

1969

The Effect of Rope Jumping on Cardio-Respiratory Fitness of High School Students

Yoshio Kobayashi

Eastern Illinois University

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**THE EFFECT OF ROPE JUMPING ON CARDIO-
RESPIRATORY FITNESS OF HIGH SCHOOL STUDENTS**
(TITLE)

BY

YOSHIO KOBAYASHI

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE IN PHYSICAL EDUCATION

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

1969

YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
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CHAPTER I

INTRODUCTION

Technological advances in modern times have lessened the amount of necessary physical work required of the average person. Taking our homes as an example, the use of many labor-saving devices and the generally high standard of living which contributes to our physical comfort have greatly decreased man's opportunities to engage in vital physical activities. These mechanical contrivances have become an integral part of modern living. Munn and his co-workers delineate the lack of physical activities in today's modern setting with the use of statistics as the analytical validation of such existence.¹

As a result of this modern environment, there is limited opportunity for people to develop improved cardio-respiratory function, which is the most important aspect of human fitness. Ikai pointed out the importance of cardiorespiratory function in his study as follows:

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¹Biggie Munn and others, Physical Activity in Modern Living, (New York: Prentice-Hall, Inc., 1963), pp. 1-11.

The factor of human physical fitness principally consists of three aspects; the factor which mainly requires agility, the factor which is mainly composed of muscular strength, and the factor mainly of endurance. Among those, it is very hard to tell which is the most important for humans, but it appears that the aspect of physical fitness which mainly consists of general or total body endurance is of prime importance, since humans must survive by enduring various environmental changes and various exercise loads throughout their lives. General or total body endurance is principally represented by the cardiovascular and cardiorespiratory systems.²

de Vries also indicates that the most important physiological factors are the cardiovascular and respiratory functions.³

It is interesting to note that in Japan, the results of the modified Harvard Step Test score showed that the people in the agricultural areas were superior to the people in the urban districts. The study by Yoshizawa indicated that high school students in cities were inferior in an endurance run to the students in villages of the same state, although they were superior to the students in villages

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² Michio Ikai, "Seineki ni Hitsuyo na Undo no Shoho (Exercise Standards for Physical Fitness of Youth)," Japanese Journal of Health, Physical Education, and Recreation XII, (July, 1963), pp. 351-53.

³ Herbert A. de Vries, Physiology of Exercise for Physical Education and Athletics (Dubuque, Iowa: Wm. C. Brown Company, Publishers, 1966), p. 335

on test items such as the 50-meter dash, vertical jump, and repeating side step.⁴

In addition, there is sufficient evidence to support the fact that the leading cause of death and physical impairment in civilized countries today stems from cardiovascular problems. Teraslinna and his co-workers reported the causes related to the development of cardiovascular disease as follows:

The change describing the development of susceptibility to cardiovascular disease can be brought about by the dual influence of (a) the anxiety of a competitive society which develops the metabolic readiness to action, and (b) caused by the industrialized and sedentary civilisation.⁵

Among the cardiovascular diseases, coronary heart disease is of especially high incidence. Concerning this problem, Wolfe pointed out that there is a direct correlation between the sedentary, push-button characteristics of our culture and the constantly rising incidence of coronary artery disease.⁶ A considerable amount of

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⁴Shigehiro Yoshizawa, "Chiki betsu ni mita Undonoryoku (Distinction of Motor Performance between Cities and Villages)," Japanese Research Journal of Physical Education XI, (September, 1966), pp. 58-68.

⁵Pentti Teraslinna, A. H. Ismail, D. F. MacLeod, L. W. Combs, J. E. Christian, and M. V. Kessler, "Relationships Between Physical Fitness and Susceptibility to Cardiovascular Disease," Research Quarterly XXXIX, (October, 1968), pp. 735-47.

⁶Joseph B. Wolfe, "Prevention of Disease through Exercise and Health Education," Health and Fitness in the Modern World, (Chicago: Athletic Institute, 1961), pp. 75-82.

evidence to support this statement has been presented in other studies. 7, 8, 9, 10

Therefore, certain physical fitness programs must be included in man's daily life in order to attain and maintain a certain level of physical fitness that will allow him to live a full life, meet emergencies on any given day and hopefully increase his longevity.

⁷ S. M. Fox, and J. S. Skinner, "Physical Activity and Cardiovascular Health," American Journal of Cardiology XIV, 1964, pp. 931-46.

⁸ W. L. Haskell, and S. M. Fox, "The Possible Place of Stress Testing to Discover, and Physical Activity to Prevent, Coronary Heart Disease," Southern Medical Journal, LIX, 1966, pp. 642-49.

⁹ J. N. Morris, A. Kagan, and D. C. Pattison, "Incidence and Prediction of Ischemic Heart Disease in London Busmen," The Lancet, 1966, pp. 553-59.

¹⁰ J. Truett, J. Cornfield, and W. Kannel, "Multivariate Analysis of the Risk of Coronary Heart Disease in Framingham," Journal of Chronological Disease XX, 1967, pp. 511-24.

I. THE PROBLEM

Statement of the Problem

This study was conducted to determine changes in the physiological response of male high school students to exercise performed on a motor-driven treadmill after eight weeks of participation in a planned and supervised five-minute rope-jumping program. The measurement of the training effect was undertaken to compare the work capacity of the heart through recovery of the subjects' heart rates and amounts of oxygen uptake during the motor-driven treadmill test.

Importance of Vigorous Exercise During High School Years

Statements of the objectives for high school physical education generally include the physical, social, and intellectual development of the youth. The physical aspect of the objectives should consist of motor skills and physical fitness. Although all aspects of physical fitness should be developed in physical education classes, aspects regarding muscular strength and especially cardiorespiratory endurance must be developed through appropriate fitness programs during the high school years. A principal reason for this is that the heart-lung function grows remarkably during this time as compared to other factors of physical fitness.

There are scientific data to support the facts as mentioned above. Morehouse and Miller suggested that the physiological pro-

cess involving the brain, nerves, heart, lung, and kidney, are weak during infancy and early childhood, become maximum by puberty, and then declines.¹¹ Oka reported that the weight of the heart reaches 50 percent of an adult's at 10 years, and 70 percent at 15 years in the male.¹² Grimm also reported that the age of maximal development concerning the weight of the heart is 16 to 17 years.¹³ These data indicate that the heart muscle develops remarkably at the age of high school students.

Morse and his co-workers found that children under twelve years of age do not have the capacity to utilize oxygen that older boys do because of a relatively smaller stroke volume of the heart and a consequent smaller capacity for increased circulation of blood through the lungs.¹⁴ Astrand also indicated that although maximal oxygen uptake (l/min.) of 10 year old boys is 50 percent of that of adults, the function develops to the point of 90 percent of that of adults at

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¹¹Laurence E. Morehouse and Augustus T. Miller, Physiology of Exercise (New York: The C. V. Mosby Company, 1967,) p. 272

¹²Akira Oka, "Statistical Observation of Anatomical Materials in the Pathology Research Room of Kyoto University," The Medical Journal of Kyoto XXXVIII, 1941, pp. 431-47.

¹³H. Grimm, "Jugend und Sport," Lehrbuch d. Sportmedizin, 1956, pp. 447-83.

¹⁴M. Morse, F. W. Schultz, and D. E. Cassels, "Relation of Age to Physiological Responses of the Older Boy (10-17 Years) to Exercise," Journal Applied Physiology I, 1949, p. 683.

15 to 16 years of age.¹⁵ In a study on boys in the 10 to 17 year age group, Morse and his co-workers found that exhaustion in treadmill running was reached at the lowest levels of oxygen intake at the age of thirteen years and that the ability to increase occurred at the age of seventeen years.¹⁶

On the other hand, there have been presented significant data regarding the development of the respiratory function during high school age. According to Stewart, between six and sixteen years of age the mean vital capacity increased about 197 percent in boys, and 156 percent in girls. The relative rate of annual increase in vital capacity became more rapid with the onset of puberty.¹⁷ The increase in vital capacity was, at these ages, established by other studies.¹⁸ These studies supported the comment

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¹⁵P. O. Astrand, "Experimental Studies of Physical Working Capacity in Relation to Sex and Age," (Ejnar Munksgaard, 1952); Cited in Toshio Kodama et. al., Sports Igaku Nyumon (Introduction to Sports Medicine) (Tokyo: Taiiku no Kagaku Sha, 1965), pp. 222-23.

¹⁶Morse, et al., Loc. cit. (p. 6.)

¹⁷Chester A. Stewart, "The Vital Capacity of the Lungs of Children in Health and Disease," American Journal of Disease of Children, XXXI (December, 1922), p. 453.

¹⁸Frank Falkner, et. al., Human Development (Philadelphia: W. B. Saunders Company, 1966), pp. 164-66.

that the vital capacity of a 10-year-old boy is half that of an adult, but the function of a 15-year-old boy is increased to 90 percent of the vital capacity of an adult.¹⁹ Astrand's study indicated that the maximal breathing, or ventilation capacity (l/min.) reached complete development at 15 to 16 years of age in males.²⁰

Dill and Consolazio stated that the function of the boys in supplying carbohydrate fuel to the tissues is superior at an older age than at a younger age.²¹

Kato divided the development of humans into three sections: (1) Infancy (0-9 yrs.) which is characteristic of the development of neuro-muscular control; (2) Childhood (10-14 yrs.), which is characteristic of the rapid growth of the body; (3) Early adolescence (15-18 yrs.) which is characteristic of the remarkable development of the muscle-skeletal system, internal organs, and the cardiorespiratory function. When the cardiorespiratory function in adolescence is made durable with strenuous training, it is possible to have endurance training through certain severe exercise loads during this period.²²

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¹⁹The Japan Ministry of Education, *Jido Seito Tairiyoku Chosa Hokoku Sho* (Survey Report of Physical Fitness in Elementary and Secondary School), 1957.

²⁰Astrand, *op. cit.* (p. 7).

²¹D. B. Dill and F. C. Consolazio, "Responses to Exercise as Related to Age and Environmental Temperature," Journal Applied Physiology, XVII, 1962, pp. 645-48.

²²Kitsuo Kato, "Gakko Taifuku ni okeru Tairiyoku Zukuri (Physical Fitness Programs in Physical Education at Schools)," Japan Journal of Health, Physical Education and Recreation, XVI (July, 1966), pp. 386-89.

Nagorny recommended that the sports which require physical fitness such as agility and power, should be begun at the age of 11 to 13 years. However, the sports which require the maximal muscular strength and endurance, such as long distance running, weight training, etc., should not be begun before the age of 15 to 17 years.²³

Asagawa stated in his book that the organs such as muscle, heart, lungs, and blood vessels are especially adaptable to strenuous exercise during senior high school age.²⁴ In the experiment of the treadmill test (different speed and grade for each age), Ikai found the interesting result that running time on the treadmill increased in proportion to the increase in age between 12 and 17 years. However, he reported there was no increase in running time in the ages between 20 and 30.²⁵

From the views mentioned above, it is apparent that high school age is the period in which the cardiorespiratory and cardiovascular functions grow rapidly and is an important period for developing their functions.

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²³V. E. Nagorny, "Overall Physical Development in the Preparation of Youthful Sportsmen, Importance of", Physical Education in School, 1959, 1, pp. 6-10.

²⁴Seichi Asagawa, "Kindai Training to Koko Taiiku (The Modern Training and Physical Education in Senior High School)", Kindai Training (The Modern Training in Sports) (Tokyo: Taiikukan, 1963), p. 266.

²⁵Michio Ikai, "Seinanki ni okeru Undo Fukaryo no Shoho (Optimal Exercise Standards for Physical Fitness in Youth)", The Proceedings of the 16th Japan Medical Society Annual Convention, X, 1963, pp. 207-11.

Need for the Study

Urbanisation has tended to limit the play space necessary for man's participation in large muscle activities. Running and jogging are considered excellent for the cardiovascular function. Participation in these activities has been made difficult by the development of a complex traffic system; therefore, in countries with inadequate indoor facilities, the amount of physical activity is greatly dependent upon the weather. Considering these factors, it becomes evident that any exercise which increases cardio-respiratory ability and function, which can be performed in a small area at any hour of the day, has great value in a daily physical fitness program.

The activity of rope-jumping demands a similar type of work load as running, which is considered to be the best method of developing physical fitness of the total body. This activity was therefore selected for the study for this reason, and also because rope-jumping is an activity familiar to both sexes and all ages. The rope is an inexpensive piece of equipment which is readily obtained; rope-jumping is an interesting and challenging activity, may be done in a restricted space regardless of weather, and can allow for individual differences in skill and physical development.

Limitation of the Study

Due to the length of time needed for the pre-test and post-test, the study was limited to thirteen non-athlete male high school students. Oxygen uptake, pulmonary ventilation, heart rate, and body weight were the only parameters considered. Due to the late arrival of the newly-purchased oxygen and carbondioxide analyzers, the pre-training test data, although probably quite accurate, should be considered as a valid estimate.

II. DEFINITION OF TERMS

Aerobic: The metabolic process to supply the energy needs of muscle contraction which takes place in the presence of adequate oxygen to oxidize the carbohydrate sources of energy completely to CO_2 and H_2O .²⁶

Cardiorespiratory System: Comprised of the heart, the circulatory system, and the ventilation of the lungs. The function of the cardiorespiratory system is to supply blood and oxygen to the tissues of the body.

Electrocardiograph: An instrument for recording the electric current produced by the action of the heart muscle.

Maximal Oxygen Uptake: Maximal amount of oxygen which a subject consumes when oxygen intake per unit of time has attained its maximum and remains constant...owing to the limitation of the circulatory and respiratory systems.²⁷ In this study, maximal oxygen uptake was defined as the maximal amount of oxygen which could be consumed during hard workload exercise.

Pulmonary Ventilation: Refers to the periodic renewal of the air in the lung alveoli.²⁸

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²⁶de Vries, op. cit., p. 2.

²⁷A. V. Hill, Muscular Activity (Baltimore: The Williams & Wilkins Co., 1926), p. 93.

²⁸Morehouse and Miller, op. cit., p. 6.

Rope Jumping: A bouncing movement in which the performer hops on both feet as rope is passed under the body. The rope passes over the head of the performer and under the feet.

Steady State: The steady state refers to the condition in which oxygen intake is adequate to meet oxygen requirements, so that no further accumulation of lactic acid and oxygen debt takes place.²⁹ This is the physiological adaptation by the body when all organs, especially the cardiorespiratory system, are in balance.

Submaximal Work: Submaximal work is the work performed at an intensity in which the energy expended by the cardiorespiratory system continues to provide sufficient oxygen to meet the needs of muscle.³⁰

t. Ratio: Unit of statistical measurement used in the study to represent gains in analysing pre- and post-test results.

Telemetry: An electronic apparatus for transmitting the electric current produced by the action of the heart muscle, to an electrocardiograph.

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²⁹Morehouse and Miller, op. cit., p. 6.

³⁰W. W. Tuttle and Byron A. Schottelmeier, Textbook of Physiology (St. Louis: C. V. Mosby Company, 1961) p. 310.

CHAPTER II

REVIEW OF RELATED LITERATURE

It is understood this is the first study of physical fitness of youth in rope-jumping training at this age level.

The value of rope jumping as a physical conditioner has been suggested by several authors.

Mellby and Anderson stated that this type of physical activity is an excellent physical education activity at schools and that it is excellent in improving the coordination of children, and a phase of a well-rounded physical education program.^{31, 32} Moore also described how rope jumping helped coordinate movements.³³ Rope jumping is said to cause improvement in endurance and stamina.^{34, 35, 36}

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³¹Rolf E. Mellby, "Rope Jumping," Journal of Health and Physical Education VII, (February, 1936), pp. 93-95.

³²Theresa Anderson, "Rope Jumping," Journal of Health and Physical Education XVII, (June, 1946), p. 196.

³³Martha Moore, "Rope Jumping for Coordination," Journal of Health and Physical Education XVII, (November, 1946), pp. 554-56.

³⁴Ben W. Miller, Karl W. Bookwalter, and George E. Schlafer, Physical Fitness for Boys, (New York: A. S. Barnes and Company, Inc., 1943), p. 210.

³⁵Mabel Lee and Miriam M. Wargner, Fundamentals of Boys' Mechanics and Conditioning, (Philadelphia: W. B. Saunders Company, 1949), p. 179.

³⁶Newton C. Loken and Robert J. Willeughby, Complete Book of Gymnastics, (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1961), p. 179.

In addition to improving endurance, conditioning value of rope jumping is also mentioned. According to Fahey, and Casady, Mapes and Alley, boxers have used rope jumping as a conditioning exercise for many years.^{37, 38} From a remedial point of view, Stafford and Duncan stated that rope jumping is a good exercise for conditioning, i. e., they pointed out that rope jumping helped a boy who had trouble rising to his toes.³⁹

Fahey, and Loken and Willoughby suggested that rope jumping would be a valuable exercise to carry over into post-school years, since it contributes to endurance, stamina and other factors of physical fitness.^{40, 41}

Several studies have also been conducted to determine the effects of rope jumping on cardiorespiratory and cardiovascular fitness. DiOrta, using nine fitness tests on younger boys, found various effects on cardiovascular fitness in the Schneider Test, Heartograph, expiratory force and breath-holding test after exercise.⁴²

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³⁷Helen Fahey, "Everyone Jumps Rope," Journal of Health and Physical Education, XI, (September, 1940), pp. 420-22.

³⁸Donald R. Casady, Donald F. Mapes, and Louis E. Alley, Handbook of Physical Fitness Activities, (New York: The Macmillan Company, 1965), p. 129.

³⁹G. T. Stafford and R. O. Duncan, Physical Conditioning, (New York: A. S. Barnes and Company, 1942), p. 28.

⁴⁰Fahey, loc. cit.

⁴¹Loken and Willoughby, loc. cit.

⁴²Louis P. DiOrta, "Effects of a Physical Training Program on Cardiovascular-Respiratory Fitness of Young Boys," (Unpublished Master's thesis, University of Illinois, 1955.)

Bird reported the effects of rope skipping on the energy expenditure of an athletic man, forty-two years of age. The subject jumped a rope using both feet at a rate of 120 jumps per minute for five minutes the first day. Each succeeding session he increased his jumping time by thirty seconds until on the thirteenth day he jumped rope for eleven consecutive minutes. The result of the Harvard Step Test showed that the Physical Fitness Index of the subject improved.⁴³

Powell investigated to determine the effects of rope skipping on five elementary school boys between the ages of nine and eleven years. The rope skipping training was given to the subjects for an hour and a half for ten consecutive Saturday mornings. In addition, the subjects were required to train at home for fifteen minutes a day.

The average vital capacity increased from seventy-eight cubic inches to eighty-six cubic inches. When considering recovery heart rates, three boys improved, one boy remained the same, and one boy showed a slight regression for the five-minute Step Test. Data from the heartometer indicated improved heart efficiency. Four boys could run longer in the "all-out" treadmill run at five miles per hour at an 8.6 percent grade. All subjects showed improvement in the 600-yard run.⁴⁴

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⁴³Patrick J. Bird, "Effects of a Program of Progressive Rope Skipping on the Energy Expenditure of One Middle Aged Man," (Unpublished Master's thesis, University of Illinois, 1957.)

⁴⁴John T. Powell, "Effects of Rope Skipping on Pre-pubescent Boys," (Unpublished Master's thesis, University of Illinois, 1957.)

Jones, Squires, and Rodal investigated the effect of rope skipping on cardiovascular fitness of seven untrained, non-athletic women, nineteen to twenty-four years of age. The subjects participated in a daily five-minute rope skipping program (except Saturday and Sunday), during a four-week period. At a rate of seventy-six skips per minute, the subjects had an interval-type of training, i. e., one minute of skipping and two minutes of rest, one minute of skipping and two minutes of rest, etc., for a total of five minutes rope skipping.

The results of the bicycle ergometer test at 450 kpm per minute showed that the mean pulse rate dropped from 159 beats at the beginning of training to 141 beats at the end of the four-week training period. This decrease was statistically significant beyond the 0.01 level. The estimated maximal oxygen uptake according to the Astrand nomogram increased from 1.71 liters per minute to 2.28 liters per minute, representing a 25 percent improvement in physical work capacity.

The mean pulse rate after five minutes of rope skipping also was lowered from 168 beats per minute during the first week, to 145 beats per minute during the last week.⁴⁵

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⁴⁵D. Merrit Jones, Chadwick Squires, and Kaare Rodahl, "Effect of Rope Skipping on Physical Work Capacity," Research Quarterly, XXXIII (May, 1962), pp. 236-38.

Garret, Sablie, and Pangle conducted a study on the effect of cardiovascular fitness of college freshmen (N = 43) during volleyball instruction. The four treatments, each administered during the final three or four minutes of the scheduled teaching period, twice a week, were: Carlson's Spot Running, rope skipping, bench stepping (using a 17-inch bench at a pace of 30 steps per minute), and a control group. The subjects in the rope skipping group participated in a regimen of rope skipping with alternating periods of maximal and moderate effort.

The writers concluded that performance on the Harvard Step Test for all subjects showed significant improvement over the experimental period. They stated, however, that gain could not statistically be attributed to a single treatment approach. According to the scores on the Physical Fitness Index by each group in the Harvard Step Test, the following improvements were noticed: running in place (+15); rope skipping (+13); bench stepping (+8); and control group (+).⁴⁶

Cascino, in his study, stated that a program of progressive rope skipping will improve the cardiovascular fitness of adult men. Ten subjects skipped rope for a period of eight weeks, five days a week. The subjects were asked to reach a level where they could skip rope for ten continuous minutes. Once the ten-minute level of continuous skipping was reached, each subject attempted to increase the number of skipping repetitions within the ten-minute period.

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⁴⁶ Leon Garret, Mohammed Sablie, and Roy Pangle, "Four Approaches to Increasing Cardiovascular Fitness during Volleyball Instruction," Research Quarterly, XXXVI, (December, 1965,) pp. 996-99.

Cascino reported the results of the three cardiovascular tests as follows: The Schneider Index standard scores improved an average of twenty-five percent during the eight-week training period. On the Harvard Step Test, the total number of pulse beats of the subjects, following the step test, was reduced from a pre-program mean of 169 beats, to a post-program mean of 133 beats. On the physical work capacity test, the subjects improved an average of thirteen percent in predicted maximal oxygen intake.⁴⁷

Baker, in his research, tried to compare the effects upon cardiovascular efficiency that resulted from programs of rope skipping and jogging. The Harvard Step Test was administered to 92 male college students in order to determine their level of cardiovascular efficiency. Subjects in Group I skipped rope 10 minutes per day, 5 days a week, for 6 weeks. The beginning skipping speed was 125 turns of the rope per minute. As the investigation progressed, the subjects were allowed to gradually increase skipping speed in accordance with the Prentiss's Table skipping speeds: (1) 125 to 135; (2) 135 to 145; (3) 150 to 160; and (4) 165 to 170 turns per minute. Subjects in Group II jogged 30 minutes per day, five days a week, for 6 weeks. The beginning speed was three minutes per 440 yards. As individual condition and ability developed, subjects were allowed to progress to 2 1/2 minutes per 440 yards, and 2 minutes per 440 yards.

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⁴⁷ Joseph A. Cascino, "The Effects of a Program of Progressive Rope Skipping on the Cardiovascular Fitness of Adult Men," (Unpublished Master's thesis, Temple University, 1964.)

Baker reported that there was no significant difference in the mean performance of the two groups but there was significant difference between pre- and post-test mean performance of both the ropeskipping and jogging groups ($p = 0.05$). It was concluded in the study that a daily 10-minute program of rope-skipping was as efficient as daily 30-minute programs of jogging for improving cardiovascular efficiency.⁴⁸

In the study by Spencer, et. al., sixty-eight healthy sedentary college women 16 to 21 years of age were assigned to one of three groups: Group A skipped rope four days a week for four weeks. The program consisted of 76 skips per minute for one minute, then a two-minute rest; alternating this pattern for a total of five minutes of skipping. Group B participated in physical education classes, and Group C was the control group.

For Group A, the mean predicted maximal oxygen uptake according to Astrand nomogram, significantly increased (0.001), and represented an improvement of twenty-one percent in physical work capacity. The writers concluded that the five-minute daily rope-skipping exercise program improved physical work capacity to a greater degree than did participation in physical education classes twice per week.⁴⁹

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⁴⁸ John A. Baker, "Comparison of Rope Skipping and Jogging as Methods of Improving Cardiovascular Efficiency of College Men," Research Quarterly XXXIX, (May, 1968,) pp. 240-43.

⁴⁹ Marguerite E. Spencer, et. al., "Effects of Rope Skipping and Physical Education Classes on Physical Work Capacity of Sedentary College Women," American College of Sports Medicine and The Athletic Institute, (1968), pp. 79-81

Kobayashi, Takeuchi, and Obayashi found significant improvement of the modified Harvard Step Test (a three-minute stepping on a 45 centimeter bench) as a result of alternate programs of rope jumping and jogging. Five non-athlete high school freshmen participated in five-minute rope jumping per day, twice a week, and 1500-meter jogging (running speed: approximately 55-seconds per 200 meters) per day, twice a week during a 40-day summer vacation.

After the submaximal exercise of a 10 kg. workload bicycle ergometer for three minutes (R. M. R. 3-4), the subjects immediately rode the bicycle ergometer at full speed (R. M. R. 15-20) for one minute. At the same time, the maximal oxygen intake was measured and the pulse rate also was checked each time after finishing the maximal load exercise for five minutes. At the conclusion of the investigation, the writers found that the pulse rate recovery for five minutes after the maximal exercise improved significantly from the pre-test. Oxygen-pulse of the subjects improved remarkably. However, there was statistically no significant difference in the maximal oxygen intake between the pre-test and the post-test.⁵⁰

⁵⁰ Yoshio Kobayashi, Shinya Takeuchi, and Hideyuki Obayashi, "Kaki Kyuka ni okeru Kokosei no Tairyoku Kanri, (Administration of High School Students' Physical Fitness of Cardiorespiratory Functions during Summer Vacation)," Japan Research Journal of Physical Education XII, July, 1968), p. 52.

In the study by Curtis, one hundred thirty-three boys and girls of the fourth, fifth, and sixth grades were included in the experimental group of the study. The subjects jumped rope for five minutes daily for eight weeks. The writer of the study, however, found no significant improvement in endurance for boys and girls.⁵¹

In the studies of gymnastic training programs for young boys such as rope skipping, trampolining and tumbling, Wilkstrom and Wright found no significant improvement on cardiovascular fitness.^{52, 53}

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⁵¹Delores M. Curtis, "Rope Skipping and the Endurance, Leg Power, Agility, and Coordination of Children," (Unpublished Doctoral Dissertation, University of Illinois, 1963.)

⁵²Robert B. Wilkstrom, "Effects of Gymnastic Training on the Progressive Pulse Rate Test of Boys," (Unpublished Master's Thesis, University of Illinois, 1954.)

⁵³James N. Wright, "The Effects of Gymnastic Training on the Heartograms of Young Boys," (Unpublished Master's Thesis, University of Illinois, 1954.)

CHAPTER III

PROCEDURE

I. SUBJECTS

For this particular study, thirteen subjects were chosen by the instructor of physical education at Charleston High School in Charleston, Illinois. The selection was determined by their cooperation and willingness to participate in the study. The male subjects were non-athlete high school students ranging from 16.3 years to 17.7 years, with a mean of 17.1 years. A mean of their body weights was 161.5 pounds, and a mean of their heights was 178.03 centimeters. Each subject received his parents' approval and the approval of a local physician prior to participation in this study.

II TRAINING PROGRAM

The training in rope jumping was conducted for five minutes daily in the physical education classes five days a week, between March 25 and May 16, 1969 - a total of eight weeks. The total number of daily periods of rope jumping was thirty-five. To help motivate the subjects, they were told to perform as many jumps as possible in the five-minute period. In addition to this, the subjects were required to record their recovery heart rates each day. Results of the jumping

may be found on Page 32. Daily training was administered by the investigator in an exact manner, that is, the subjects were required to jump rope with both feet, and all subjects started and stopped jumping at the investigator's signals. During rope jumping the elapsed time was called to all subjects each minute, and after the exercise, the subjects sat down on the floor and took their heart rates at the carotid artery for a 15-second period, 15 seconds after cessation of the exercise. The rope jumping program was held at the beginning of the eight o'clock physical education class in the Charleston High School, Charleston, Illinois. Following the daily rope-jumping activity, subjects returned to their normal non-strenuous class activity such as volleyball, kickball and limited softball outdoors.

III TESTS

Three basic tests were administered one week before (T_1) and one week after (T_2) the 8-week rope jumping program. Body weight, submaximal treadmill run and the Modified Johnson Treadmill Test were administered in the Physical Education Research Laboratory at Eastern Illinois University, Charleston, Illinois.

Body Weight

Wearing only an athletic supporter, each subject was weighed to the nearest quarter-pound by a calibrated Healthometer Scale.

Sub-Maximal Treadmill Run

The test had two purposes. Number one was to serve as a warmup for the Johnson Treadmill Test and number two, to obtain some submaximal heart rate and oxygen consumption data. The test consisted of a four-minute run at six miles per hour (no grade), followed by a four-minute recovery period.

Heart Rate. In order to monitor heart rate during each minute of exercise as well as during each minute of recovery a telemetry system was employed. Two surface electrodes for recording the action current (E. C. G.) of the heart were placed on the chest, thus enabling the investigator to determine heart rate response to exercise. Chest electrodes were placed at the V_5 and V_{5R} positions. The following procedure was used in placing the disposable electrodes (Telectrode made by Johnson and Johnson) on the subjects:

- (1) The skin was shaved and was rubbed with a towel
- (2) A small amount of electrode jelly was applied to a cotton Q-tip
- (3) The skin where the electrodes were to be placed was rubbed briskly with the Q-tip until it became red in color, then excess jelly was removed
- (4) A pea-sized drop of electrode paste was placed on the electrode contact screen
- (5) The electrode was positioned on the skin

The E. C. G. was transmitted via telemetry to an R. K. G. Model 100 receiving unit manufactured by Hamilton-Standard, Windsor Locks,

Connecticut. The signal was then sent to a Sanborn Model 500 Viso Cardiette where at a paper speed of 25 mm/sec., the QRS complex of each beat was observed and counted as the heart rate of the subject. A five-second sample of the heart rate taken during the last five seconds of each of the eight minutes was used in describing heart rate response to a submaximal test.

Oxygen Consumption. Connected in open circuit to a Kofranyi-Michaelis Respirometer (manufactured by the Max-Planck Institute, Gettingen, West Germany), the subject with nose clips in place and breathing into a Collins Triple J Valve (made by Warren E. Collins, Braintree, Massachusetts), ran for four minutes and remained seated for four minutes in recovery from the submaximal run. Expired air was sampled at the rate of .3 percent via the Johnson Metalized Bag method⁵⁴ and the ventilation and gas temperature were noted. One bag containing this small sample of work and recovery gas was then analysed for Oxygen and Carbon Dioxide content on a Beckman Model E₂ and Beckman Model LB₁ analyser respectively.

Unfortunately, because of the late arrival of the newly-purchased CO₂ analyser, the oxygen consumption data for T₁ will be only a crude estimate, since the necessary "true oxygen" parameter could not be obtained without knowledge of CO₂ content.

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⁵⁴Robert E. Johnson, Frances Robbins, et al, "A Versatile System for Measuring Oxygen Consumption in Man, " Journal of Applied Physiology XXII, (February, 1967), pp. 377-79.

Modified Johnson Treadmill Run

The Johnson Treadmill Run Test ⁵⁵ is a five-minute run, if the subject can stay on that long, up an 8.6% grade at 7 miles per hour. The test is designed so that heart rate response in recovery from vigorous exercise might be noted. The test was modified in that the investigator used the submaximal run described earlier as a warmup instead of the suggested warmup, and that an (maximal) oxygen uptake measure was made in conjunction with the latter stages of the run, which proved to be nearly "all out" for the subjects.

Physical Fitness Index. The heart rate response related to the Modified Johnson Treadmill test will be referred to as the Physical Fitness Index (P.F.I.). The number of heart beats between 1:00 to 1:30, 2:00 to 2:30 and 4:00 to 4:30 minutes in recovery from the run were obtained manually at the carotid artery while the subject was in a seated position. The P.F.I., an arbitrary score, was determined by adding or summing up the recovery heart beats and placing them in the appropriate formula. (See Chapter IV.)

Oxygen Uptake During Hard Work. The V_{O_2} was determined via the open circuit method. A thirty-second sample of expired air was obtained at 4:14 to 4:45 minutes of the Modified Johnson Treadmill Run,

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⁵⁵C. Frank Consolazio, Robert E. Johnson and Louis J. Pecora, Physiology Measurement of Metabolic Functions in Man (New York: McGraw-Hill Book Company, Inc., 1963), pp. 367-71.

with the exception of the few subjects who could not complete the five-minute run. For them, a 30-second sample was taken, according to their signal, at a time when they felt they could not continue more than one additional minute. Expired air passed through a Model CD₄ Parkinson-Cowan Gas Meter (Instrumentation Association, New York), then into a plexiglass sample chamber where it was drawn out by a small vacuum pump in the metalized bag described earlier. From there, the process of gas analysis and determination of oxygen consumption was performed as previously indicated.

It must be pointed out again that due to the unavailability of a CO₂ analyser during T₁, this Oxygen Uptake measure is a gross estimate and cannot be an exact measure.

CHAPTER IV

ANALYSIS OF DATA

Thirteen male high school students were studied to determine the effects of a rope jumping training program on cardiorespiratory fitness. A total of 38 five-minute workouts were performed during the eight-week training period. Body weight, submaximal treadmill run, and a Modified Johnson Treadmill Run Test were the basic three tests administered before (T_1) and after (T_2) the eight-week program.

I. DATA CONVERSION

The body weight scores were converted to kilograms for the analysis. The pulmonary ventilation and oxygen consumption data from the submaximal treadmill run and the Modified Johnson Treadmill Run were corrected to Standard Temperature and Pressure Dry (S.T.P.D.) and oxygen expressed in milli liters per kilogram of body weight per minute. The 3 thirty-second heart counts in recovery from the Modified Johnson Treadmill Run were placed in the following formula to determine a Physical Fitness Index (P.F.I.).

$$P.F.I. = \frac{(\text{Seconds the subject}) \times 100}{2 \times \text{Sum of the 3 thirty-second heart counts}}$$

II. STATISTICAL TREATMENT

The t test for determining the significance of the difference between the means for small correlated samples, is described in the following derived formula.⁵⁶

$$t = \frac{M_1 - M_2}{\sqrt{\frac{\sum D^2 - \frac{(\sum D)^2}{N}}{N(N-1)}}$$

A t test was used to determine the significance of the difference between the average number of rope jumps performed on the first and last training day.

A t test was also used to determine the significance of the difference between means obtained at T₁ and T₂. The t ratios were computed for body weight, heart rates during and after a submaximal treadmill run, the Physical Fitness Index derived from heart beats in recovery from the Modified Johnson Treadmill Run, total pulmonary ventilation during and in recovery from the submaximal treadmill run, and oxygen uptake and pulmonary ventilation related to hard workload as performed in the Modified Johnson Treadmill Run. Data were also converted to Standard Scores and the percent changes in various parameters was determined.

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⁵⁶Charles H. McCloy and Norman D. Young, Tests and Measurements in Health and Physical Education (New York: Appleton-Century-Crofts Inc., 1954), pp. 430-31.

In some instances, all thirteen subjects were not included in the analysis because of questionable equipment performance during T_2 .

III FINDINGS

Repe Jumps on First and Last Training Day

The number of rope jumps for a five-minute period was recorded each day. The mean number of jumps on the first day was 239.1. The mean number of jumps on the last day of the training program was 494.1.

A t ratio of 18.6 was found. This represented a significant difference beyond the .01 level of confidence. One can also note the improved ability of the group as shown by the increased average number of jumps per day. The numbers each day are presented in Figure 1.

Body Weight

The mean body weight prior to the training program was 73.42 kilograms. The mean body weight at the end of the training program was 72.98 kilograms.

A t value of .63 was found not significant at the .05 level. The mean body weight of the subjects during the period before training and the period after training have been presented in Table I.

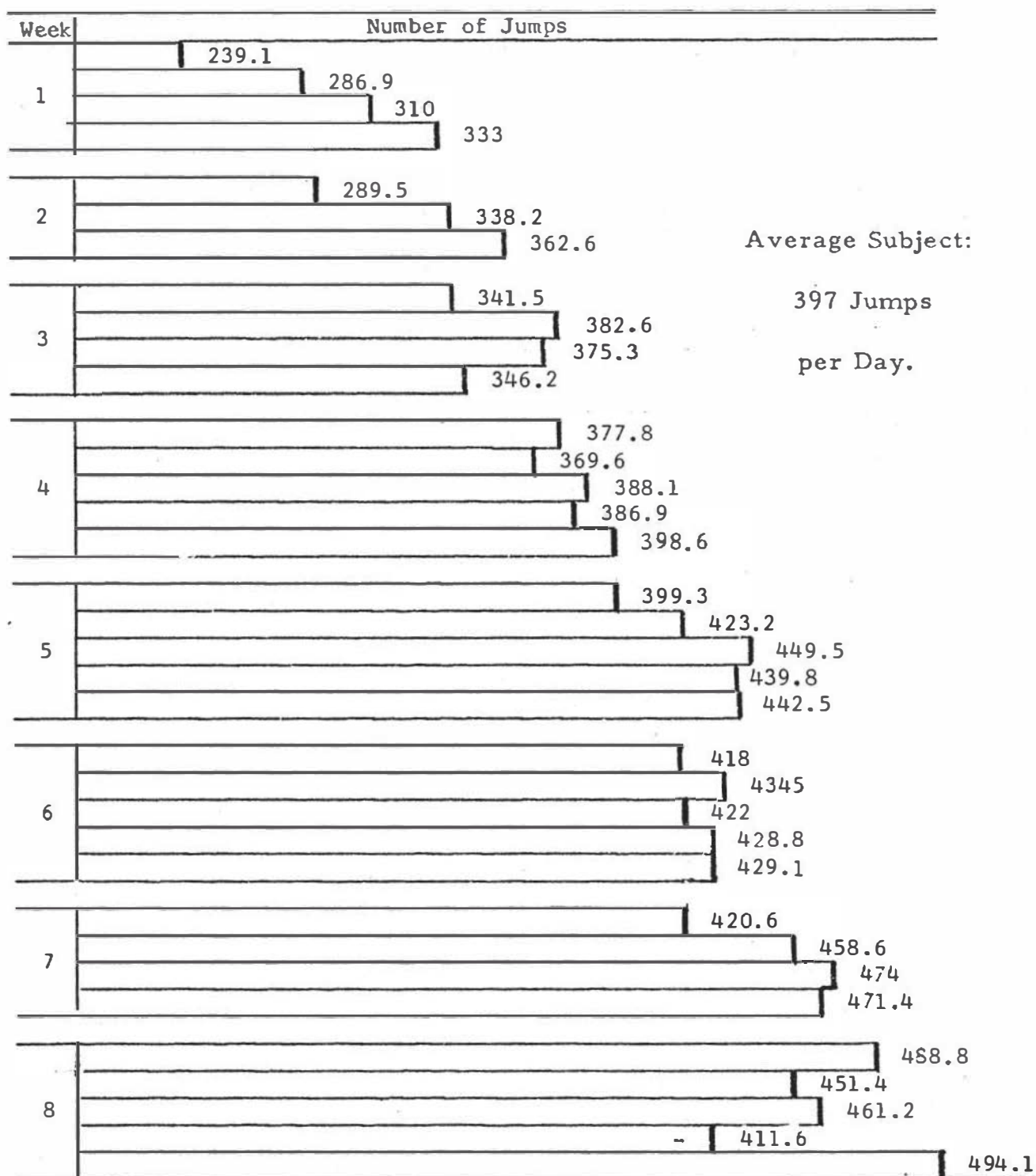


Figure 1

Number of Jumps Per Day (Average Subject)

TABLE I

BODY WEIGHTS BEFORE AND AFTER TRAINING PERIOD

Subject	Body Weight (kg.)		Standard Deviation		Difference Between T ₁ and T ₂	<u>t</u>
	T ₁	T ₂	T ₁	T ₂		
Mean	73.42	72.98	10.39	11.30	.44	.63
1	59.89	60.90	-----	-----	+ 1.01	
2	82.73	76.76	-----	-----	- 6.03	
3	66.48	65.90	-----	-----	- .58	
4	60.23	59.09	-----	-----	- 1.14	
5	80.80	80.80	-----	-----	0	
6	83.98	83.30	-----	-----	- .68	
7	76.48	77.73	-----	-----	+ 1.25	
8	67.95	68.75	-----	-----	+ .80	
9	72.39	70.09	-----	-----	- 2.30	
10	96.48	100.11	-----	-----	+ 3.63	
11	69.32	67.16	-----	-----	- 2.16	
12	66.70	66.48	-----	-----	- .22	
13	71.02	71.70	-----	-----	+ .68	

Heart Rates

The heart rates of the subjects were taken both during and in recovery from a submaximal treadmill run and after the Modified Johnson Treadmill Run.

Submaximal Workload. Figure 2 reveals the average heart rates during each minute of work and recovery related to the submaximal treadmill run. One can see that at each minute, the average heart rate during T_2 was lower than the average heart rate during T_1 . However, there were no statistically significant differences between the two tests during the run. (See Table II.)

In recovery from the run, statistically significant differences are noted at 1, 3, and 4 minutes of recovery. (See Table III.)

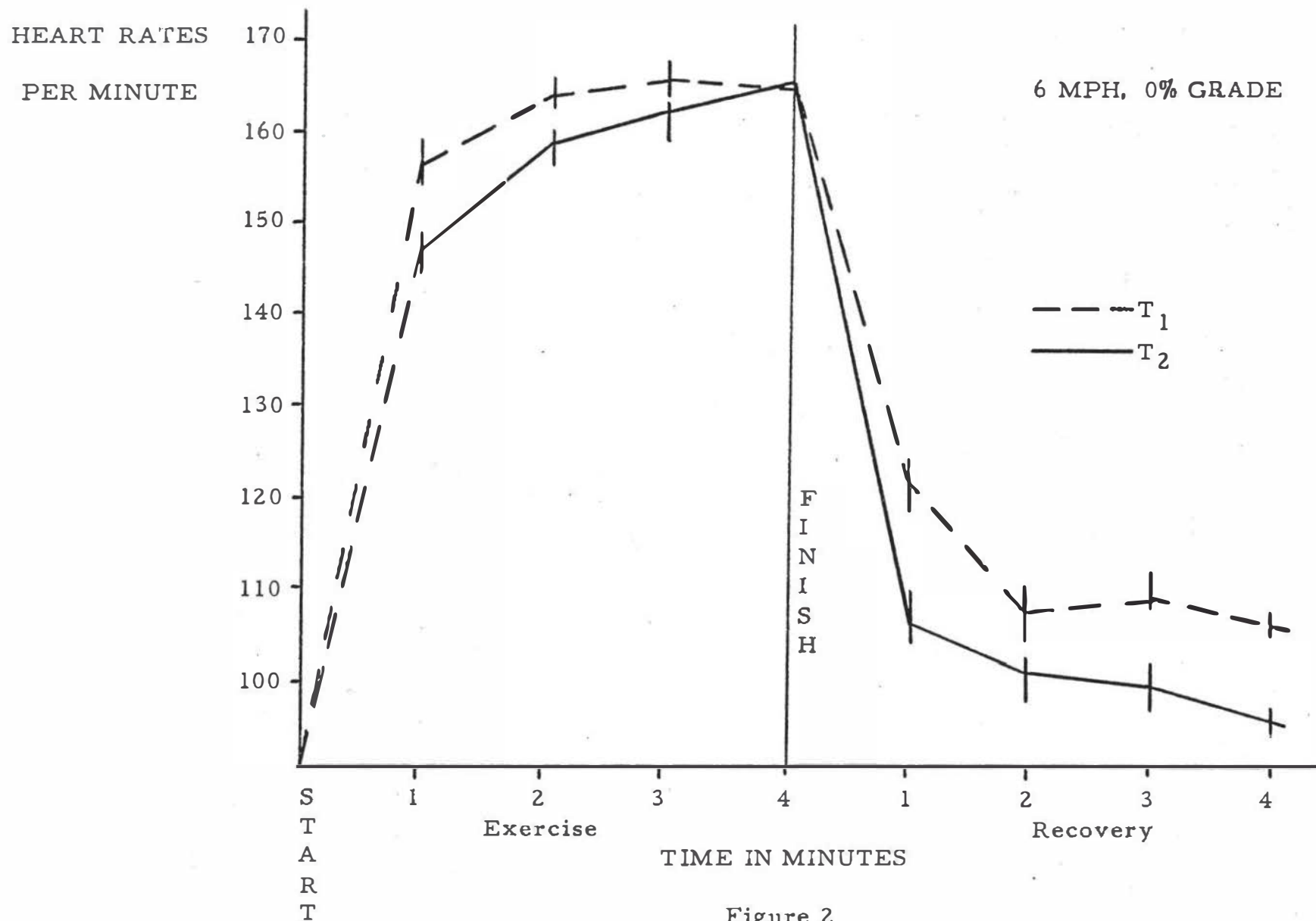


Figure 2
AVERAGE HEART BEATS DURING SUBMAXIMAL
TREADMILL RUN AND FOUR-MINUTE RECOVERY PERIOD AT T₁ AND T₂

TABLE II

MEAN HEART RATES

DURING FOUR-MINUTE SUBMAXIMAL TREADMILL RUN

ON PRE-TEST (T_1) AND POST-TEST (T_2)

Time (minute)	Mean		Standard Deviation		Diff. between Mean	t Ratio
	T_1	T_2	T_1	T_2		
1	156.8	148.1	8.9	22.6	-8.7	1.65
2	163.5	157.6	20.5	12.6	-5.9	1.61
3	164.8	161.8	13.3	10.9	-3.0	.96
4	163.7	163.8	16.2	13.4	+ .1	.009

TABLE III
MEAN HEART RATES DURING RECOVERY PERIOD
ON PRE-TEST AND POST-TEST
FOLLOWING SUBMAXIMAL TREADMILL RUN

Time (minute)	Mean		Standard Deviation		Diff. between mean	t Ratio
	T ₁	T ₂	T ₁	T ₂		
1	120.3	105.1	20.9	24.9	-15.2	3.01 *
2	106.9	99.2	21.1	19.8	- 7.7	1.95 *
3	108.0	98.7	15.5	16.0	- 9.3	2.50 *
4	106.4	96.4	20.1	13.9	-10.0	6.60 ***

* Significant at .05 level of confidence

*** Significant at .01 level of confidence

Recovery from the Modified Johnson Treadmill Run. Nine

subjects completed the five-minute run at T_1 . Eleven subjects completed the run at T_2 . Two subjects who failed to complete the run initially, finished it at T_2 . Of the two remaining subjects, one showed a decreased time on the treadmill at T_2 , while the other subject logged a similar time at T_1 and T_2 .

Though no attempt was made to statistically analyze T_1 and T_2 mean heart counts at each of the three recovery periods, one can see from Figure 3 that the T_2 mean was lower than the T_1 mean during all three periods.

A t test was performed to determine the significance of the difference between P. F. I. scores at T_1 and T_2 . Table IV reveals that eleven of the subjects improved their P. F. I. scores, while two subjects showed a decrease. The difference between the mean at T_1 (75.4) and the mean at T_2 (81.9), was statistically significant at the .05 level of confidence. The increase represented a 7.9 percent improvement in the standard score from the pre-training level.

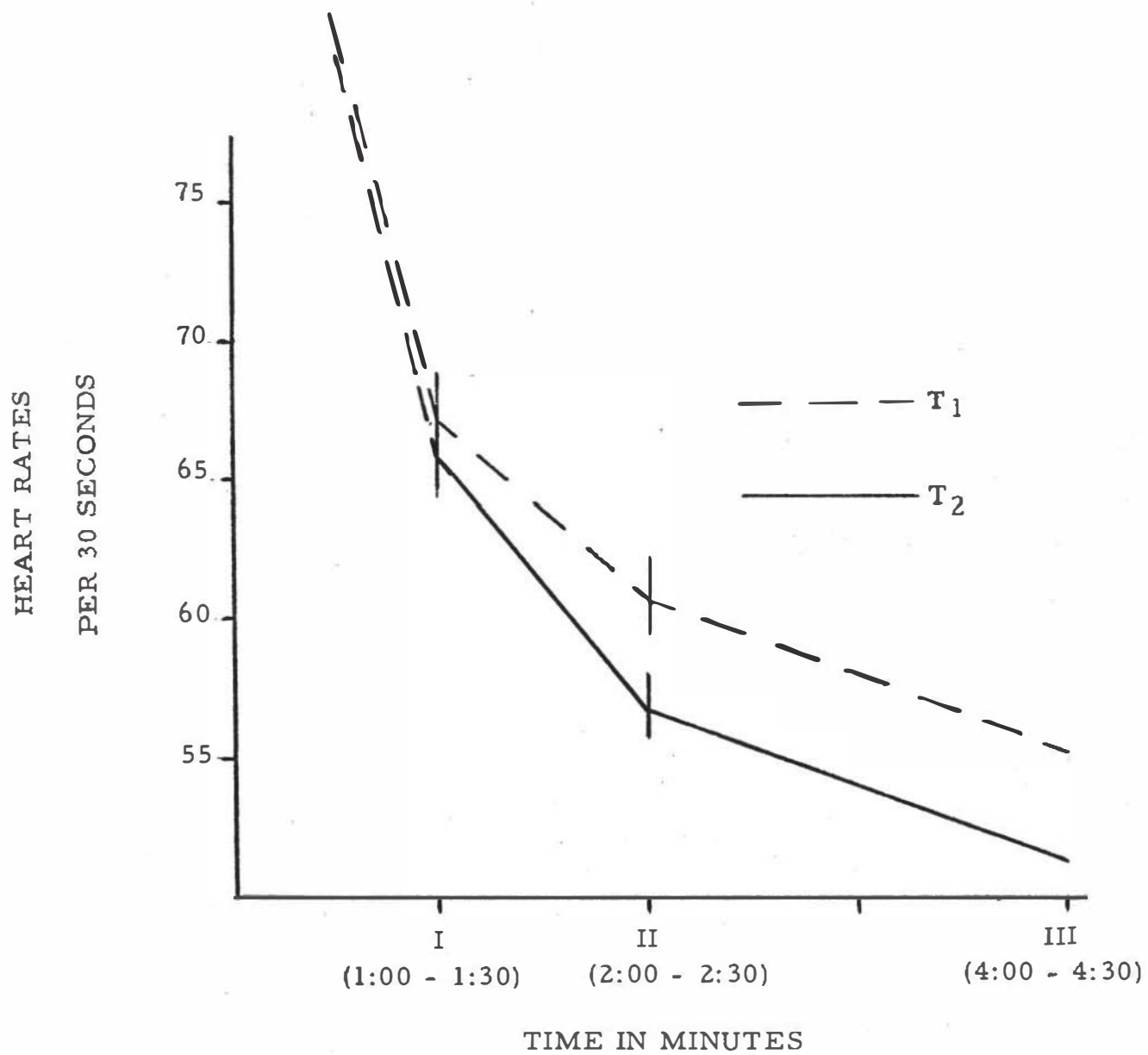


Figure 3

RECOVERY HEART BEATS AT T₁ AND T₂
FOLLOWING MODIFIED JOHNSON TREADMILL RUN

TABLE IV
THE MODIFIED JOHNSON TREADMILL RUN
PHYSICAL FITNESS INDEX

Subject	Index			Standard Score		
	T ₁	T ₂	Diff.	T ₁	T ₂	Percent of diff.
1	74.6	77.3	+2.7	41.7	47.2	+5.5
2	73.1	68.5	-4.6	39.0	30.5	-8.5
3	87.2	88.2	+1.0	66.2	68.1	+1.9
4	96.2	97.4	+1.2	80.5	82.1	+1.6
5	78.9	81.5	+2.6	50.4	55.2	+4.8
6	83.8	91.5	+7.7	59.9	73.6	+13.7
7	48.6	53.3	+5.7	6.7	10.2	+3.5
8	59.6	77.3	+17.7	17.1	47.2	+30.1
9	102.0	111.9	+9.9	87.5	95.1	+7.6
10	50.0	47.7	-2.3	7.6	6.1	-1.5
11	47.9	71.4	+23.5	6.2	35.4	+29.2
12	107.1	120.9	+13.8	92.1	98.2	+6.1
13	73.9	78.5	+5.6	40.5	49.6	+9.1
Mean	75.6	81.9	+6.3	45.8	53.7	+7.9
S.D.	19.8	20.7	--	--	--	--
t Ratio	2.18 *					

* Significant at .05 level of confidence

Pulmonary Ventilation

Submaximal Workload. The total pulmonary ventilation was measured during both a four-minute submaximal treadmill run and a four-minute recovery period.

Table V reveals minute volume per kilogram of the body weight of the total pulmonary ventilation. Ten of the subjects decreased their total ventilation, while three subjects showed increase. The mean pulmonary ventilation was decreased from 41.5 liters per minute on T_1 to 38.6 liters per minute on T_2 . The difference between the mean of 2.73 liters per kilogram per minute was statistically significant beyond the .01 level of confidence. Using a standard score, the average percentage of decrease was 10.6 percent.

Hard Workload. Data from only seven of the thirteen subjects were used for the hard workload exercise because of questionable equipment performance during T_2 as mentioned earlier.

Table VI shows the minute volume of ventilation during the latter stages of the Modified Johnson Treadmill Run. The mean pulmonary ventilation in this measurement was also decreased from 107.92 liters per kilogram per minute to 107.81. There was, however, no statistically significant difference between T_1 and T_2 .

TABLE V
TOTAL PULMONARY VENTILATION DURING
FOUR-MINUTE SUBMAXIMAL TREADMILL RUN AND
THE FOUR-MINUTE RECOVERY PERIOD
(liters /min., S. T. P. D.)

Subject	Raw Score			Standard Score		
	T ₁	T ₂	Diff.	T ₁	T ₂	Percent of Diff.
1	37.21	36.59	- .62	32.64	29.46	- 3.18
2	49.53	46.46	-3.07	92.36	83.15	- 9.21
3	43.62	39.29	-4.33	70.19	44.83	-25.36
4	31.57	27.70	-3.87	9.68	2.94	- 6.74
5	39.53	39.72	+ .17	46.41	47.61	+ 1.20
6	49.59	46.62	-2.97	92.51	83.89	- 8.62
7	38.08	35.25	-2.83	37.83	22.96	-14.87
8	39.44	35.28	-4.16	45.62	22.96	-22.66
9	37.43	39.76	+2.33	34.09	47.61	+13.52
10	56.40	50.60	-5.80	99.94	94.84	- 5.10
11	45.17	36.31	-8.86	77.94	28.10	-49.84
12	36.13	34.50	-1.63	27.09	19.49	- 7.60
13	35.71	35.85	+ .14	25.14	25.78	+ .64
Mean	41.49	38.76	-2.73	53.18	42.58	-10.60
S. D.	6.98	6.10				
t Ratio	3.412***					

*** Significant at the .01 level of confidence

TABLE VI
 MINUTE VOLUME OF PULMONARY VENTILATION
 DURING HARD WORKLOAD EXERCISE
 (liters, S.T.P.D.)

Subject	Raw Score			Standard Score		
	T ₁	T ₂	Diff.	T ₁	T ₂	Percent of Diff.
1	108.10	105.41	- 2.69	50.80	48.8	- 1.92
3	105.98	109.01	+ 3.03	44.83	53.19	+ 8.36
4	92.65	83.21	- 9.44	4.46	4.27	+ .19
6	105.81	123.96	+18.15	44.43	56.66	+12.23
8	90.65	89.30	- 1.35	11.51	9.85	- 1.66
10	126.84	127.69	+ .85	90.66	91.16	+ .50
11	125.42	116.11	- 9.31	88.88	71.90	-16.98
Mean	107.92	107.81	- .11	55.08	52.29	- 2.79
S.D.	13.97	16.89				
t Ratio	.342					

Oxygen Uptake

Submaximal Workload. The total oxygen uptake was measured for eight minutes: during the four-minute submaximal treadmill run and the four-minute recovery period.

The minute volume of oxygen uptake is presented in Table VII. Nine subjects increased their oxygen uptake under the condition, while four subjects decreased their oxygen uptake. The means of the oxygen uptake were 21.21 milliliters per kilogram per minute on T_1 and 21.76 milliliters on T_2 . The average increase of .55 milliliters from the pre-training level did not indicate any statistical significance.

Hard Workload. Only seven subjects were used for the hard workload oxygen uptake measurements for the same reason as mentioned previously.

Table VIII reveals that all but one of the subjects (#1) showed increases. The average percentage of increase in the standard score for the hard workload was about twenty-two percent with the degree of increase ranging approximately from plus two percent to plus fifty-six percent in terms of standard scores.

The mean oxygen uptake under the hard workload was 47.3 milliliters per kilogram, per minute on T_1 and 51.29 milliliters per kilogram, per minute on T_2 . This difference was statistically significant at the .02 level of confidence.

TABLE VII
TOTAL OXYGEN UPTAKE DURING SUBMAXIMAL
WORKLOAD AND RECOVERY PERIOD
(ml/kg/min.)

Subject	Raw Score			Standard Score		
	T ₁	T ₂	Diff.	T ₁	T ₂	Percent of Diff.
1	20.20	22.66	+2.46	24.51	73.89	+49.87
2	20.66	21.12	+ .46	32.64	42.07	+ 9.43
3	25.27	26.40	+1.13	98.08	99.36	+ 1.28
4	19.59	20.65	+1.06	15.15	32.64	+17.49
5	18.44	19.56	+1.12	4.85	14.65	+ 9.84
6	23.46	22.69	- .77	85.99	74.54	-11.49
7	21.71	22.13	+ .42	55.17	64.06	+ 8.89
8	23.40	22.70	- .70	65.31	73.23	-12.08
9	20.31	22.69	+2.38	46.11	74.54	+28.47
10	21.77	20.68	-1.09	56.36	33.00	-23.36
11	20.20	21.14	+ .94	24.20	42.47	+18.27
12	20.99	19.40	-1.59	29.36	12.71	-16.65
13	19.71	21.01	+2.89	16.60	39.74	+23.14
Mean	21.21	21.76	+ .55	46.28	51.76	+ 5.48
S. D.	1.88	1.81				
t Ratio	1.571					

TABLE VIII

OXYGEN UPTAKE DURING HARD WORKLOAD

(ml/kg/min.)

Subject	Raw Score		Diff.	Standard Score		
	T ₁	T ₂		T ₁	T ₂	Percent of Diff.
1	50.59	54.84	+4.25	59.48	84.61	+25.13
3	50.69	55.39	+4.70	60.26	86.86	+26.60
4	54.62	55.17	+ .55	83.65	85.99	+ 2.34
6	45.95	52.70	+6.75	26.11	73.57	+47.46
8	32.82	43.32	+9.50	2.68	9.85	+ 7.17
10	41.55	51.24	+9.69	7.64	64.06	+56.42
11	48.90	47.35	-1.55	47.21	35.94	-11.27
Mean	46.44	51.29	+4.85	41.00	62.98	+21.98
S.D.	5.56	4.87				
t Ratio	3.142 **					

** Significant at the .02 level of confidence

II. DISCUSSION OF THE FINDINGS

Training Program

Establishing a desired exercise standard is important for the subject to establish a good physiological effect from the training. However, it is difficult to establish a physiological and psychological standard. The standard for training the subjects was a five-minute daily exercise program of rope jumping. This daily exercise load was sufficient to improve cardiorespiratory fitness.

As the writer mentioned earlier, rope jumping and running (which is considered the best exercise for improvement of endurance), demand a similar type of workload. The average heart rate fifteen seconds following a daily workout was between 140 and 150 beats per minute. From the standpoint of heart rate only, this workload was similar to the jogging or running which was recommended as a daily physical fitness program for improved endurance.⁵⁷

Validity of the Testing

In this investigation, a motor-driven treadmill test at a speed of 7 mph at a grade of 8.6 percent (following a warmup exercise consisting of a treadmill run at a speed of 6 mph at no grade,) was used to determine the effects of the training on cardiorespiratory fitness.

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⁵⁷Michio Imai, "Karada Zukuri no Gensoku (Basic Principles of Physical Fitness Training), Japan Journal of Health, Physical Education, and Recreation, XVI (December, 1966), pp. 686-88.

Johnson, et al., founders of the original Johnson Treadmill Run, described in their book some values of the test as a physical fitness test for hard muscular work.⁵⁸ In addition to this, there are a few scientific studies to support the testing workload used in this study.

Cureton pointed out that the test must be a maximal test which will overload the circulatory-respiratory capacity enough to bring about exhaustion within five minutes or less, to determine maximal physical efficiency as a testing workload. Cureton recommended that a treadmill run at about 7 mph, 8.6% grade, be used as a test for an ordinary healthy young man.⁵⁹

Astrand also stated that a running speed on the treadmill which will force the subject to an "all out" state at five or six minutes, must be used as a testing load for endurance. For this reason, Astrand explained that a five or six minute exercise duration is necessary in order for the full involvement of the respiratory and circulatory systems in the exercise.⁶⁰

As the writer mentioned previously, some of the subjects had to stop running on the treadmill, even though they could have continued, because the Johnson Physical Fitness Index was used in the investigation.

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⁵⁸ Conzelasio, Johnson, and Pecora, loc. cit.

⁵⁹ Thomas K. Cureton, Physical Fitness of Champion Athletes (Urbana, Illinois: University of Illinois Press, 1951), p. 314.

⁶⁰ P. O. Astrand, "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, XVI, 1961, pp. 977-81.

Cardiorespiratory Fitness

A main objective in this investigation was to determine the subject's changes in cardiorespiratory (circulorepiratory is used by some scholars) fitness when rope jumping training was used. Strictly speaking, the word "fitness" refers to "endurance." Although there are several ways to test cardiorespiratory endurance, the training effects of cardiorespiratory fitness in the study will be described in four phases:

Phase I. Heart Rate

Phase II. Gross (Total) Oxygen Uptake and Pulmonary Ventilation

Phase III. Maximal Oxygen Uptake

Phase IV. Oxygen Removal Rate

Phase I. Heart Rate. The sharp acceleration in heart rate which occurred with the commencement of submaximal exercise, and the gradual linear increase in heart rate that occurred after the first minute and continued when the steady state was reached, are typical heart rate responses to submaximal workload (see Figure 2, page 35.)

Although there was no significant difference between T_1 and T_2 , slow increase of heart rate during exercise was on T_2 . Generally speaking, it was obvious that the trained subject showed a slower increase of the heart rate in response to a given exercise workload.

Rapid heart rate recovery from submaximal exercise appears to indicate that cardiorespiratory efficiency increased with training. (See Table II, page 36.) Lower pulse rates, especially during recovery, are good evidence of cardiorespiratory efficiency and cardiac output.

This finding in the study tends to corroborate that reported in other studies by Balke, Schneider, Deal, and Matsui.^{61, 62, 63, 64} They reported that a ratio of recoverate heart rate was valuable as an evaluation for endurance.

In the study, the physical fitness index following a hard workload treadmill run, was used as a criterion for cardiorespiratory improvement (see Table IV, page 40.) As recovery heart rates were presented in Figure 3, mean heart rates on the post-training level at each point decreased more rapidly than the heart rates on the pre-training level. In the Physical Fitness Index, a 7.7 percent improvement in the standard score was found with statistical significance at the .05 level of confidence.

From the data in this study, it can be considered that rapid recovery of heart rates to the normal after the hard workload treadmill run (or an increase of the physical fitness index), indicated cardiorespiratory adaptation to strenuous exercise and an evidence of cardiorespiratory improvement. This fact indicates certain improvement of cardiorespiratory function due to a given workload exercise.

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⁶¹ B. Balke, "Experimental Evaluation of Work Capacity as related to Chronological and Physical Aging," Civil Aeromedical Research Institute Publication (Oklahoma City: 1963), p. 18

⁶² C. E. Schneider and C. Crapton, "A Comparison of Some Respiratory and Circulatory Reactions of Athletes and Non-athletes," American Journal of Physiology, CXXIX (April, 1940), p. 165.

⁶³ Michio Imai, Shigehiro Yoshisawa, and I. Nakagawa, "Treadmill Ho ni yoru Zenshin Jikynsei no Hyoka (An Evaluation of Endurance through Treadmill Run)," Japanese Journal of Physical Fitness, X (August, 1962), pp. 227-38.

⁶⁴ Hideji Matsui, "Shinpakku Su ni yoru Training no Kenri (Administration of Training through the Heart Rates)," Olympia, XX, 1963, pp. 2-8.

There are many studies which report that highly trained athletes showed rapid recovery of heart rates from hard workload or maximal workload exercise.^{65, 66, 67} This means the same workloads require less functional reserves of athletes, than they do of the individual out of training.

Phase II. Gross Oxygen Uptake and Pulmonary Ventilation.

Morehouse and Miller⁶⁸ pointed out that through training, the oxygen requirement for submaximal exercise is diminished as a result of more efficient use of muscles and of greater mechanical efficiency of the muscles themselves.

The findings of the writer's study showed no significant difference in T_1 and T_2 oxygen consumption from the submaximal treadmill run. It is interesting to note that the total pulmonary ventilation during the submaximal treadmill run and in the recovery period, showed a significant decrease at the .01 level of confidence, with mean difference of 2.73 l/kg. per min. and with 10.6 percent decrease in the standard score. This fact may indicate that there was good indication of greater economy and less strain on the energy metabolism needed. This fact may also

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⁶⁵J. Shimmer, O. Holloszy, and T. Cureton, "Effects of a Program of Endurance Exercise on Physical Work, American Journal of Cardiology, XIV (December, 1964), p. 749.

⁶⁶Takaaki Asami and H. Kagaya, "Shinpaiku Su kara mita Jikyasai Noryoku (Endurance Capacity from the Standpoint of Heart Rate)," Japan Journal of Health, Physical Education, and Recreation, XIV (May, 1964), pp. 270-76.

⁶⁷Toshihiro Ishiko, "Aerobic Capacity and External Criteria of Performance," Proceeding of the International Symposium on Physical Activity and Cardiovascular Health, The Canadian Medical Association Journal LIX (March, 1967), pp. 746-49.

⁶⁸Morehouse and Miller, loc. cit., p. 6.

indicate that the same workload under submaximal conditions, encroached less on the functional responses of the subjects and that there was more efficient oxygen transport by the cardiorespiratory system. It is obvious that other things being equal, the physically fit or athletically trained individual has lower pulmonary ventilation for a given exercise workload.

There are studies which tend to support the statement that the pulmonary ventilation for a given exercise workload decreases with training.^{69, 70}

From the results of the data and other studies which support the findings, the writer believes that the decrease in the total pulmonary ventilation during the submaximal workload shows a phase of improved cardiorespiratory fitness.

Phase III. Maximal Oxygen Uptake. As written previously, the oxygen uptake during the Modified Johnson Treadmill Run cannot be called true maximal oxygen uptake. For the following reasons, however, it is sure that the oxygen uptake was very close to the maximal oxygen uptake: The workload of 7 mph, at 8.6 percent grade for five minutes was considered almost a workload for the subjects, by the writer's observation. In addition to this, the subjects experienced a steady state before the treadmill run. The steady state could help them display maximal functions of the cardiorespiratory system during

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⁶⁹C. E. Schneider and G. C. Ring, "The Influence of a Moderate Amount of Physical Training on the Respiratory Exchange and Breathing during Physical Exercise," American Journal of Physiology, XCI, 1929, pp. 103-14.

⁷⁰C. Gormall, W. Booth, and W. Peacock, "Muscular Training I," American Journal of Physiology, XCI, 1930, pp. 253-70.

The strenuous exercise workload. The oxygen uptake during the hard workload had obviously high value as a substitute for the maximal oxygen uptake.

Many studies reported that maximal oxygen uptake is probably the best measurement of aerobic work capacity and circulatory-respiratory function. 71, 72, 73, 74, 75, 76, 77

In the study, inspection of Table VIII reveals that the difference between T_1 and T_2 means for oxygen uptake was significant (at the .02 level.) The standard score shows 21.6 percent improvement. This finding indicates that cardiorespiratory and other physiological functions could adapt to the increased metabolic needs of hard exercise.

⁷¹P. A. Astrand, "Human Physical Fitness with Special Reference to Sex and Age," The Journal of Clinical Investigation XXXVI, July, 1956, pp. 307-35.

⁷²Michio Ikai and Muneharu Shindo, "Zenshin Jikyu Sei no Kenkyu (A Study of Endurance), Japan Journal of Health, Physical Education and Recreation XV, (November, 1965), pp. 669-73.

⁷³K. Lange Anderson, "Physiological Work Capacity," Health and Physical Fitness in the World, (Athletic Institute, 1961), pp. 365-67.

⁷⁴H. L. Taylor, E. Buskirk, and A. Henschel, "Maximal Oxygen Intake as an Objective Measurement of Cardiorespiratory Performance," Journal of Applied Physiology, VIII, 1955, p. 73.

⁷⁵A. Helmgren, "Cardiorespiratory Determinants of Cardiovascular Fitness," Canadian Medical Association Journal, XII, (March, 1967), pp. 687-702.

⁷⁶Michiharu Miyamura, "Shinpaiko Shutsuryo kara mita Zenshin Jikyu Sei (A Study of Endurance with Respect to Cardiac Output)," Japan Research Journal of Physical Education, XI, (September, 1966), pp. 69-76.

⁷⁷J. H. Mitchell, B. J. Sproule, and C. B. Cahpmann, "The Physiological Meaning of the Maximal Oxygen Intake Test," The Journal of Clinical Investigation, XXXVII, (April, 1958), pp. 535-38.

The maximal oxygen uptake relates not only to the ability of the heart to pump blood to working tissues, but also to the ability of the body's tissues to absorb oxygen from the circulating blood. This means the maximal oxygen uptake is significant to determine endurance of the body.

Therefore, it is evident that the subject gained certain improvement in endurance from the increase of oxygen uptake under the condition of a hard workload.

Phase IV. Oxygen Removal Rate. Oxygen removal rate is the ratio of oxygen uptake (milliliter per minute) to ventilation (liter per minute). It is the reciprocal of the ventilation equivalent.^{78, 79, 80.} The oxygen removal rate gives the quantity of oxygen consumed for each liter of air breathed. Koff, et al, stated that oxygen removal rate declined as the effective ventilation -- perfusion ratio -- was exceeded.⁸¹

There are different opinions concerning physiological relation between oxygen uptake and the ventilation capacity. Chapman and Mitchell⁸² claim that maximal oxygen intake has nothing to do with the capacity of the lungs for ventilation or diffusion.

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⁷⁸Consolazio, Johnson, and Pecora, op. cit., p. 200.

⁷⁹M. Imai, S. Yoshizawa, and I. Nakagawa, "Treadmill Hoken yori Jikyuusei no Hyoka, Marathon Senshu o chushin to shite (An Evaluation of the Endurance through a Treadmill Run, especially the Test of Marathon Runners)," *Olympia*, XI, 1962, pp. 66-73.

⁸⁰Miyoshi Urabe and Takashi Tsubokawa, Kokyu Junkan Kiso Kensa Ho (The Tests and Measurements in Respiratory-Circulatory Functions.) (Tokyo: Nankodo, 1961), pp. 44-45.

⁸¹Arnold Koff et al., "Cardiorespiratory Responses to Strenuous Exercise in Physically Trained and Untrained Normal Men," Research Quarterly, XXXIV (March, 1963), pp. 41-49.

⁸²Carlson B. Chapman and Jere H. Mitchell, "The Physiology of Exercise," Scientific American, CCXII (May, 1965,) pp. 88-96.

Cureton, however, contended that oxygen uptake is dependent on many factors; among them the total ventilation of the lungs, the oxygen-carrying capacity of the blood, etc.⁸³ Ishiko also reported the ventilation capacity of the lungs is one of the factors which influences the maximal oxygen uptake capacity,⁸⁴ and with this position in mind, the writer of this paper decided to consider oxygen removal rate in the analysis of data.

The data gathered from the submaximal workload of this study showed there was no significant difference in the oxygen uptake between T_1 and T_2 . The ventilation data, however, showed a significant decrease at the .05 level on T_2 (see Table V, page 42.) Oxygen removal rate showed a fair increase on T_2 at the .01 level of confidence. The oxygen removal rate during submaximal work is presented in Table IX, and shows greater mechanical efficiency as indicated by a lower ventilation for a given amount of work. This must be considered evidence of improved cardiorespiratory fitness.

On the other hand, there was an inverse phenomenon in the data obtained under the hard workload. The ventilation data was similar at T_1 and T_2 . However, the oxygen consumption during T_2 was significantly higher when compared to the measurement recorded at the time of the initial testing. The oxygen removal rate during hard work at T_2 also increased. The data for the oxygen removal rate has been presented in Table X.

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⁸³Cureton, loc. cit., p. 48.

⁸⁴Toshihiro Ishiko, "Sanzo Seeshu Kyo no Genkai (The Limitation of Oxygen Intake)," Sports Igaku Nyumon (Introduction to Sports Medicine) Tokyo: Taiiku no Kagaku Sha, 1965), pp. 79-80

TABLE IX
OXYGEN REMOVAL RATE DURING
SUBMAXIMAL TREADMILL RUN
AND IN RECOVERY PERIOD
(ml/l/min.)

Subject	T ₁			T ₂		
	oxygen uptake (ml)	ventilation (l)	O. R. R. (ml/l)	oxygen uptake (ml)	ventilation (l)	O. R. R. (ml/l)
1	1210	37.21	32.52	1380	36.59	37.72
2	1710	49.53	34.53	1620	46.46	34.87
3	1680	43.62	38.58	1740	39.29	44.29
4	1180	31.57	37.38	1220	27.70	37.65
5	1490	39.55	37.67	1580	39.72	39.78
6	1970	49.59	39.44	1890	46.62	40.54
7	1660	38.08	43.59	1720	35.25	48.91
8	1890	39.44	40.31	1560	35.28	44.22
9	1470	37.43	39.27	1590	39.76	39.99
10	2100	56.40	37.23	2070	50.60	40.91
11	1400	45.17	30.99	1420	36.31	39.11
12	1400	36.13	38.75	1290	34.50	37.39
13	1400	35.71	39.20	1510	35.85	42.12
Mean	1560	41.49	37.64	1580	38.76	40.58
S.D.	270	6.98	3.02	240	6.10	3.65
t Ratio	3.92 ***					

*** Significant at the .01 level of confidence

TABLE X

OXYGEN REMOVAL RATE DURING HARD WORKLOAD

(ml/l/min.)

Subject	T ₁			T ₂		
	oxygen uptake (ml)	ventilation (l)	O. R. R. (ml/l)	oxygen uptake (ml)	ventilation (l)	O. R. R. (ml/l)
1	3030	108.1	28.03	3340	105.41	31.69
3	3370	105.98	31.49	3650	109.01	33.48
4	3290	92.65	35.51	3260	83.21	39.17
6	3960	105.81	37.43	4490	123.96	36.22
8	2230	90.65	24.60	2910	89.30	32.60
10	3910	126.84	30.83	5130	127.60	40.18
11	3390	125.42	27.03	3180	116.11	27.39
Mean	3310	107.92	30.70	3710	107.81	34.39
S.D.	580	13.97	4.31	810	16.89	4.47
t Ratio	2.64 *					

* Significant at the .05 level of confidence

Figures 4 and 5 indicate an increased cardiorespiratory efficiency by revealing changes in oxygen uptake and pulmonary ventilation. Figure 4 indicates that during submaximal exercise, the minute volume of ventilation on T_2 (vertical axis) decreased, while the minute volume of the oxygen uptake on both T_1 and T_2 were almost the same amount (horizontal axis). On the other hand, Figure 5 shows that the minute volume of ventilation on both T_1 and T_2 were the same during the hard workload.

As the limiting factors of endurance, Ikai et al.,⁸⁵ found decrease of tidal volume, decrease of oxygen pulse, and decrease of oxygen removal rate during "all out" exercise.

In this study, therefore, the writer considers that the increase in the oxygen removal rate for both submaximal and hard workload conditions reveals a fairly significant improvement of cardiorespiratory fitness.

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⁸⁵ Michio Ikai, Shinjiro Ebashi, H. Kagaya, et al., "Treadmill Ho ni yoru Seishone no Undo Shoho ni kansuru Kenkyu (II) (Optimal Exercise Standard for Physical Fitness of Youth (II), The Limiting Factors of Endurance)", Japan Research Journal of Physical Education, VII (February, 1965), pp. 61-71.

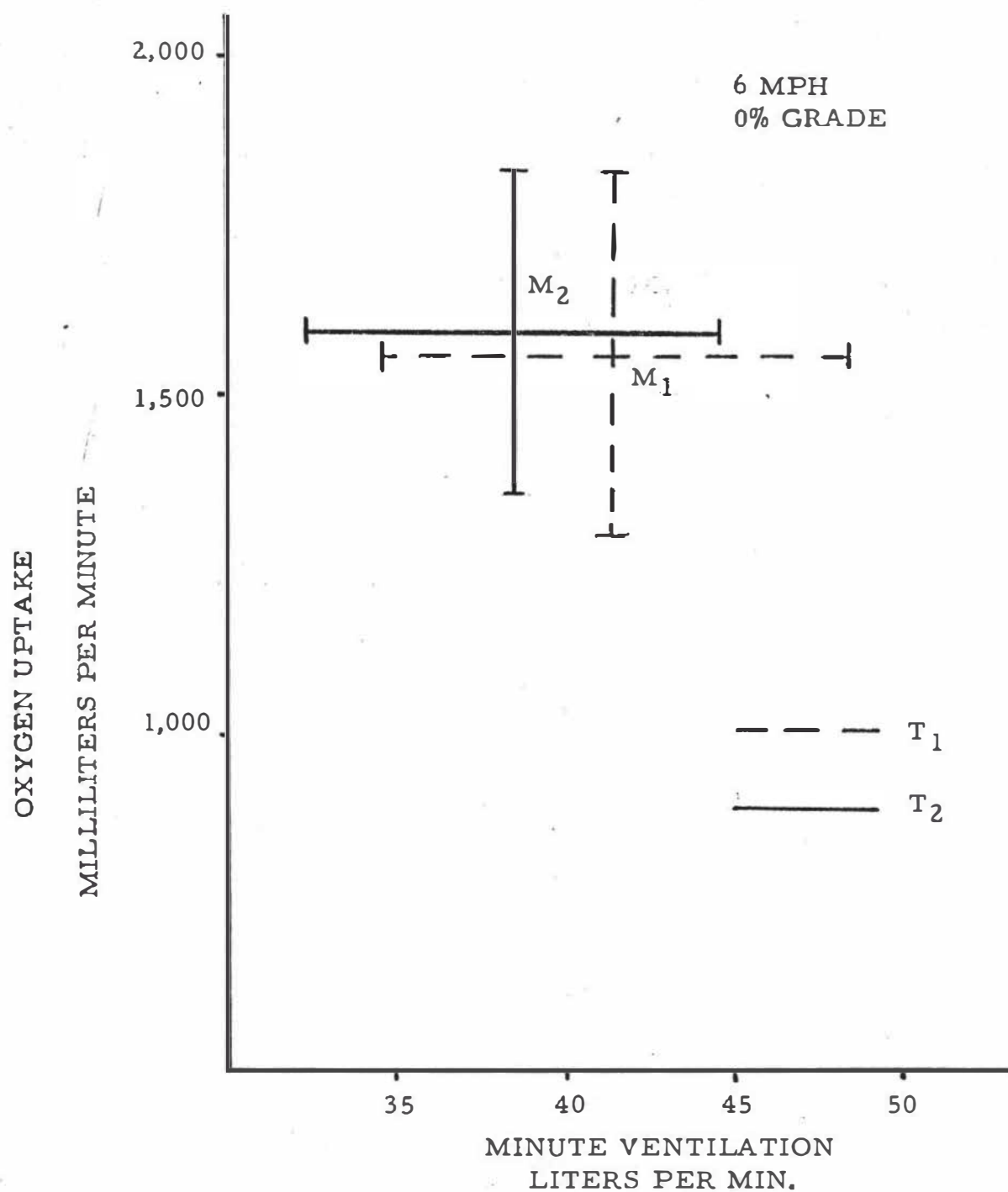


Figure 4

COMPARATIVE VARIABILITY (STANDARD DEVIATION)
OF RESPIRATORY AND CIRCULATORY RESPONSES TO SUBMAXIMAL
EXERCISE

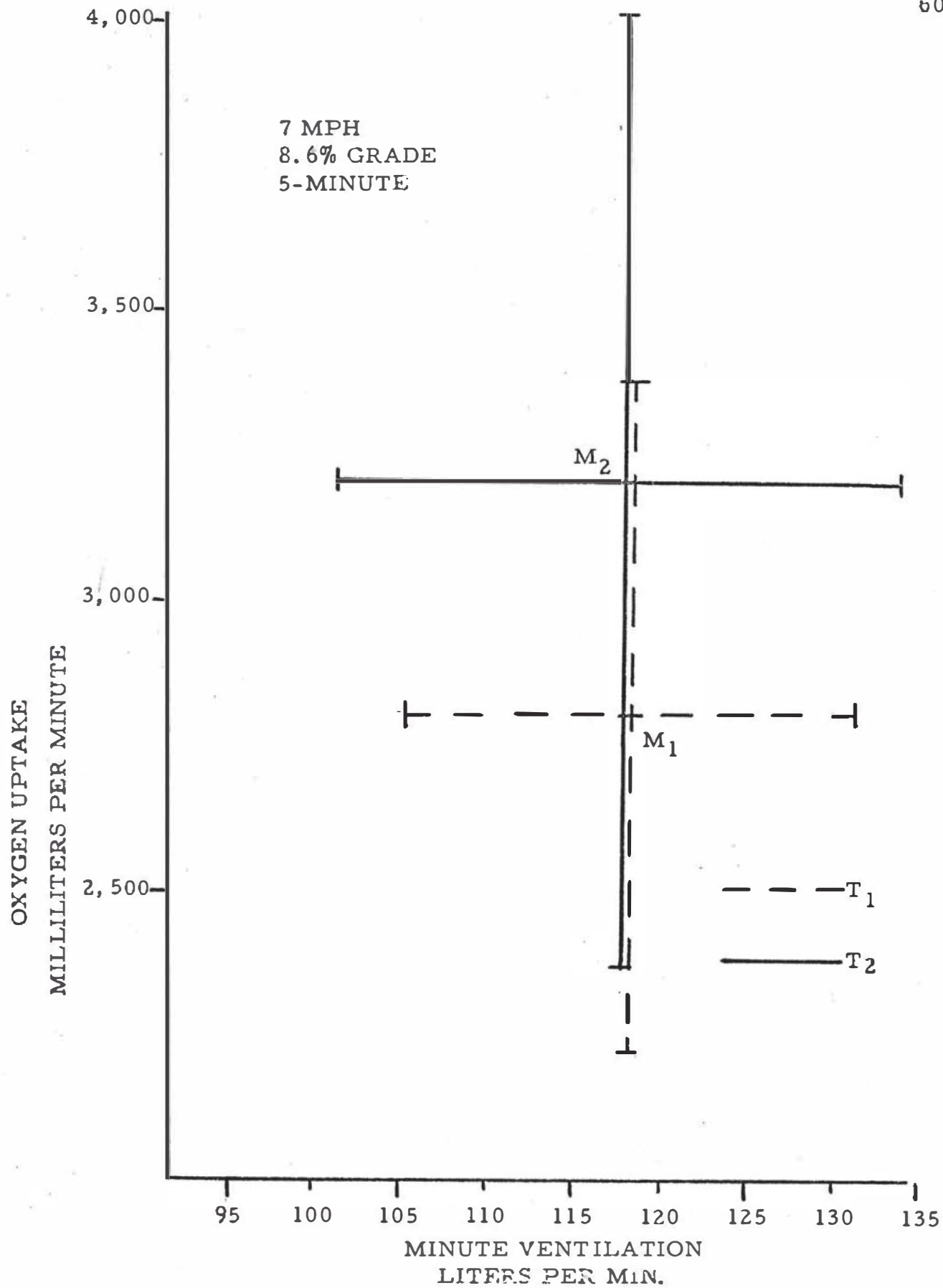


Figure 5

COMPARATIVE VARIABILITY (STANDARD DEVIATION)
OF RESPIRATORY AND CIRCULATORY RESPONSES TO
HARD WORK EXERCISE

CHAPTER V

SUMMARY AND CONCLUSION

I. SUMMARY

The main purpose of this study was to determine the effects of an eight-week rope jumping program on the cardiorespiratory fitness of high school students.

Thirteen male non-athlete students at Charleston High School, Charleston, Illinois, served as subjects. The rope jumping program consisted of thirty-five daily training sessions, administered over an eight-week period during the first five minutes of the regular physical education class. Subjects were required to jump a rope with both feet simultaneously as many times as possible.

Oxygen consumption and heart rate response to submaximal and vigorous treadmill runs were studied before and after the training program. In addition, pre and post training body weights were investigated.

A t test was used to determine the significance of the difference between pre and post training means. Data were also converted to Standard Scores and the percent change in various parameters was determined.

II. CONCLUSION

Based on the findings of this investigation, the following conclusion appears warranted. A program of rope jumping as performed in this study will improve the cardiorespiratory fitness of male non-athlete high school students, as determined by:

1. Improved heart rate recoveries from submaximal and hard treadmill runs
2. Lower pulmonary ventilation during submaximal work
3. Increased oxygen uptake capacity during hard workload
4. Increased oxygen removal rate for a given workload.

BIBLIOGRAPHY

BIBLIOGRAPHY

A. BOOKS

- Anderson, K. Lange, Wolffe, Joseph, et al. (ed.) Health and Fitness in the Modern World. Chicago: Athletic Institute, 1961.
- Asagawa, Shoichi, Imai, Michio, et al. (ed.) Kindai Training (The Modern Training in Sports). Tokyo: Taishukan, 1965.
- Casady, Donald R., Maoss, Donald F., and Alley, Louis E., Handbook of Physical Fitness Activities. New York: The Macmillan Company, 1965.
- Consolazio, C. Frank, Johnson, Robert., and Pecora, J. Louis, Physiology Measurement of Metabolic Functions in Man. New York: McGraw-Hill Book Company, Inc., 1963.
- Cureton, Thomas K., Physical Fitness of Champion Athletes. Urbana, Illinois: University of Illinois Press, 1951.
- de Vries, Herbert A., Physiology of Exercise for Physical Education and Athletics. Dubuque, Iowa: Wm. C. Brown Company, Publishers, 1966.
- Falker, Frank, et al., Human Development. Philadelphia: W. B. Saunders Company, 1966.
- Hill, A. V., Muscular Activity. Baltimore: The Williams and Wilkins Company, 1926.
- Kodama, Toshio, et al. (ed.) Sports Igaku Nyumon (Introduction to Sports Medicine). Tokyo: Nankodo, 1965.
- Lee, Mabel and Wargner, Miriam M., Fundamentals of Boys Mechanics and Conditioning. Philadelphia: W. B. Saunders Company, 1949.
- Loken, Newton C. and Willoughby, Robert J., Complete Book of Gymnastics. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1961.

McCloy, Charles and Young, Norman D., Tests and Measurements in Health and Physical Education. New York: Appleton-Century-Crofts, Inc., 1954.

Miller, Ben W., Bookwalter, Karl W., and Schlafer, George E., Physical Fitness for Boys. New York: A. S. Barnes and Company, 1949.

Morehouse, Laurence E. and Miller, Augustus T., Physiology of Exercise. New York: The C. V. Mosby Company, 1967.

Munn, Biggie, et al., Physical Activity in Modern Living. New York: Prentice-Hall, Inc., 1963.

Stafford, G. T. and Duncan, R. O., Physical Conditioning. New York: A. S. Barnes and Company, 1942.

Tuttle, W. W. and Schottelius, Byron A., Textbook of Physiology. St. Louis: C. V. Mosby Company, 1961

Urabe, Miyoshi and Tsubokawa, Takashi. Kokyu Junkan Kiro Kensa Ho. (The Tests and Measurements in Respiratory-Circulatory Functions). Tokyo: Nankodo, 1961.

B. PERIODICALS

Anderson, Theresa, "Rope Jumping," Journal of Health and Physical Education, Vol. 17, No. 2. (June, 1946), 196.

Asami Takaaki and Kagaya, H., "Shinpakusu kara mita Jikyu Sei Noryoku (Endurance Capacity from the Standpoint of Heart Rate)," Japan Journal of Health and Physical Education and Recreation, Vol. 14, No. 5. (May, 1964), 270-76.

Astrand, P. O., "Experimental Studies of Physical Working Capacity in Relation to Sex and Age," Ejnar Munksgaard, 1952.

Astrand, P. O., "Human Physical Fitness with Special Reference to Sex and Age," The Journal of Clinical Investigation, Vol. 36. (July, 1956), 307-335.

Astrand, P. O., "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, Vol. 16, 1961, 977-81.

- Baker, John A., "Comparison of Rope Skipping and Jogging as to Improving Cardiovascular Efficiency of College Men," Research Quarterly, Vol. 39, No. 2. (May, 1968), 240-43.
- Chapman, C. B. and Mitchell, H. J., "The Physiology of Exercise," Scientific American, Vol. 212, No. 5. (May, 1965), 88-96.
- Dill, D. B. and Consolazio, F. C., "Responses to Exercise as Related to Age and Environmental Temperature," Journal of Applied Physiology, Vol. 17, 1962, 643-48.
- Fahey, Helen. "Rope Jumping," Journal of Health and Physical Education, Vol. 11, No. 9. (September, 1940), 420-22.
- Fox, S. M. and Skinner, J. S., "Physical Activity and Cardiovascular Health," American Journal of Cardiology, Vol. 14, 1964, 931-46.
- Garrett, Leon, Sabie, Mohammed, and Fangle, Roy. "Four approaches to Increasing Cardiovascular Fitness during Volleyball Instruction," Research Quarterly, Vol. 36, No. 4. (December, 1965), 496-99.
- Gemmell, C., Booth, W., and Pocock, W., "Muscular Training. (I), The Physiological Effect of Daily Repetition of the Same Amount of Light Muscular Work," American Journal of Physiology, Vol. 91, 1930, 253-70.
- Grim, H., "Jugend und Sport," Lehrbuch d. Sportmedizin, 1956, 447-83.
- Haskell, W. L. and Fox, S. M. "The Possible Place of Stress Testing to Discover, and Physical Activity to Prevent, Coronary Heart Disease," Southern Medical Journal, Vol. 59, 1966, 642-49.
- Ikai, Michio. "Seinenki ni Hitsuyo na Undo no Shoho (Exercise Standards for Physical Fitness of Youth)," Journal of Health, Physical Education, and Recreation, Vol. 12, No. 7. (July, 1963), 351-53.
- Ikai, Michio. "Karada Zukuri no Genseku (Basic Principles of Physical Fitness Training," Japan Journal of Health, Physical Education, and Recreation, Vol. 16, No. 12. (December, 1966), 686-88.
- Ikai, Michio and Shindo, Muneharu. "Zenshin Jikyu Sei no Kenkyu (I) (A Study on Endurance, I), Japan Journal of Health, Physical Education, and Recreation, Vol. 15, No. 11. (November, 1965), 669-73.
- Ikai, Michio and Shindo, Muneharu. "Zenshin Jikyu Sei no Kenkyu (II) (A Study on Endurance, II), Japan Journal of Health, Physical Education, and Recreation, Vol. 15, No. 12. (December, 1965), 734-39.

Iwai, Michio, Yoshizawa, Shigehiro, and Nakagawa, I., "Treadmill Ho ni yoru Zenshin Jikyu Sei no Hyoka (Test of Endurance through Treadmill Run)," Japanese Journal of Physical Fitness, Vol. 10, No. 4, (August, 1962), 227-38.

Iwai, Michio, Yoshizawa, Shigehiro, and Nakagawa, I., "Treadmill Ho ni yoru Jikyu Sei no Hyoka - Marathon Benshu o Chushin to shite (An Evaluation of Endurance through Treadmill Run, especially the Test of Marathon Runners)," Olympia, No. 11, 1963, 41-49.

Iwai, Michio, Ebashi, Shinjiro, Kagaya, H., et al., "Treadmill Ho ni yoru Seisho Nen no Undo Shoho ni kansuru Kenkyu (II) (Optimal Exercise Standard for Physical Fitness of Youth. (II), The Limiting Factors of Endurance)," Japan Research Journal of Physical Education, Vol. 8, Nos. 3,4. (February, 1965), 61-71.

Johnson, Robert E., Robbins, Frances, et al., "A Versatile System for Measuring Oxygen Consumption in Men," Journal of Applied Physiology Vol. 22, No. 2, (February, 1967), 377-79.

Jones, D. Merritt, Squires, Chadwick, and Redahl, Kaare. "Effect of Rope Shipping on Physical Work Capacity," Research Quarterly, Vol. 33, No. 2, (May, 1962), 236-38.

Kaff, Arnold, Bruce, Robert A., Fernandes, Kenneth, Ovensall, David, and Cutler, Russell K., "Cardiorespiratory Responses to Strenuous Exercise in Physically Trained and Untrained Normal Men," Research Quarterly, Vol. 34, No. 2, (March, 1963), 41-49.

Kato, Katsuo, "Gakko Taiku no okeru Tairyoku Zukuri (Physical Fitness Programs in Physical Education in Schools)," Japan Journal of Health, Physical Education and Recreation, Vol. 16, No. 7, (July, 1966), 386-89.

Kobayashi, Yoshio, Takeuchi, Shinya, and Hideyuki, Obayashi, "Choki Kyuka ni okeru Koko Sei no Tairyoku Kanri (Administration of High School Student's Physical Fitness of Cardiorespiratory Functions during Summer Vacation.)" Japan Research Journal of Physical Education, Vol. 12, No. 4, (July, 1968), 52.

Matsui, Hideji. "Shinpaaku Su ni yoru Training no Kanri (Administration of Training through the Heart Rates)," Olympia, No. 20, 1963, 2-8.

- Mellby, Rolf E., "Rope Jumping," Journal of Health and Physical Education, Vol. 7, No. 2, (February, 1936), 93-95.
- Mitchell, J. H., Sproule, K., and Chapman, C. B., "The Physiological Meaning of the Maximal Oxygen Intake Test," Journal of Clinical Investigation, Vol. 37, No. 2, (April, 1958), 535-38.
- Miyamura, Michiharu. "Shinpaku Shutsu Ryo kara mita Zenshin Ukyu Sei (A Study on Endurance with Respect to Cardiac Output)," Japan Research Journal of Physical Education, Vol. 11, No. 2, (September, 1966), 69-76.
- Moore, Martha. "Rope Jumping for Coordination," Journal of Health, and Physical Education, Vol. 17, No. 11, (November, 1946), 554-56.
- Morris, J. N., Kagan, A., and Pattison, D. C., "Incidence and Prediction of Ischemic Heart Disease in London Busmen," The Lancet, Vol. 2, No. 7463, (September, 1966), 642-49.
- Morse, M., Schultz, F. W., and Cassels, D. E., "Relation of Age to Exercise," Journal of Applied Physiology, Vol. 1, No. 4, (July, 1949), 683.
- Nageray, V. E., "Importance of Overall Physical Development in the Preparation of Youthful Sportsmen," (Fizicheskaya Kultwca V Shkole) Physical Education in School, Vol. 1, 1959, 6-10.
- Oka, Akira. "Kyodai Kaibogaku Kyoshitsu Boken Zairyo no Tokeigaku teki Kansatsu (Statistical Observation of Anatomical Materials in the Pathology Research Room at Medical School,) University of Kyoto, Vol. 38, 1941, 431-47, The Medical Journal of Kyoto.
- Schneider, C. E. and Crayton, C., "A Comparison of Some Respiratory and Circulatory Reactions of Athletes and Non-athletes," American Journal of Physiology, Vol. 129, No. 4, (April, 1940), 165-69.
- Schneider, C. E., and Ring, G. C., "The Influence of a Moderate Amount of Physical Training on the Respiratory Exchange and Breathing During Physical Exercise," American Journal of Physiology, Vol. 91, No. 1, (January, 1929), 103-04.
- Skinner, J., Hellesay, P., and Cureton, T. K., "Effects of a Program of Endurance Exercise on Physical Work," American Journal of Cardiology, Vol. 16, No. 6, (December, 1964), 749.

Stewart, Chester A., "The Vital Capacity of the Lungs of Children in Health and Disease." American Journal of Disease of Children, Vol. 24, (December, 1922), 453.

Taylor, H. L., Buskirk, E., and Henschel, A., "Maximal Oxygen Intake as an Objective Measure of Cardiorespiratory Performance," Journal of Applied Physiology, Vol. 8, No. 1, January, 1955, 73.

Teraslinna, Pentti, Ismail, A. H., MacLeod, D. F., Combs, L. W., Christian, K. E., and Kessler, M. V., "Relationship Between Physical Fitness and Susceptibility to Cardiovascular Disease," Research Quarterly, Vol. 39, No. 3, (October, 1968), 735-47.

Truett, J. Corafield, J., and Kannel, W., "A Multivariate Analysis of the Risk of Coronary Heart Disease in Framingham," Journal of Chronological Disease, Vol. 20, 1967, 511-24.

Yoshizawa, Shigehiro. "Chikhi Betsu ni mita Undo Noiryaku (I) (Distinction of Motor Performance between Cities and Villages)", Japan Research Journal of Physical Education, Vol. 11, No. 2, (September, 1966), 58-68.

C. REPORTS

Balke, B. "Experimental Evaluation of Work Capacity as Related to Chronological and Physiological Aging," Civil Aeromedical Research Institute Publication, Oklahoma City: No. 63, (September, 1963), 18.

Holmgren, A. "Cardiorespiratory Determinants of Cardiovascular Fitness," Proceedings of the International Symposium on Physical Activity and Cardiovascular Health, The Canadian Medical Association Journal, Vol. 59., (March, 1967), 687-702.

Ikai, Michio. "Seinen Ki ni okeru Undo Fuka Ryo no Shoho (Optimal Exercise Standards for Physical Fitness in Youth.)," The Proceedings of the 16th Japan Medical Society Annual Convention, Vol. 10, 1963, 207-11.

Ishiko, Toshihiro. "Aerobic Capacity and External Criteria of Performance," The Proceedings of the International Symposium on Physical Activity and Cardiovascular Health, The Canadian Medical Association Journal, Vol. 59, (March, 1967), 746-749.

Spencer, Marguerite E., et al., "Effects of Rope Skipping and Physical Education Classes on Physical Work Capacity of Sedentary College Women," American College of Sports Medicine and The Athletic Institute, 1968, 79-81.

D. UNPUBLISHED MATERIALS

- Bird, Patrick J., "Effects of a Program of Progressive Rope Skipping on the Energy Expenditure of One Middle Aged Man," Unpublished Master's thesis, University of Illinois, 1957.
- Cascino, Joseph A., "The Effects of a Program of Progressive Rope Skipping on the Cardiovascular Fitness of Adult Men," Unpublished Master's thesis, Temple University, 1964.
- Curtis, Delores M., "Rope Skipping and the Endurance, Leg Power, Agility and Coordination of Children," Unpublished Doctoral dissertation, University of Illinois, 1963.
- Di Orto, Louis P., "Effects of a Physical Training Program on Cardiovascular Respiratory Fitness of Young Boys," Unpublished Master's thesis, University of Illinois, 1955.
- Powell, John Talbot, "Effects of Rope Skipping on Pre-pubescent Boys," Unpublished Master's thesis, University of Illinois, 1957.
- Wilkstrom, Robert B., "Effects of Gymnastic Training on the Progressive Pulse Ratio Test of Boys," Unpublished Master's thesis, University of Illinois, 1954.
- Wright, James N., "The Effects of Gymnastic Training on the Heartograms of Young Boys," Unpublished Master's thesis, University of Illinois, 1954.

APPENDIX

APPENDIX 1

HEART RATES DURING SUBMAXIMAL TREADMILL RUN AND IN RECOVERY PERIOD ON PRE-TEST

Subject	Exercise (Minutes)				Recovery (Minutes)			
	1	2	3	4	1	2	3	4
1	160	165	170	170	94	103	102	109
2	170	175	173	173	121	110	114	110
3	152	155	160	167	105	108	105	103
4	84	145	160	167	85	84	100	81
5	150	163	167	170	110	105	109	110
6	140	150	155	148	89	82	82	87
7	160	167	170	160	117	101	99	103
8	150	155	160	170	122	122	108	100
9	160	165	160	167	85	77	95	95
10	144	160	170	173	122	105	98	95
11	170	170	165	173	135	129	120	121
12	125	128	135	130	59	65	59	66
13	145	149	152	155	97	91	95	96

APPENDIX II

HEART RATES DURING SUBMAXIMAL TREADMILL RUN

AND IN RECOVERY PERIOD ON POST-TEST

Subject	Exercise (Minutes)				Exercise (Minutes)			
	1	2	3	4	1	2	3	4
1	160	165	167	165	---	---	---	109
2	170	175	175	173	121	110	114	110
3	160	172	174	173	130	118	117	118
4	150	180	175	160	100	95	87	95
5	150	160	165	170	119	96	110	108
6	160	170	175	173	110	108	108	108
7	160	175	170	170	129	115	109	107
8	170	160	160	158	166	148	140	125
9	150	153	150	149	86	92	98	100
10	155	170	175	182	130	110	108	109
11	165	160	165	160	128	121	116	115
12	135	125	124	126	94	59	78	72
13	150	160	169	170	132	111	111	110

APPENDIX III

RECOVERY HEART RATES AFTER THE MODIFIED

JOHNSON TREADMILL RUN ON PRE-TEST

Subject	Running Time (Sec.)	I	II	III
		1:00-1:30	2:00-2:30	3:00-3:30
1	300	75	66	60
2	300	77	66	62
3	300	64	57	51
4	300	61	54	41
5	300	68	63	59
6	300	65	58	56
7	195	74	68	58
8	255	79	68	67
9	300	51	48	48
10	215	88	67	60
11	210	82	73	64
12	300	53	46	41
13	300	77	67	59

APPENDIX IV

RECOVERY HEART RATES AFTER THE MODIFIED JOHNSON TREADMILL RUN ON POST-TEST

Subject	Running Time (Sec.)	I 1:00-1:30	II 2:00-2:30	III 3:00-3:30
1	300	72	64	58
2	300	81	70	66
3	300	63	57	50
4	300	62	53	39
5	300	67	53	50
6	300	63	55	46
7	195	68	60	55
8	300	75	63	56
9	300	51	43	40
10	185	74	63	57
11	300	76	71	61
12	300	48	39	37
13	300	72	62	57

VITA

The writer was born in the City of Nagoya, Japan, on September 13, 1935. He entered Aichi University of Education in April, 1955. He pursued a course of study with a major in Geology. While at Aichi University of Education, he participated in track and cross country, earning the varsity letters. In March, 1959 he was graduated with a Bachelor of Education degree.

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