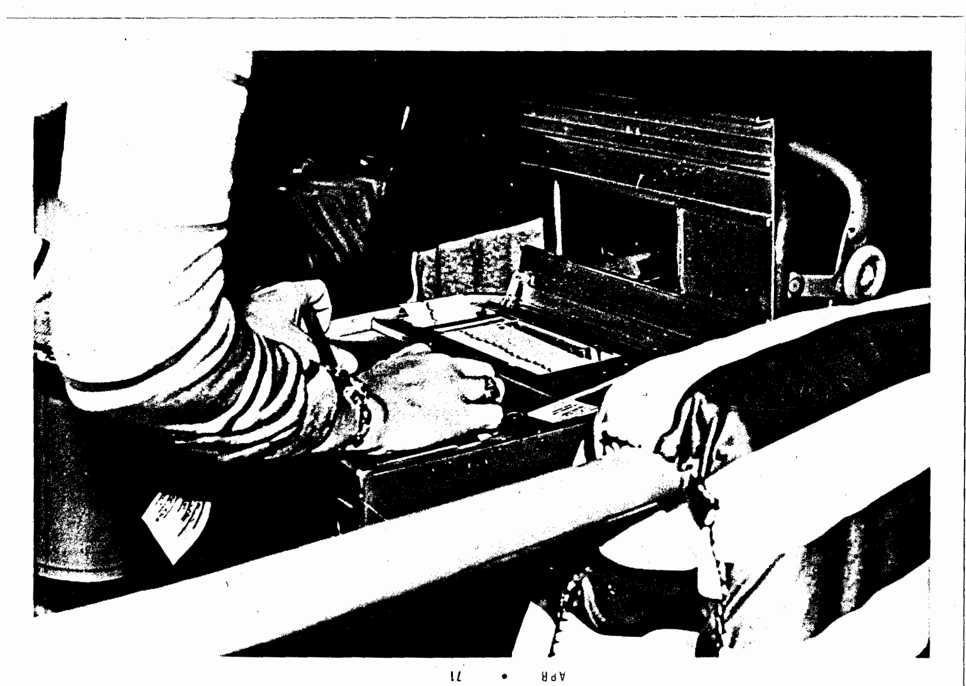

Figure 6.--Heart rate monitored by the EKG recorder.

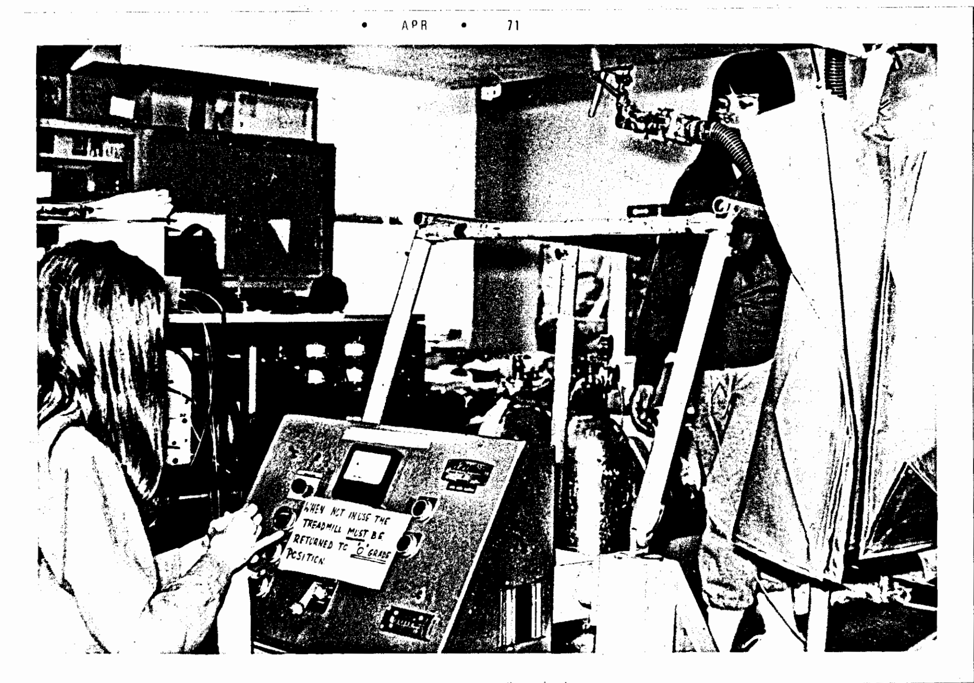

Figure 7.--Operation of treadmill and subject in position for collection of gas sample.

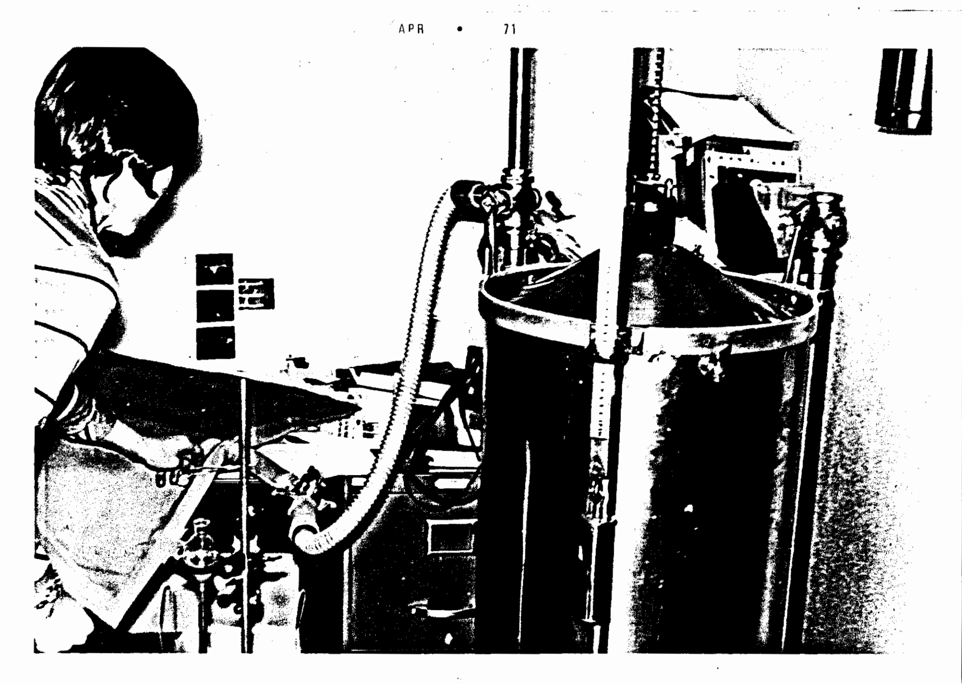

Figure 8.--Volume of gas sample being measured in a Tissot spirometer.

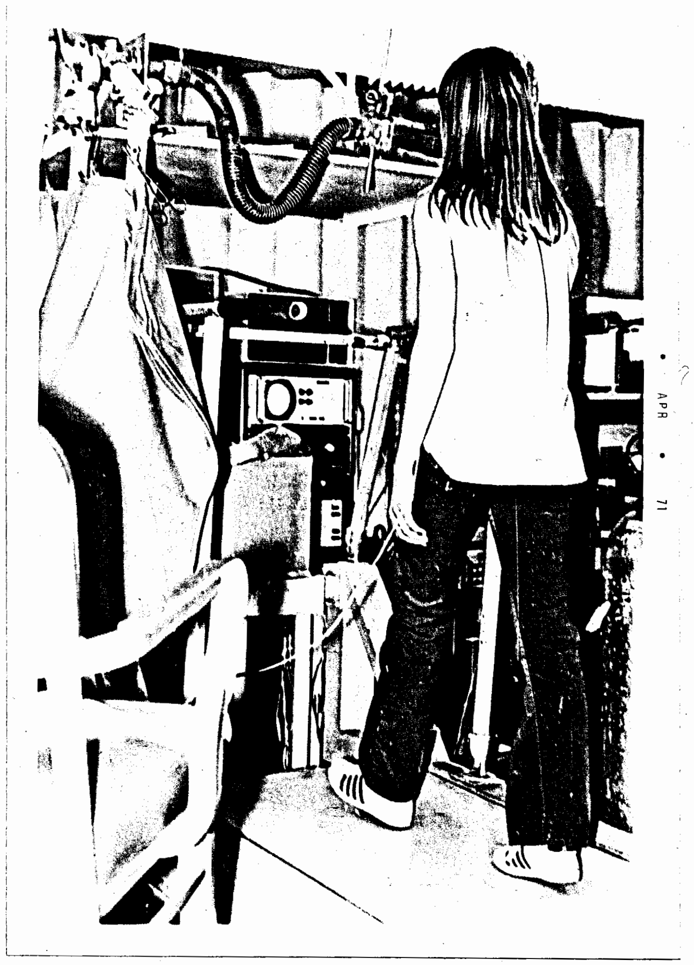

Figure 9.--Subject walking on the treadmill during test.

Figure 10.--Collection of gas samples in Douglas bags.

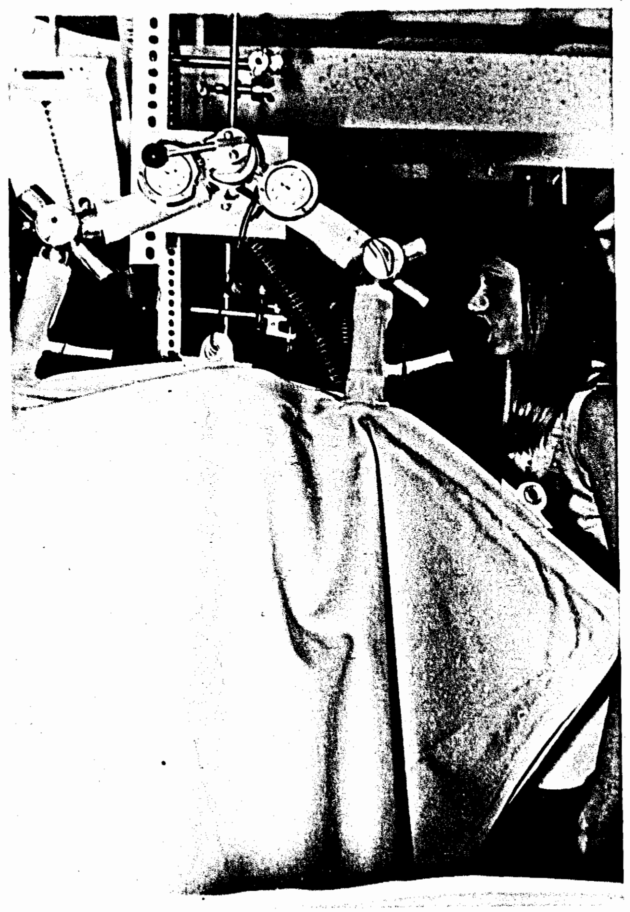

Figure 11.--Douglas bags, valves, and stopwatches of testing apparatus.

Figure 12.--Gas sample being stored in mercury tonometer.

APPENDIX B

RAW DATA FOR GROUP TEST SAMPLES BEFORE TRAINING

Sample 1

N = 14	Work Load		Oxygen Uptake		HR		$\dot{V}E$
Subject	Speed (mph)	Grade (%)	L/min	ml/kg/min	b/min	RQ	(BTPS)
D.P.	3	7 1/2	1.21	20.99	150	.95	48.30
K.L.	3	5	.84	19.17	158	.82	29.73
A.W.	3	10	1.24	25.65	159	.83	37.89
S.F.	3	7 1/2	1.31	28.43	163	.87	28.43
M.S.	3	7 1/2	1.33	22.89	151	.87	22.89
P.H.	3	10	1.40	20.77	162	.92	20.77
G.K.	3	7 1/2	1.38	27.76	165	.94	52.20
S.B.	3	7 1/2	1.32	28.71	150	.90	51.85
M.J.	3	12 1/2	1.23	24.97	155	.87	42.52
P.B.	3	7 1/2	1.25	23.33	151	.81	35.99
T.T.	3	7 1/2	1.27	22.29	155	.82	39.76
L.S.	3	15	1.38	31.02	155	.92	48.81
P.M.	3	10	1.17	24.54	153	.94	34.28
K.J.	3	7 1/2	1.05	22.24	162	.85	37.81

RAW DATA FOR GROUP TEST SAMPLES
BEFORE TRAINING--Continued

Sample 2

N = 14 Subject	Work Load Speed (mph)	Grade (%)	Oxygen Uptake L/min	ml/kg/min	HR b/min	RQ	$\dot{V}E$ (BTPS)
D.P.	3	10	1.37	23.58	170	.94	53.58
K.L.	3	7 1/2	1.01	23.05	169	.87	33.57
A.W.	3	10	1.37	28.34	165	.86	40.72
S.F.	3	10	1.33	28.86	172	.87	54.04
M.S.	3	10	1.51	25.99	174	.90	54.13
P.H.	3	10	1.56	73.14	170	.94	51.30
G.K.	3	10	1.45	29.17	179	.97	53.24
S.B.	3	10	1.71	37.20	165	.90	56.92
M.J.	3	12 1/2	1.26	25.58	165	.91	46.10
P.B.	3	10	1.33	24.83	165	.81	34.31
T.T.	3	10	1.65	28.96	178	.83	51.98
L.S.	3	17 1/2	1.48	33.27	170	.90	55.09
P.M.	3	12 1/2	1.55	32.52	172	.92	32.52
K.J.	3	10	1.12	23.72	175	.83	23.72

RAW DATA FOR GROUP TEST SAMPLES AFTER TRAINING

Sample 1

N = 14	Work Load		Oxygen Uptake		HR		$\dot{V}E$
Subject	Speed (mph)	Grade (%)	L/min	ml/kg/min	b/min	RQ	(BTPS)
D.P.	3	7 1/2	1.47	23.78	160	.96	52.43
K.L.	3	7 1/2	1.30	28.60	155	.82	43.93
A.W.	3	10	1.33	26.36	150	.88	39.10
S.F.	3	10	1.15	23.87	158	.88	34.92
M.S.	3	7 1/2	1.29	22.80	151	.88	33.16
P.H.	3	10	1.60	23.39	150	.89	38.52
G.K.	3	7 1/2	1.44	28.04	159	.91	44.98
S.B.	3	10	1.14	24.47	149	.91	32.13
M.J.	3	12 1/2	1.31	26.32	152	.95	50.32
P.B.	3	10	1.25	23.51	150	.87	32.77
T.T.	3	7 1/2	1.27	22.09	155	.87	34.16
L.S.	3	15	1.46	32.12	159	.97	56.14
P.M.	3	10	1.36	28.71	151	.65	19.37
K.J.	3	7 1/2	1.04	22.27	155	.82	30.03

RAW DATA FOR GROUP TEST SAMPLES
AFTER TRAINING--Continued

Sample 2

N = 14	Work Load		Oxygen Uptake		HR		$\dot{V}E$
Subject	Speed (mph)	Grade (%)	L/min	ml/kg/min	b/min	RQ	(BTPS)
D.P.	3	10	1.69	27.34	170	.94	61.18
K.L.	3	10	1.28	28.16	165	.84	43.29
A.W.	3	12 1/2	1.58	31.32	169	.92	48.41
S.F.	3	12 1/2	1.31	27.19	166	.87	41.96
M.S.	3	10	1.51	26.68	168	.90	45.91
P.H.	3	12 1/2	1.99	29.09	169	.92	56.09
G.K.	3	10	1.61	31.35	175	.95	51.32
S.B.	3	12 1/2	1.43	30.69	160	.98	39.26
M.J.	3	15	1.47	29.54	165	.93	55.41
P.B.	3	12 1/2	1.46	27.45	171	.91	40.38
T.T.	3	10	1.33	23.13	165	.89	37.90
L.S.	3	17 1/2	1.60	35.20	174	1.01	65.32
P.M.	3	12 1/2	1.46	30.60	170	.88	29.38
K.J.	3	10	1.09	23.34	168	.89	32.98

RAW DATA FOR MEAN OF SAMPLES 1 & 2 BEFORE TRAINING

N = 14 Subject	Oxygen Uptake 4 min	Oxygen Uptake ml/kg/min	HR b/min	RQ	$\dot{V}E$ (BTPS)
D.P.	1.29	22.29	160	.94	50.94
K.L.	0.93	21.11	164	.85	31.65
A.W.	1.31	27.00	162	.85	39.31
S.F.	1.32	28.65	168	.87	55.32
M.S.	1.42	24.44	163	.88	47.80
P.H.	1.48	21.96	166	.93	49.04
G.K.	1.42	28.47	172	.95	52.72
S.B.	1.52	32.96	158	.90	54.39
M.J.	1.25	25.28	160	.89	44.31
P.B.	1.29	24.08	158	.81	35.15
T.T.	1.45	25.63	167	.82	45.87
L.S.	1.43	32.15	163	.91	51.95
P.M.	1.36	28.53	163	.93	37.71
K.J.	1.09	22.98	169	.84	37.81

RAW DATA FOR MEAN OF SAMPLES 1 & 2 AFTER TRAINING

N = 14 Subject	Oxygen Uptake L/min	 ml/kg/min	HR b/min	RQ	$\dot{V}E$ (BTPS)
D.P.	1.58	25.56	165	.95	56.81
K.L.	1.29	28.38	160	.83	43.61
A.W.	1.46	28.84	159.50	.90	43.76
S.F.	1.23	25.53	162	.88	38.44
M.S.	1.40	24.74	159.50	.89	39.54
P.H.	1.80	26.24	159.50	.90	47.31
G.K.	1.53	29.70	167	.93	48.15
S.B.	1.29	27.58	154.50	.95	35.70
M.J.	1.39	27.93	158.50	.94	52.87
P.B.	1.36	25.48	160.60	.89	36.58
T.T.	1.30	22.61	160	.88	36.03
L.S.	1.53	33.66	166.50	.99	60.73
P.M.	1.41	29.66	160.50	.77	24.38
K.J.	1.07	22.81	161.50	.86	31.51

RAW DATA FOR HEART RATE AT $\dot{V}O_2$ OF 25 ML/KG/MIN AND VO_2 AT HEART RATE OF 170 B/MIN (N = 14)

N = 14 Subject	HR Before	HR After	Abs. Δ HR	%Δ HR	$\dot{V}O_2$ ml/kg/min Before	$\dot{V}O_2$ ml/kg/min After	Abs. Δ $\dot{V}O_2$	%Δ VO_2
D.P.	176	163	-14	-7.4	24.0	27.0	3.0	12.5
K.L.	174	126	-48	-27.5	23.2	29.3	6.1	26.2
A.W.	156	146	-10	-6.4	29.4	31.1	1.7	5.7
S.F.	137	160	23	16.7	28.9	28.4	-0.5	-1.7
M.S.	166	159	-7	-4.2	25.2	27.2	2.0	7.9
P.H.	178	156	-22	-12.3	23.0	29.2	6.2	26.9
G.K.	126	142	16	12.6	28.1	30.0	1.9	6.7
S.B.	142	150	8	5.6	39.9	37.2	-2.7	-6.7
M.J.	155	158	3	1.9	26.2	31.3	5.1	19.4
P.B.	165	157	-8	-4.8	25.4	26.9	1.5	5.9
T.T.	165	185	20	12.1	26.3	23.5	-2.8	-10.6
L.S.	111	123	12	10.8	33.0	34.2	1.2	3.6
P.M.	153	113	-40	-26.1	32.1	31.0	-1.1	-3.4
K.J.	181	195	14	7.7	23.1	23.1	0.0	0.0

RAW DATA FOR ANTHROPOMETRIC MEASUREMENTS OF SUBJECTS BEFORE AND AFTER TRAINING

N = 14	Before			After		
Subject	Age (Years)	Height (cm)	Weight (kg)	Age (Years)	Height (cm)	Weight (kg)
D.P.	13	160.66	58.11	13	160.66	61.81
K.L.	13	161.93	43.81	13	161.93	45.45
A.W	13	157.48	48.35	13	157.48	50.45
S.F.	13	166.98	46.08	13	166.98	48.18
M.S.	13	153.67	58.11	13	153.67	56.59
P.H.	14	160.02	67.42	14	160.02	68.40
G.K.	12	166.37	49.71	12	166.37	51.36
S.B.	14	162.56	45.97	14	162.56	46.59
M.J.	12	160.66	49.26	12	160.66	49.77
P.B.	13	156.85	53.57	14	156.85	53.18
T.T.	13	161.29	56.98	13	161.29	57.50
L.S.	12	160.66	44.49	12	160.66	45.45
P.M.	13	150.50	47.67	13	150.50	47.72
K.J.	14	156.85	47.22	14	156.85	46.70

APPENDIX C

KENNETH H. COOPER, M. D.
~~LIEUTENANT COLONEL, U.S.A.F. MEDICAL CORPS~~
110 INSPIRATION DRIVE
SAN ANTONIO, TEXAS 78228

19 August 1970

Mrs. Sue Mottinger
2775 Northaven #1028
Dallas, Texas 75229

Dear Mrs. Mottinger:

I want to thank you for your letter of 27 July 1970 and I hope that you are able to complete your research project with 7th and 8th grade girls.

At present, the only place where maximal oxygen consumption studies can be done would be at Southwestern Medical School in Dallas. Dr. Jere Mitchell ordinarily would be the one to contact but, unfortunately, he is on a one year sabbatical in Europe. In his absence, you might contact Dr. Gunnar Bloomquist at Southwestern Medical School. I doubt that they would be able to support your work since they have a large number of research projects of their own.

If the project could possibly be delayed until early 1971, we may be able to help you with our Cooper Clinic and Research Foundation in Dallas. Presently, we are contemplating an opening of both the clinic and research foundation by mid-Jan 1971.

I am sorry that I am unable to be of any further assistance at this time but please feel free to contact me again. We will be in San Antonio until the last week in September and subsequent to that time will be living in Dallas, Texas. I do not have an address as yet but you will be able to contact me under the Cooper Clinic and Research Foundation.

Sincerely,

Kenneth H. Cooper

Kenneth H. Cooper, M.D.

KHC/mc

October 14, 1970

Dr. Gunnar Blomqvist
Department of Cardiology
The University of Texas
Southwestern Medical School
5323 Harry Hines
Dallas, Texas

Re: Proposed Research Investigation

Dear Sir:

This letter is written as a follow-up to our conversation in your office on Wednesday, October 7, 1970 with reference to my proposed research investigation. The following is a brief summary of the proposed investigation.

Title: The Influence of Interval Training of 12 minutes Duration on the Maximal Aerobic Oxygen Intake of Junior High School Girls

By: Mrs. Sue Mottinger and Dr. Richard V. Ganslen of Texas Woman's University

Protocol: It is proposed to investigate the influence of interval (run-walk) training on the aerobic oxygen intake of young teenaged girls, 12-14 years of age. The procedure will involve a recent modification of the Balke Test tq provide controlled work intensities. The A.R. Young Treadmill will be operated a 3 mph (7.6 km/hr) at an initial grade of 5% and increased 2.1/2% every two minutes until the pulse rate approximate 170 beats per minute. The pulse rate will be monitored continuously and the respiratory gas collected at the end of the second minute of exercise at each grade level for Scholander Analysis.

Extensive investigations have shown that the pulse rate increases as does the oxygen intake linearly with increasing work intensity until approximately 170 beats per minute in women (Astrand, 1956) and 180 per minute in men (Balke, 1961). This linear increase in these metabolic variables is not influenced by drugs (Ganslen et al, 1963).

Great difficulty is anticipated in evaluating data on the maximal oxygen intake where motivation, pain tolerance, or will power influence the data as is the case with anaerobic work.

Since we will have an external criterion of performance for evaluating the subjects (distance covered in a 12 minute interval) improvements of the oxygen intake as a result of the training should be reflected in the treadmill testing. (e.g.) Improvement of aerobic working capacity.

page 2

It is anticipated that the study will proceed in three phases, only one of which will be used to make the respiratory gas collection: T_1 will involve a treadmill familiarization program for all of the girls. In T_2 a screening test identical to the final test will be used to get a rough assessment of the fitness levels of the individual girls as a guide to the subsequent respiratory gas collection protocol. This assessment will involve only monitering the pulse rate. In stage 3, respiratory gas samples will be collected and the pulse rate monitored up to the maximum aerobic working capacity of the individual girls, or a pulse rate of 170 beats per minute. Upon the completion of the pretest procedure, the girls will enter into a supervised training program of not less than 8 weeks duration.

Continuous evaluation of the data graphically, statistically or mathematically is anticipated.

Respectfully submitted,

Sue Mottinger

THE UNIVERSITY OF TEXAS
SOUTHWESTERN
MEDICAL SCHOOL AT DALLAS

DEPARTMENT OF INTERNAL MEDICINE

5323 HARRY HINES BLVD.
DALLAS, TEXAS 75235

October 30, 1970

Gunnar Blomqvist, M.D.
Department of Internal Medicine

Dear Dr. Blomqvist:

The Human Research Review Committee has approved your request for a study on the effect of training on maximal oxygen uptake in young girls.

The Committee asked me to remind you that both the University and the Public Health Service regulations require that written consents must be obtained from all human subjects in your studies. These consent forms must be kept on file and will, no doubt, be subject to inspection by the Public Health Service in the future.

Furthermore, we have been directed to review any change in research procedure that you might find necessary. In other words, should your project change, another review by the Committee is required, according to present Public Health Service regulations.

Sincerely yours,

J. P. Sanford, M.D., Chairman
Human Research Review Committee

JPS/jh

THE UNIVERSITY OF TEXAS
SOUTHWESTERN
MEDICAL SCHOOL AT DALLAS

DEPARTMENT OF INTERNAL MEDICINE
THE PAULINE AND ADOLPH WEINBERGER
LABORATORY FOR CARDIOPULMONARY RESEARCH

5323 HARRY HINES BLVD.
DALLAS, TEXAS 75235

November 4, 1970

Mrs. Sue Mottinger
Dewitt Perry Junior High School
1709 Belt Line Rd.
Carrollton, Texas

Dear Mrs. Mottinger:

The Human Research Committee at the medical school has formally approved your project and we should be all set to start whenever you would like to begin.

Sincerely,

Gunnar Blomqvist, M.D.
Asst. Professor
Internal Medicine

THE UNIVERSITY OF TEXAS
Southwestern
MEDICAL SCHOOL AT DALLAS

CONSENT TO INVESTIGATIONAL PROCEDURE OR TREATMENT

PATIENT____________________________________ UNIT NO.____________

1. I hereby authorize Mrs. Sue Mottinger the principal investigator to perform the following procedure or treatment:

   The procedure will involve controlled work intensities performed on an A.R. Young Treadmill. The pulse rate will be monitored continuously and the respiratory gas collected during the exercise.

   ____
   NAME OF PATIENT OR MYSELF

2. The nature and purpose of the procedure, the risks involved and the possibility of complications have been explained to me by Mrs. Sue Mottinger . I fully understand that the procedure to be performed is investigational. With full knowledge of this, I voluntarily consent to the procedure or treatment designated in Paragraph 1 above upon

   ____
   NAME OF PATIENT OR MYSELF
   and hereby release The University of Texas Southwestern Medical School, its doctors and staff, from all liability in connection therewith.

__________________ DATE

__________________ TIME

Witness:__________________ Signed:__________________
PATIENT OR PERSON RESPONS

Witness:__________________ __________________
RELATIONSHIP

Verification of explanation and patient consent should be recorded in progress of the medical record.

Instructions as to persons authorized to sign:

If the patient is not competent, the person responsible shall be the legally appointed guardian or the nearest of kin.

If the patient is a minor under 21 years of age, the person responsible is the mother or father or legally appointed guardian.

If the patient is unable to write his name, the following is legally acceptable:

His
John H. X Doe and two (2) witnesses.
Mark

THE STATE OF TEXAS X

KNOW ALL MEN BY THESE PRESENTS:

COUNTY OF DALLAS X

THAT WHEREAS, (I) (We) (am) (are) the parent(s) of

____, a student of the. CARROLLTON-FARMERS BRANCH INDEPENDENT SCHOOL DISTRICT who desires to participate in the research project of Mrs. Sue Mottinger and

WHEREAS, (I) (we) hereby request said School District to permit said daughter to participate in the Research Program for the school year 1970-71.

NOW THEREFORE, (I) (we) do hereby release Mrs. Sue Mottinger or any designated parent from liability in connection with (my) (our) daughter's participation in said project or in transportation to and from The University of Texas Southwestern Medical School.

____

____

SUBSCRIBED AND SWORN TO before me, this the __________day of ______,A.D.

____
Notary Public in and for Dallas County, Texas

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