1971

# A Comparison of Circulorespiratory Responses to Weight-Supported and Non Weight-Supported Exercises in Moderately Obese Subjects

Charles G. Brown
*Eastern Illinois University*

PAPER CERTIFICATE

TO: Graduate Degree Candidates who have written formal theses.

SUBJECT: Permission to reproduce theses.

The University Library is receiving a number of requests from other institutions asking permission to reproduce dissertations for inclusion in their library holdings. Although no copyright laws are involved, we feel that professional courtesy demands that permission be obtained from the author before we allow theses to be copied.

Please sign one of the following statements.

Booth Library of Eastern Illinois University has my permission to lend my thesis to a reputable college or university for the purpose of copying it for inclusion in that institution's library or research holdings.

May 25 1971
Date

_______________
Author

I respectfully request Booth Library of Eastern Illinois University not allow my thesis be reproduced because _______________

_______________

_______________

_______________
Date

_______________
Author

A COMPARISON OF CIRCULORESPIRATORY RESPONSES TO WEIGHT-SUPPORTED AND NON WEIGHT-SUPPORTED EXERCISES IN MODERATELY OBESE SUBJECTS

(TITLE)

BY

CHARLES G. BROWN

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

1971
YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING THIS PART OF THE GRADUATE DEGREE CITED ABOVE

May 25, 1971
DATE

ADVISER

May 25, 1971
DATE

DEPARTMENT HEAD

## ACKNOWLEDGEMENTS

To his thesis advisor, Dr. M. Thomas Woodall, the writer wishes to express his most sincere appreciation for valuable instruction and assistance in the completion of the paper.

The writer also expresses his sincere appreciation to Dr. Robert A. Carey and Dr. Walter E. Lowell for their constructive criticism and guidance in the preparation of the paper.

To his wife, Andrea, the writer is indebted for typing and proof reading of the many draft copies that were required in the final preparation of the thesis.

The writer is indebted to the graduate students, who gave their time and assistance with the experimental laboratory procedure, and to Miss Judy Westendorf for her help in the final preparation of the paper.

TABLE OF CONTENTS

Page

## LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The average layman believes that being in "good shape" implies the ability to climb a flight of stairs without breathing hard, or the ability to play nine holes of golf without stopping to rest for a few minutes. Technically, the term "fitness" indicates a relationship between the capability of the individual to perform all the tasks of a normal day plus any emergency which may occur during the day.[1]

For many years researchers have spent a considerable amount of time searching for a single test that would best measure physical fitness. As early as 1884, an Italian physiologist by the name of Mosso, invented the ergograph and helped establish the relationship between physical condition and muscular activity. Mosso's hypothesis was that the ability of a muscle to perform was dependent upon the efficiency of the circulatory system.[2] Following Mosso's work, a number of experimenters have

---

[1] Laurence E. Morehouse and Augustus T. Miller, Physiology of Exercise (Saint Louis: The C. V. Mosby Company, 1967), p. 263.

[2] Donald L. Mathews, Measurement in Physical Education (Philadelphia: W. B. Saunders Company, 1968), p. 199.

worked to show certain cardiovascular factors to be related to good physical condition.

Basically, there have been two main approaches to ascertain physical performance: (1) physical fitness tests which involve actual performance scoring of an activity or motor skill, and (2) studies of cardiovascular function at rest and/or during exercise.

The so-called fitness tests, including evaluation of flexibility, skill, strength, etc. are not considered suitable for an analysis of basic physiological functions. The tests are often related to special gymnastic or athletic performance. Results of the test may be greatly influenced through practice and training in the performance. This point can be illustrated by examination of the Kraus-Weber Test, American girls and boys were definitely inferior to European children.[3] However, the European children had a distinct advantage because the activities included in the test were typical and in common use in European physical education classes. The American children might have been superior to the European children, had testing procedure included activities popular in the United States.

Per-Olof Astrand stated that from a pedogogic and psychological viewpoint, widespread use of such test

---

[3]Hans Kraus and Ruth Hirschland, "Minimum Muscular Fitness Tests in School Children," Research Quarterly, XXV (May, 1954) pp. 178-188.

batteries in physical education can be justified. But from a physiological and medical viewpoint, any test battery for the evaluation of physical fitness is rather meaningless unless it is based on sound physiological considerations.[4]

Studies of a cardiovascular nature give a better representation of physiological fitness. In different terms, this means the ability of the circulatory and respiratory system to adjust to and recover from the effects of exercise or work. Cardiovascular and respiratory functions are unquestionably two of the key components of physical fitness. To some physical educators, these functions are the single most indicative measures of a person's physical condition.[5]

## I. IMPORTANCE OF THE STUDY

The most accurate measure of cardiovascular fitness is considered to be maximal oxygen uptake, which measures the amount of oxygen consumed per kilogram of body weight per minute of exercise. In order to measure maximal oxygen uptake, large muscle groups of the body must be actively engaged, which will load the respiratory and circulatory functions to a maximum.

---

[4] Per-Olof Astrand and Kaare Rodahl, Textbook of Work Physiology (New York: McGraw-Hill Book Company, 1970), p. 344.

[5] Barry L. Johnson and Jack K. Nelson, Practical Measurements for Evaluation in Physical Education (Minneapolis, Minn: Burgess Publishing Company, 1969), p. 298.

In laboratory experiments three methods of producing standard work loads have been generally applied: (1) working on a bicycle ergometer, (2) running on a treadmill, and (3) using a step test. The great capacity for work and the high degree of accuracy reproduced in the more exacting bicycle ergometer and treadmill tests, makes their use in this study preferable to that of the step test. The testing procedure varies, however, from one laboratory to another, and the question still remains, whether the three procedures give similar results.

## II. DESCRIPTION OF BICYCLE ERGOMETER AND TREADMILL TESTS

The bicycle ergometer and the treadmill are very similar in that they are capable of producing the necessary load for accurate cardiovascular testing. However, the structure and mechanics of the two tests are very different.

When riding on the bicycle ergometer in the sitting position, the subject mounts the ergometer by sitting on the seat provided him. This position should be almost vertical over the pedals. The seat should be high enough so that the leg is almost completely stretched when the pedal is in its lowest position. The subject's hands are gripped to the handle bars, rendering the arms free of exercise. In this position the subject is actually sitting on the bicycle ergometer and hence the name weight-supported exercise.

In contrast, when running on the treadmill, the subject's body assumes a different position. He actually supports all of his body weight while running on his legs. His arms are also exercised by the pumping motion coordinated with his legs. For these reasons we can see that the treadmill is a non weight-supported exercise. It is the weight-supported exercise verses the non weight-supported exercise that is the concern of this paper.

## III. STATEMENT OF THE PROBLEM

In this investigation, the primary problem was to compare certain cardiovascular parameters during sub maximal and maximal weight-supported and non weight-supported tests on moderately obese subjects.

## IV. LIMITATIONS OF THE STUDY

The study was limited to fourteen moderately obese male college students. Oxygen uptake, pulmonary ventilation, heart rates, body weight, and thigh girth were the only parameters considered in this study.

## V. DEFINITION OF TERMS

Aerobic: Aerobic is the metabolic process that supplies the energy needed for muscle contraction which takes place in the presence of oxygen.

Cardiovascular Measurements: Cardiovascular measurements are those tests which measure the physiological characteristics necessary for the healthy or normal function of an organism. In this study, pulmonary ventilation, oxygen uptake, and heart rates were the cardiovascular measurements considered.

Electrocardiograph: The electrocardiograph is an instrument for recording the electrical potential produced by the heart muscle. In this study, the ECG was used to obtain heart rates during exercise.

Maximal Oxygen Uptake: Maximal oxygen uptake is the amount of oxygen which a person consumes when oxygen intake per unit of time has attained its maximum and remains constant....circulatory and respiratory systems being the limiting factors.

Moderately Obese: The subjects for this particular study have been termed as moderately obese, based on a range of body fat from about 15 per cent to 25 per cent. The mean of fourteen subjects was 20.6% body fat.

Non Weight-Supported Exercise: The non weight-supported exercise requires the subject to support his own body weight on his legs while exercising. In this study, the subjects exercised carrying their own body weight by running on a treadmill.

Physical Work Capacity: The physical work capacity (PWC) may be defined as the maximum level of metabolism (work) of which an individual is capable. Physical work capacity is measured objectively by heart rates as the result of exercise. ($PWC_{150}$) is used in this study when the heart rate raises to 150 beats per minute during a submaximal exercise load. ($PWC_{max}$) is used in this study when the heart rate raises to the maximum during a maximal exercise load.

Pulmonary Ventilation: Pulmonary ventilation refers to the periodic renewal of the air in the lung alveoli and is the amount of air expired per unit of time.

Steady State: The steady state is 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.

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

Weight-Supported Exercise: The weight-supported exercise is one in which the subject does not carry his own weight while exercising. For this study, the apparatus used to carry the body weight of the subject while he exercised was the bicycle ergometer.

# VI. SUMMARY

The study compared oxygen consumption, pulmonary ventilation, and heart rates during exercise and in recovery from a submaximal and maximal weight-supported and non weight-supported exercise.

## CHAPTER II

## REVIEW OF THE LITERATURE

The literature reveals studies that compare cardiovascular values obtained during a bicycle ergometer test and a treadmill test. Some authors have directed their study toward a comparison of cycling with the legs to running uphill, while other investigators compared cycling to cranking with arms on the bicycle ergometer. For this reason the literature was studied in three parts: (1) bicycle ergometer test versus treadmill test; (2) bicycle ergometer cycling versus cranking; and (3) bicycle ergometer cycling versus treadmill uphill. Some studies placed in one category could be placed in another category because of the versatility of the study.

### I. BICYCLE ERGOMETER TEST VERSUS TREADMILL TEST

The human adaptability project of the International Biological Programme has a specific proposal to standardize methods of predicting the aerobic work capacity.[1] There

---

[1] J. Weiner, "International Biological Programme: Guide to the Human Adaptability Proposals," I. C. S. U. Special Committee for the International Biological Programme, 1965.

has been a further proposal that ergometry should be restricted to certain well defined types of crank and pedal operated bicycle ergometers.[2] Since these proposals, there has been surprisingly little data on which to decide between, the treadmill or the bicycle ergometer, as the best method for the assessment of cardiovascular fitness. Astrand[3] stated: "The critical question is whether or not the different types of work mentioned above give the same maximal oxygen uptake."

Astrand and Saltin[4] compared maximal work of various types, all of which engaged large muscle groups. The investigators found little difference between the maximal oxygen uptake obtained during bicycling with the legs only (mean of 4.23 liters per minute) or with arm and legs simultaneously (mean of 4.24 liters per minute) or when skiing (mean of 4.48). However, when comparing running on a treadmill, inclination of 7.9%, a mean of 4.69 liters per minute was obtained as compared to a mean of 4.47 liters per minute using the legs in a sitting position

---

[2] H. Mellerowicz, Chairman of Symposium on the Standardization of Ergometry. 16th World Congress of Sports Medicine, Hanover, 1960.

[3] P. O. Astrand and K. Rodahl, Textbook of Work Physiology (New York: McGraw-Hill Book Company, 1970), p. 344.

[4] Per-Olof Astrand and Bengt Saltin, "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity", Journal of Applied Physiology, XVI (November, 1961), pp. 977-981.

and a mean of 3.85 liters per minute in a supine position on the bicycle ergometer. They concluded that running uphill revealed about 5 per cent higher maximal oxygen uptake than other types of large muscle exercises, at least in well-trained subjects.

A study to compare metabolic response to exercise on the bicycle ergometer, the treadmill, and the stool step was reported by Paul.[5] The author used ten college students who were analyzed as two separate groups using an analysis of variance and a factorial design to determine the manner in which the subjects responded to exercise on the different machines. The results showed a significant interaction effect on the treadmill, but a non significant interaction effect on the bicycle ergometer or the stool step.

Wyndham, et. al,[6] measured the maximum oxygen intakes of 40 active young men during a bicycle ergometer test, a step test and during an intermittent and a continuous treadmill test. The speed at which subjects ran during the continuous treadmill exercise began at 4.5 miles per

---

[5] Tom LesPaul, "A Comparison of the Energy Cost of Exercises on the Bicycle Ergometer, the Treadmill, and the Stool Step" (unpublished Doctor's dissertation, Florida State University, Tallahassee, 1965).

[6] C. H. Wyndhan, N. B. Strydom, W. P. Leary, and C. G. Williams, "Studies of the Maximum Capacity of Men for Physical Effort", <u>Internationale Zeitschrift Fuer Angewandte Physiologie Einschliesslich Arbeitsphysiologie</u>, XXII (March, 1966) pp. 285-295.

hour and increased by .5 miles per hour every two minutes. The run continued until the subject under observation was compelled to stop because of fatigue. With the grade of the treadmill at less than one per cent, a mean of the oxygen uptake was found to be 3.08 liters per minute. The work position on the bicycle ergometer was different than regular ergometer cycling. The subject sat in a chair behind the cycle ergometer with his legs almost horizontal. The position is very similar to cycling in the supine position, which is less efficient for loading the oxygen transport system. A mean oxygen uptake in this position yielded 2.84 liters per minute. The results indicate that maximum oxygen intakes obtained during the treadmill test at the higher maximum oxygen values, but they are closely similar at low levels of exercise.

## II. BICYCLE ERGOMETER CYCLING VERSUS CRANKING

Astrand, et. al.[7] reported the mechanical efficiency of obese individuals during work on a bicycle ergometer. A group of eight obese women and four obese men were examined for oxygen intake when working with submaximal loads on a bicycle ergometer. With the work load at 300 kpm/min the

---

[7] I. Astrand, P. O. Astrand and A. Stunkard, "Oxygen Intake of Obese Individuals During Work on a Bicycle Ergometer", <u>Acta Physiologica Scandinavica</u>, L (March, 1960), pp. 294-299.

average for the obese women was 1.05 liters per minute. The obese men had a higher oxygen uptake than the control group of 25 non-obese men, mean of 1.08 liters per minute and 0.96 liters per minute, respectively.

Sitting and supine work performed on the bicycle ergometer was investigated by Stenberg, et. al.[8] Submaximal and maximal work was performed on the bicycle ergometer with arms, with legs, and with arms and legs, in sitting and supine position, respectively. During maximal exercise with the arms plus legs in the sitting position, the mean oxygen uptake was 3.95 liters per minute. The value exceeds the value found for cycling the ergometer with the legs in the sitting position (mean of 3.87 liters per minute). A relatively low oxygen intake was measured for leg cycling in the supine position (mean of 3.42 liter per minute). At a given ~~sub-maximal~~ oxygen consumption heart rates and pulmonary ventilation were the same in leg exercise as in combined work, but the values were significantly higher during arm work.

---

[8] J. Stenberg, P. O. Astrand, B. Ekblom, J. Royce, and B. Saltin, "Hemodynamic Response to Work with Different Muscle Groups, Sitting and Supine", Journal of Applied Physiology, XXII (January, 1967), pp. 61-70.

## III. BICYCLE ERGOMETER CYCLING VERSUS TREADMILL UPHILL

Astrand[9] was unsuccessful in demonstrating any significant difference in maximal oxygen uptake comparing running on a treadmill (inclination 1° = 1.75%) and bicycling on an ergometer. Thirty-three female subjects were reported to have a mean value of 2.89 liters per minute on the treadmill as compared to a 2.76 liters per minute on the bicycle ergometer. A mean of 4.04 liters per minute on the treadmill for 34 male subjects were compared to a mean of 4.03 liters per minute on the bicycle ergometer.

Three direct tests of maximal oxygen uptake and one indirect test was given to 24 male subjects by Glassford, et. al.[10] One direct test was given to subjects on the treadmill and followed the procedures of Taylor, Buskirk and Henschel.[11] The procedures consisted of a 10 minute warmup at 3.5 mph and 10 per cent grade followed by an all out run at 7 mph with the grade being determined by previous

---

[9] Per-Olof Astrand, Experimental Studies of Physical Working Capacity in Relation to Sex and Age (Copenhagen: Munksgard, 1952).

[10] R. G. Glassford, G. H. Y. Boycraft, A. W. Sedgwick, and R. B. J. Macnab, "Comparison of Maximal Oxygen Uptake Values Determined by Predicted and Actual Methods", Journal of Applied Physiology, XX (May, 1965), pp. 509-513.

[11] H. L. Taylor, E. Buskirk, and A. Henschel, "Maximal Oxygen Intake as an Objective Measure of the Cardio-respiratory Performance", Journal of Applied Physiology, VIII (January, 1955), pp. 73-80.

fitness tests. On the following day the procedure was repeated with the subject running at a grade 2.5 per cent higher. The mean oxygen uptake was 3.758 liters per minute. Another direct test was given on the treadmill but followed the procedures of Mitchell, Sproule and Chapman.[12] This procedure varies in that it can be administered on one testing day. After a 10 minute warmup at 3 mph and a 10 per cent grade, the subject began running at 6 mph at no grade for a period of 2 minutes and 30 seconds at which time expired air was collected. After a 10 minute rest, the grade was increased to 2.5 per cent and this procedure was continued until the oxygen consumption, on two consecutive runs, leveled off or declined. The mean oxygen consumption for 24 subjects was 3.752 liters per minute. A third direct test employing the procedures of Astrand[13] was given on a Monark bicycle ergometer. The pedalling frequency was 50 times per minute and the work load began at 600 kpm for six minutes but increased to 900 kpm, 1,200 kpm, 1,500 kpm, 1,800 kpm after five minute rest periods, respectively. A mean of 3.48 liters per

---

[12] J. H. Mitchell, B. J. Sproule and C. B. Chapman, "The Physiological Meaning of the Maximal Oxygen Intake Test", Journal of Applied Physiology, XXXVII (August, 1958), pp. 538-576.

[13] P. O. Astrand and K. Rodahl, "Maximal Heart Rate During Work in Older Men", Journal of Applied Physiology, XIV (July, 1959), pp. 562-566.

minute was obtained during this exercise. Using the Astrand-Ryhming[14] nomogram, a mean oxygen uptake of 3.71 liters per minute was obtained during an indirect bicycle ergometer test. The maximal oxygen uptake was estimated from the heart rate response to submaximal work.

Correlation coefficients between the various oxygen uptake tests as well as a fitness test were all found to be significant +.62 to +.83. It was concluded that direct treadmill tests, employing greater muscle mass, yield higher maximal oxygen uptake values (8 per cent) than does the direct bicycle ergometer test.

Chase, et. al.[15] found a 15 per cent difference in maximal oxygen uptake during a treadmill exercise and a bicycle ergometer exercise in favor of the treadmill. Eighteen young men were used in the experiments. The procedures used in the treadmill exercise were those employed by Taylor, et. al.[16] The mean value for oxygen uptake was found to be 3.86 liters per minute. Maximal oxygen consumption was determined on a bicycle ergometer using a

---

[14] P. O. Astrand and I. Ryhming, "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate During Submaximal Work", Journal of Applied Physiology, VII (February, 1954), pp. 218-221.

[15] G. A. Chase, C. Grove, and L. B. Rowell, "Independence of Changes in Functional and Performance Capacities Attending Prolonged Bed Rest," Aerospace Medicine, XXXVII (December, 1966), pp. 1232-1238.

[16] Taylor, loc. cit.

modification of the method of Luft, et. al.[17] The work load on the bicycle ergometer was set at 300 kgm per minute (50-60 rpm) for three minutes warmup, then the load was increased 85 to 100 kgm per minute until the subject could no longer pedal at the required rate. The mean oxygen uptake was 3.28 liters per minute.

Hermansen and Saltin[18] used 55 male subjects, 19 to 69 years of age, to perform maximal exercise on the treadmill running uphill (grade of 3° = 5.25 per cent) and on the bicycle ergometer with a pedal frequency of 50 revolutions per minute. The procedure suggested by Astrand and Saltin[19] was used for the bicycle exercise. For the treadmill a modified procedure originally described by Taylor et. al.[20] was used. After predicting maximal oxygen uptake from heart rate and submaximal work load on the

---

[17] U. C. Luft, D. Cardus, T. Lim, E. C. Anderson and J. L. Howarth, "Physical Performance in Relation to Body Size and Composition", "Annals New York Academy of Sciences, 110 (April, 1963), pp. 795-808.

[18] Lars Hermansen and Bengt Saltin, "Oxygen Uptake During Maximal Treadmill and Bicycle Exercise", Journal of Applied Physiology, XXVI (January, 1969), p. 31-37.

[19] P. O. Astrand and B. Saltin, "Oxygen Uptake During the First Minutes of Heavy Muscular Exercise", Journal of Applied Physiology, XVI (November, 1961), pp. 971-976.

[20] Taylor, loc. cit.

bicycle ergometer according to Astrand,[21] the first work load was just high enough to reach the maximal oxygen uptake. The work load for the second maximal test was increased by 200 kpm/min and 2 km/hr for the bicycle and treadmill, respectively. The mean oxygen consumption on the treadmill was 4.16 liters per minute as compared to 3.90 liters per minute for the bicycle ergometer. This represents a 7 per cent difference ($P<0.001$). Forty-seven of the subjects had higher values on the treadmill. No significant differences were observed in maximal values for the work time, pulmonary ventilation and heart rate. In 6 subjects maximal running uphill (3°) gave a mean of 4.68 liters per minute as compared to a mean of 4.48 liters per minute when running maximally at no inclination. The same subjects could move only 4.34 liters per minute of oxygen on the bicycle ergometer. At pedal frequencies of 60 or 70 rpm during the maximal bicycle exercise 0.10 liters per minute higher oxygen uptake was found compared to pedal frequencies of 50 or 80 rpm.

---

[21] I. Astrand, "Aerobic Work Capacity in Men and Women with Special Reference to Age", Acta Physiologica Scandinavica, II (March, 1960), p. 15.

## IV. SUMMARY

A test of maximal oxygen uptake should load the respiratory and circulatory functions to a maximal extent. In order to accomplish this, large muscle groups must be actively engaged. The work load should be measurable and reproducible. For these reasons the bicycle and treadmill exercises have been the two most used laboratory tests for determining the aerobic power of man. The testing procedure varies, however, from one laboratory to another, and the question still remains, whether the two procedures give similar results.

The investigators have been unable to demonstrate any significant difference in maximal oxygen uptake, comparing running on a treadmill with an inclination of one degree and bicycling on an ergometer. An average difference of .13 liters per minute was shown in four studies.

It appears that a higher maximal oxygen uptake is obtained when running on the treadmill with an inclination equal to or greater than three degrees. A significant difference of .31 liters per minute was the average oxygen uptake in 113 subjects and six different studies.

Bicycle ergometer exercise, on the average, produces a lower oxygen uptake, at least compared to running uphill. In studies in which objective criteria have been used to determine whether or not the maximal oxygen uptake had been reached in bicycle ergometer or treadmill work, the values for running are on an average five to eight per cent higher than for bicycling.

In the studies which compared cranking to cycling on the bicycle ergometer, an oxygen uptake was found to be slightly higher for cycling in the sitting position. A greater value was found for arms plus legs, 3.95 liters per minute as compared to cycling with the legs, 3.87 liters per minute.

# CHAPTER III

# PROCEDURE

## I. SUBJECTS

Four students from Eastern Illinois University in Charleston, Illinois, and ten students from Lake Land Junior College in Mattoon, Illinois, took part in the investigation. The subjects were first chosen on the basis of their moderately obese appearance and then voluntarily elected to participate in the study. The subjects were male, college students and non-athletes ranging in age from 18.2 to 28.3 years, with a mean of 20.5 years. The mean of their heights was 178.79 centimeters, and the mean of their body weights was 106.82 kilograms.

The majority of the subjects were exposed to bicycle riding in their elementary years, riding on a regular basis until the ages of fifteen or sixteen. At this time the primary mode of transportation became the automobile, and bicycle riding became a forgotten activity. All subjects have been exposed to running during their required physical education programs in the schools. However, many subjects were exposed to a greater degree through intramural and athletic programs. No subject had previous experience running on a treadmill.

## II. ANTHROPOMETRIC MEASUREMENTS

All Anthropometric Measurements were performed in the Physical Education Research Laboratory at Eastern Illinois University. Four measurements were taken to describe the physical characteristics of the subjects. These measurements included: (1) body height, (2) body weight, (3) thigh girth measurements and (4) skinfold measurements. The anthropometric measurements of each subject are shown in Appendix B.

### Body Height

Each subject, wearing only an athletic supporter, stood as tall as possible with his back against a strip of tape pasted on a door and marked off in centimeters and inches. His heels, hips, shoulders and head were touching the backboard. The Frankfort plane, a line from the outer, lower corner of the eye socket to the little prominence at the front of the lower ear lobe, was horizontal. A masonite board was placed firmly on top of the subject's head, parallel to the floor. The height was recorded in centimeters at the point where the masonite board crossed the measuring tape.

### Body Weight

Each subject, wearing only an athletic supporter, was weighed to the nearest pound while standing in a steady position in the center of the platform of a caliberated Healthometer Scale. The reading was converted to kilograms by dividing by 2.2.

Girth Measurement

The procedures of Scott and French were employed to measure thigh girth.[1] Girth measurements were obtained from the right and the left thigh, using a two meter Lufkin anthropometric tape with a spring tension cylinder. Each subject stood with his feet about four to six inches apart and his thigh in a relaxed state. The tape was placed horizontally around the thigh in the gluteal fold, which is the angle made by the curve of the gluteus maximus with the near vertical line of the thigh. The thigh girth was recorded to the nearest centimeter.

Skinfold Measurements

Skinfold measurements were made at three different locations to indirectly determine the specific gravity and per cent of body fat. The three locations included: (1) the abdomen, (2) the chest, and (3) the arm. All measurements were taken on the right side of the body, with the use of a Lange Skinfold Caliper and were recorded to the nearest

[1]M. Gladys Scott and Esther French, Measurement and Evaluation in Physical Education (Dubuque, Iowa: Wm. C. Brown Company, Publishers, 1959, p. 251.

millimeter. The procedures used were described by Consolazio, et. al.[2]

Abdomen. For the abdominal skinfold measurement each subject stood erect with arms at his sides, and his upper body free of clothing. A vertical skin fold measurement was taken adjacent to the umbilicus.

Chest. Each subject s ood in an upright position, his arms at his sides and his upper body muscles relaxed. The reading was taken at the midpoint between the anterior crease of the axilla and the nipple.

Arm. The upper arm measurement, with the forearm in 90 degree flexion and the humerus hanging straight in an extended position, was taken at the midposterior midpoint between the tip of the acromion process of the scapula and the tip of the olecranon process of the ulna.

A total of six different skinfold thicknesses were recorded at the abdomen, the chest, and the arm, for reliability verification. The thickest skinfold measurement was eliminated and the remaining five measurements were averaged. Applied next, were the formulas by Brozek and Keys.[3] First,

---

[2]Frank Consolazio, Robert Johnson, and Louis Pecora, Physiologic Measurements and Metabolic Functions in Man (New York: McGraw-Hill Book Company, 1963), pp. 300-308.

[3]J. Brozek and A. Keys, "Body Fat in Adult Man", Physiological Review XXXIII (1953), p. 245.

the skinfold measurements were applied to the multiple regression equation for the estimation of specific gravity in men aged 18 to 26. The equation is:

$$S. G. = 1.017 - 0.000282A - 0.000736B - 0.000883C$$

The per cent body fat was computed from the formula:

$$\% \text{ body fat} = \left(\frac{4.201}{\text{sp. gr.}} - 3.813\right)$$

### III. BICYCLE ERGOMETER AND TREADMILL TESTS

A weight-supported test using a Monark Friction Bicycle Ergometer (B. E.) and a non weight-supported test employing an A. R. Young Treadmill (TM) was administered in the Physical Education Research Laboratory at Eastern Illinois University. Each subject appeared twice for testing during a nine day period in the afternoon hours. The laboratory schedule was arranged so that the tests were not given to a subject on consecutive days. Seven subjects took BE prior to TM while the other seven took TM before BE. (This prosedure was employed to eliminate training or learning effect.) Written and oral instructions were given to each subject prior to testing. (See Appendix A for written instructions.)

#### Bicycle Ergometer Tests

The height of the bicycle seat was adjusted to each individual so that there was a slight bending of the knee when the foot was placed on the pedal in its lowest position.

Each subject performed a submaximal ($PWC_{150}$) and a maximal ($PWC_{max}$) bicycle ergometer exercise. The term $PWC_{150}$ refers to the heart rate rising to 150 beats per minute for physical work capacity, and $PWC_{max}$ is the maximal heart rate obtained for physical work capacity.

$PWC_{150}$ Ride. The test consisted of a work load set at 300 kpm/min for the first two minutes, 600 kpm/min from two to four minutes and 900 kpm/min from four to six minutes. A metronome was set at 50 beats per minute and the subject pedaled at 20 kilopounds per hour to insure consistant work load. After the heart rate reached 150 beats per minute during submaximal exercise, the following cardiorespiratory responses were observed and recorded: (1) pulmonary ventilation, (2) oxygen consumption, and (3) the time during the ride that heart rates reached $PWC_{150}$. In addition to obtaining submaximal cardiorespiratory data, the tests also served as a warm up to the $PWC_{max}$ weight-supported exercise.

1. Pulmonary ventilation. During the $PWC_{150}$ B. E. Test, a 30 second sample of expired air was taken after the heart rate reached 150 beats per minute. Each subject, with nose clips firmly in position, inspired through a Collins "triple J" valve which was connected by a hose to a Model $CD_4$ Parkinson-Cowan Gas Meter. Barometric Pressure and Temperature of the expired air were

recorded so as to convert all respiratory data to Standard Temperature and Pressure-Dry (STPD).

2. Oxygen consumption. During the $PWC_{150}$ B. E. Test, the inspired air passed through the gas meter, mouth piece, subject and the expired air flowed through a plexiglass sampling chamber where a sample of the expired air was drawn from the chamber via a small vacuum pump to a Johnson Metalized Bag.[4] The bags of expired air were analyzed for oxygen and carbon dioxide content on a Beckman Model $E_2$ and Beckman Model $LB_1$ analyzer, respectively.

3. Heart rates. During exercise, as well as during the recovery period, a telemetry system was employed. With the subject in a supine position, the $V_5$ and $V_{5r}$ chest lead locations were prepared. Procedures used for the preparation were similar to those employed by Kobayashi.[5] After the skin was shaved, a small amount of electrode jelly was applied and rubbed with a tooth brush until the skin appeared red in color. The excess jelly was removed and a pea size drop of jelly was placed in the center of the snap on telectrodes which were secured by surgical

---

[4]Robert E. Johnson, Frances Robbins, et al, "A Versatile System for Measuring Oxygen Consumption in Man", Journal of Applied Physiology, XXII (February, 1967), pp. 377-379.

[5]Yoshio Kobayashi, "The Effects of Rope Jumping on Cardiorespiratory Fitness of High School Students" (unpublished Master's thesis, Eastern Illinois University, 1969).

tape. The electrocardiogram was sent from the transmitter to the subject, lying on a table near-by, to an HMG Model 100 receiving unit. The signal then went to a Sanborn Model 500 Viso Cardiette, where a graphic record of the QRS complex of each cycle was observed and counted as the heart rate of the subject. A physioscope also received the signal so that constant visual inspection could be observed.

A resting heart rate was taken while the subject was lying in a supine position. During the $PWC_{150}$ B. E. Test, a five second sample of the heart rate was taken periodically to determine when the rate had reached 150 beats per minute. During $PWC_{max}$ the maximum heart rate of the subject and B. E. ride were recorded. Five second recovery heart rates were recorded after $PWC_{150}$ B. E. and $PWC_{max}$ B. E. at the following times: :30, 1:00, 1:30, 2:00, 3:00, and 4:00 minutes.

<u>$PWC_{max}$ Ride</u>. The all out work test on the bicycle ergometer consisted of setting the metronome at 63 beats per minute then increasing the pedalling speed to 25 kilopounds per hour. The work load for the first two minutes was 300 kpm's and increased 300 kpm's every two minutes until the subject anticipated exhaustion within 30 seconds. Maximum pulmonary ventilation, oxygen uptake, and heart rate information were obtained as previously described in the $PWC_{150}$ Ride.

Treadmill Tests

A submaximal, ($PWC_{150}$) and maximal, ($PWC_{max}$) treadmill run were administered in that order at one testing period, and cardiorespiratory data was obtained on each subject.

$PWC_{150}$ Treadmill Run. The work for this test began with a walk, three miles per hour, and no grade for two minutes. The purpose of the walk was to prepare the inexperienced subject for treadmill exercise. The test was continued by increasing the speed to five miles per hour and no grade for the next two minutes and subsequently the grade was raised two per cent every minute. When the heart rate reached 150 beats per minute, pulmonary ventilation, and oxygen consumption data were obtained as described earlier. This test served as a warm-up for the $PWC_{max}$ Treadmill Run, as well as a tool for comparison for submaximal work loads.

$PWC_{max}$ Treadmill Run. Immediately following the submaximal treadmill run and a four minute recovery period, a maximal treadmill run began. The test required the subject to run at six miles per hour and no grade for the first minute, and at six miles per hour and four percent grade during the second minute. Each succeeding minute the grade was increased to 6, 8, and 10 per cent, respectively. When the subject anticipated fatigue within

30 seconds, he inserted the rubber mouth piece attached to the "triple J" valve, and pulmonary ventilation and oxygen consumption samples were collected as previously described. Maximum heart rates were also determined via telemetry at this time.

## IV. SUMMARY

Fourteen moderately obese male college students, who as a majority had previous experience in running and bicycle riding, took part in the investigation. Anthropometric measurements were taken first to find body height, weight, thigh girths and skinfold measurements. Pulmonary ventilation, oxygen consumption and heart rates were taken during a sub maximal and maximal weight-supported and non weight-supported exercise. Heart rates during a recovery period were taken following the previous exercise. The weight-supported test was taken on a bicycle ergometer, and the non weight-supported test was taken on a treadmill.

# CHAPTER IV

## ANALYSIS OF DATA

Fourteen moderately obese college students were studied in order to compare circulorespiratory responses to weight-supported and non weight-supported exercises. A submaximal and maximal test was given on a bicycle ergometer and on a treadmill. The parameters considered were: (1) pulmonary ventilation, (2) oxygen uptake and (3) heart rates during and in recovery from exercise. All raw data is presented in Appendices B through F.

### I. DATA CONVERSION

In order to analyze the data, in some instances, raw scores were converted to more meaningful units. The body height and weight scores were converted to centimeters and kilograms, respectively. By the use of these two variables the body surface, expressed in square meters, was computed from the nomogram presented by Consolazio, et al.[1]

Skinfold measurements were taken at the abdomen, chest and arm and recorded in millimeters. Indirectly, specific gravity and per cent body fat were derived from these measurements as described in Chapter III.

---

[1]Frank Consolazio, Robert Johnson, and Louis Pecora, Physiologic Measurements and Metabolic Functions in Man (New York: McGraw-Hill Book Company, 1963), p. 27.

The pulmonary ventilation ($\dot{V}_E$) and oxygen consumption ($\dot{V}_{O2}$) data from the bicycle ergometer (B. E.) and treadmill (T. M.) tests were corrected to Standard Temperature and Pressure Dry (S. T. P. D.) and expressed in liters per minute (L/min) and/or milliliters per kilogram per minute (ml/kg/min) via a program developed by Brown.[2] The program was run on an IBM 360 Model 2050H Computer at the Data Processing Center, Eastern Illinois University.

## II. STATISTICAL TREATMENT

Two types of statistical treatments were applied to the data collected in this study. The t Test was applied to find statistically significant differences between means. To determine what relationships, if any, existed between two variables, a correlation technique was employed. For this study, the .05 level of confidence was selected to denote statistical significance.

### t Test

After all the raw scores were punched on IBM computer cards, a t ratio program developed by DiPietro[3] was used to

---

[2] K. L. Brown, "A Calculation of Ventilation and Oxygen Consumption Program", (Charleston: Eastern Illinois University, February, 1971).

[3] A. J. DiPietro and R. J. LeBus, "Student T-Scores for Means (Cards) Between Groups", (Charleston: Eastern Illinois University, May, 1964).

determine statistically significant differences between means of various tests. The IBM 360 Model 2050H Computer was employed.

## Correlation Technique

In order to perform several supplementary analyses, with all raw scores for each subject on IBM computer cards, a correlation program developed by the Biomedical Computer Programs[4] was run through an IBM 360 Model 2050H Computer. This program calculated the mean, standard deviation and the degree of relationship between all variables.

# III. FINDINGS

## Pulmonary Ventilation

$\underline{PWC_{150}}$. Pulmonary ventilation during a submaximal B. W. and T. M. test was determined by a 30 second sample of ventilated air after the heart rate reached 150 beats per minute.

Figure 1 shows that for submaximal work, the mean pulmonary ventilation for weight-supported exercise was 62.46 liters per minute as compared to 74.39 liters per minute for non weight-supported exercise. For this study,

---

[4] W. J. Dixon (ed.), "Correlation with Item Deletion, BMD03D", Biomedical Computer Programs, (Berkeley: University of California Press, 1970), p. 160.

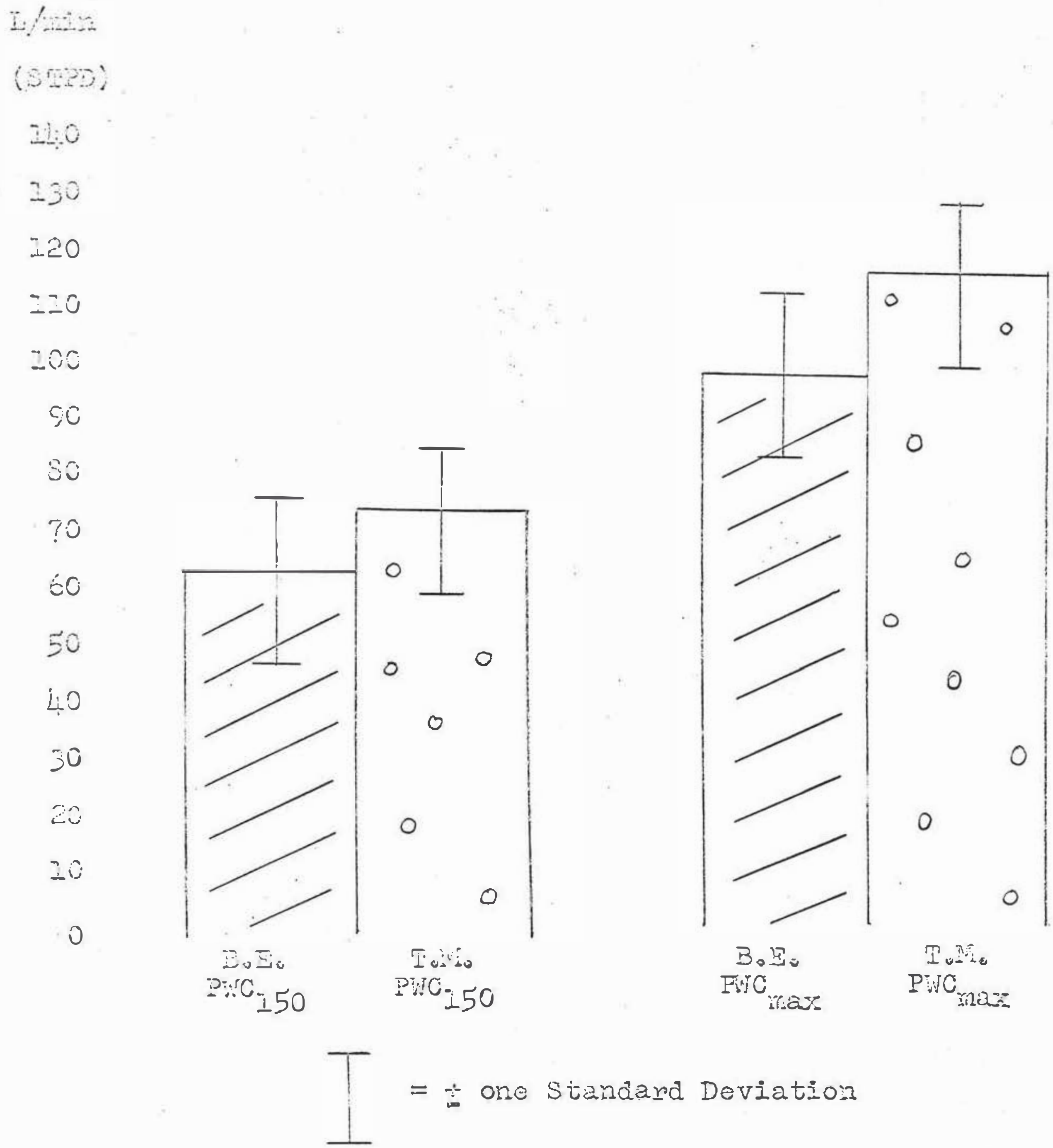


Figure 1

Pulmonary Ventilation in Submaximal ($PWC_{150}$) and Maximal ($PWC_{max}$) Ergometer (B. E.) and Treadmill (T. M.) Tests there was no statistically significant difference between the means.

$PWC_{max}$. Pulmonary ventilation was measured for 30 seconds during the last minute of the maximal B. E. and T. M. tests.

Figure 1 reveals pulmonary ventilation during the last minute of the maximal B. E. and T. M. tests. The mean pulmonary ventilation for weight-supported exercise was 99.72 liters per minute as compared to non weight-supported exercise having 114.00 liters per minute. The difference between the obtained means was found to be statistically significant at the .02 level of confidence.

Oxygen Uptake

$PWC_{150}$. For submaximal work, a metalized bag of expired air was collected during a 30 second period immediately after the heart rate reached 150 beats per minute. The expired gas was then analyzed.

All but one of the subjects had a higher oxygen uptake on the treadmill. Figure 2 shows the means of the oxygen uptake during weight-supported exercise to be 22.87 ml/kg/min (2.54 L/min) as compared to 28.33 ml/kg/min (3.14 L/min) during non weight-supported exercise. The difference between means was statistically significant at the .001 level of confidence.

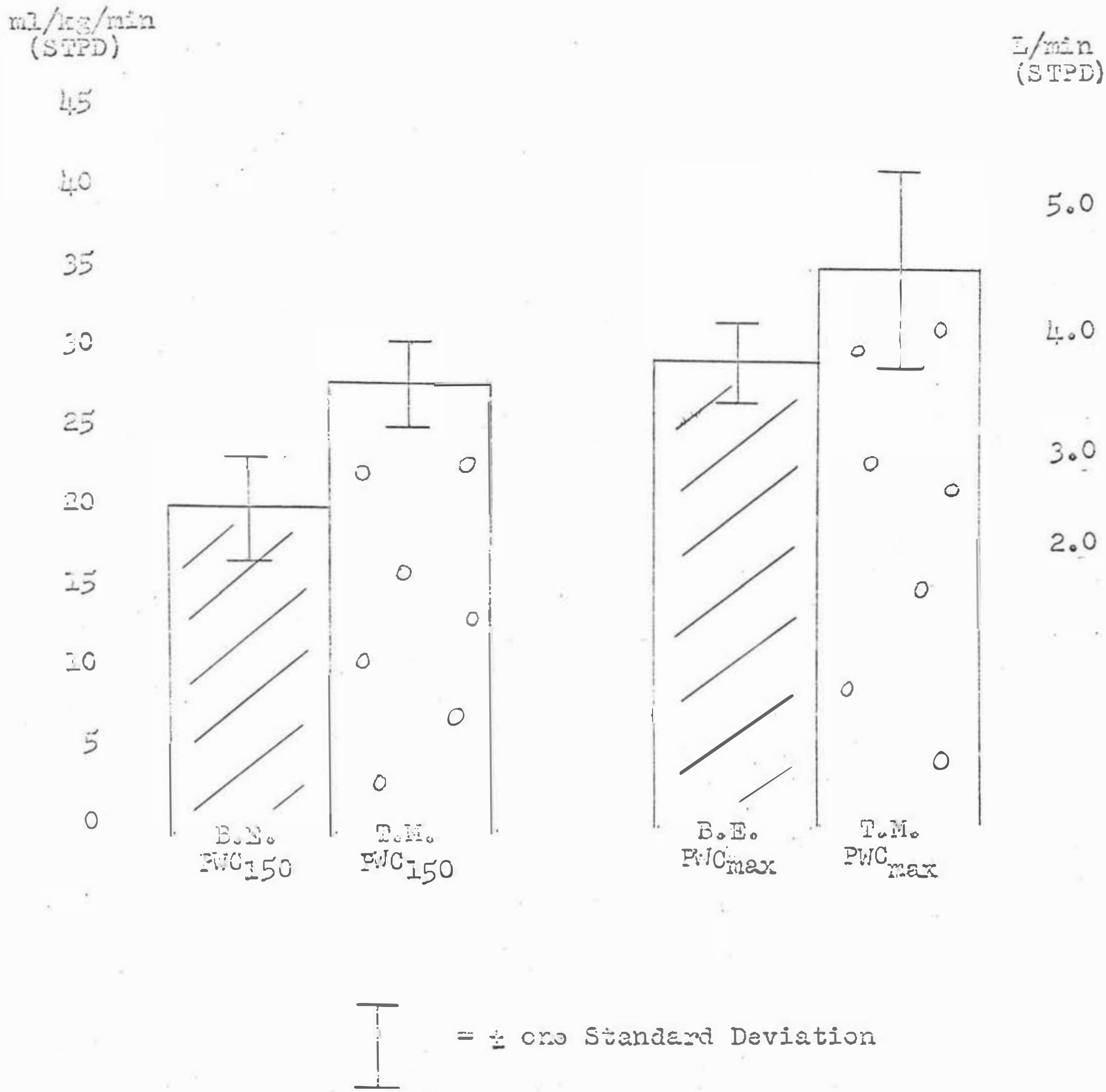


Figure 2

Oxygen Uptakes in Submaximal ($PWC_{150}$) and Maximal ($PWC_{max}$) Ergometer (B.E.) and Treadmill (T.M.) Tests

__$PWC_{max}$__. To find maximal oxygen uptake, a sample of expired air was collected and analyzed for a 30 second period during the last minute of the all out B. E. and T. M. tests.

Only one subject had a higher oxygen uptake on the bicycle ergometer than on the treadmill. Figure 2 shows a mean of 29.84 ml/kg/min (3.29 L/min) riding on the bicycle ergometer as compared to a mean of 36.89 ml/kg/min (4.08 L/min) running on the treadmill. The difference between the obtained means was found to be statistically significant at the .01 level of confidence.

## Heart Rates

__Submaximal exercise.__ The heart rates were recorded during a submaximal ($PWC_{150}$) weight-supported (bicycle ergometer) test and non weight-supported (treadmill) test.

The submaximal heart rates, both B. E. and T. M. were used to determine a specific point at which a submaximal pulmonary ventilation and oxygen consumption would be taken. Therefore, when heart rates reached 150 beats per minute, the respiratory measures were obtained. It took the average subject 6.3 minutes to reach the rate of 150 beats per minute on the B. E.. test, while this same rate was achieved after slightly more than 3 minutes on the T. M. test. Since it was not feasible to equate work loads on the B. E. and T. M. tests, there would be little value in analyzing the significance of the difference in the length of time required to achieve the $PWC_{150}$ on both tests.

Maximal exercise. The highest heart rate achieved on an all-out B. E. and T. M. test was noted for each subject. It took subjects nearly twice as long to achieve maximal heart rates on the B. E. test (4.3 minutes on T. M. test and 8.3 minutes on B. E. test). The mean maximal heart rate recorded on the B. E. test was 185 beats per minute, while it reached 194 beats per minute on the all-out T. M. run (see Figure 3). This difference was found to be statistically significant at the .02 level of confidence (see Table I).

Recovery from maximal exercise. Figure 3 depicts the recovery heart rates at :30, 1:00, 1:30, 2:00, 3:00, and 4:00 minutes following maximal efforts on the B. E. and T. M. tests. At all stages of recovery the T. M. heart rates were higher than the B. E. heart rates. However, none of the differences were statistically significant for this study (see Table I).

## Interrelationships

Many supplementary analyses between anthropometric measurements and circulorespiratory responses were interesting to note. Table II shows a higher relationship between pulmonary ventilation and anthropometric measurements

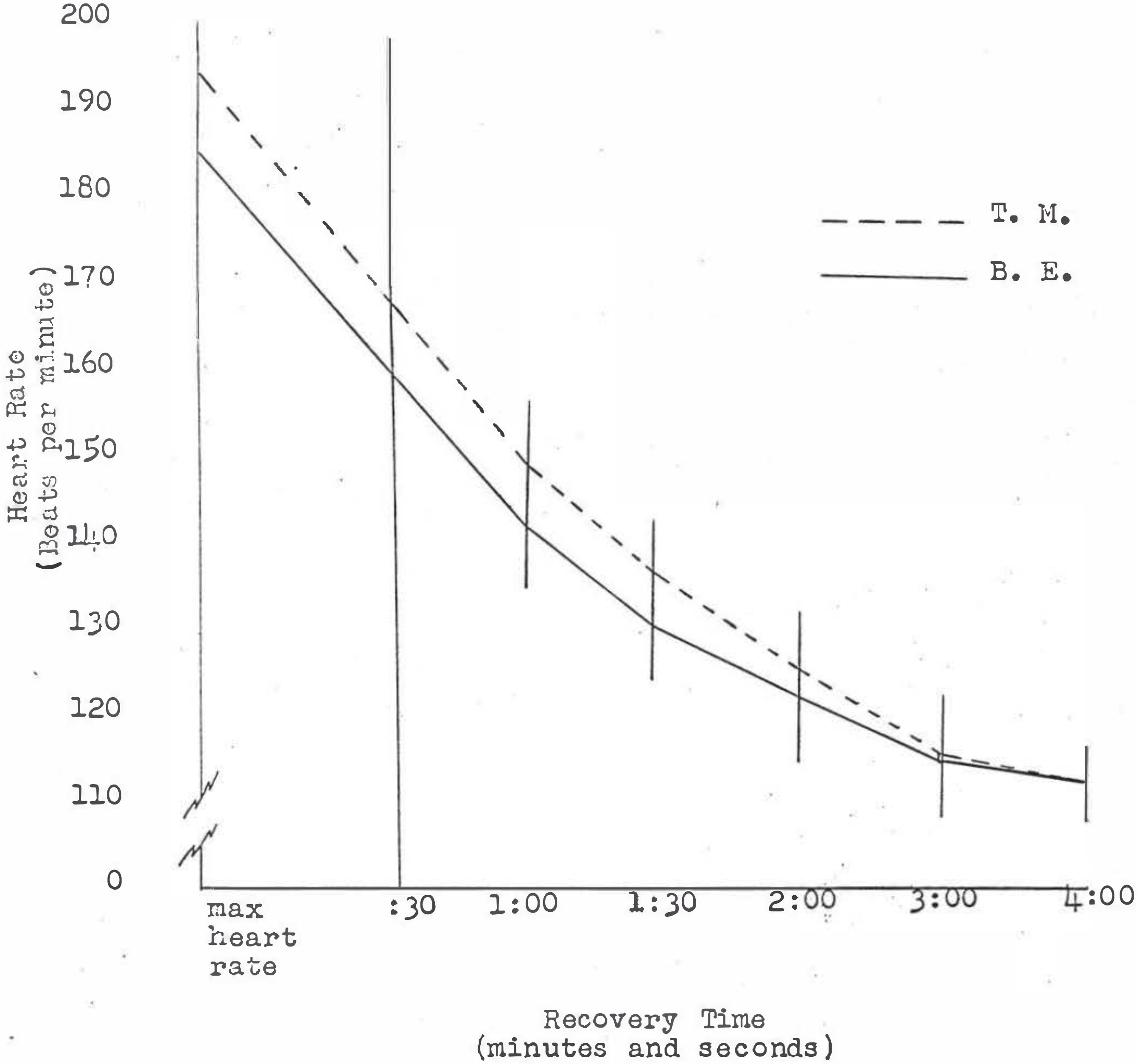


Figure 3

Maximum and Recovery Heart Rates
from All-Out ($PWC_{max}$)

TABLE I

SUMMARY OF FINDINGS
(*t* Tests)

| Parameters | B. E. Mean | B. E. S.D. | T. M. Mean | T. M. S.D. | *t* Ratio | Level of Conf. |
|---|---|---|---|---|---|---|
| $\dot{V}_E$ PWC$_{150}$ (L/min) | 62.45 | 16.15 | 74.39 | 12.03 | 2.137 | .10 |
| $\dot{V}_E$ PWC$_{max}$ (L/min) | 99.72 | 13.45 | 117.65 | 16.71 | 2.965 | .02* |
| $\dot{V}_{O_2}$ PWC$_{150}$ (ml/kg/min) | 22.87 | 3.40 | 28.33 | 2.97 | 4.359 | .001* |
| $\dot{V}_{O_2}$ PWC$_{max}$ (ml/kg/min) | 29.84 | 2.79 | 36.89 | 6.35 | 3.639 | .01* |
| H.R. PWC$_{max}$ (Beats/min) | 185 | 7.42 | 194 | 7.99 | 2.952 | .02* |
| Recovery from PWC$_{max}$ | | | | | | |
| Minutes and seconds | | | | | | |
| :30 | 160 | 10.34 | 166 | 9.88 | 1.55 | .20 |
| 1:00 | 141 | 10.86 | 148 | 12.03 | 1.62 | .20 |
| 1:30 | 131 | 9.83 | 135 | 9.63 | 1.05 | .40 |
| 2:00 | 124 | 8.44 | 126 | 10.77 | .47 | .70 |
| 3:00 | 115 | 8.38 | 116 | 9.91 | .43 | .70 |
| 4:00 | 114 | 8.48 | 114 | 9.48 | .06 | - |

* Denotes significance for this study

TABLE II

INTERRELATIONSHIPS
(Correlation Coefficients)

| Parameters | Body Weight | % Body Fat | Body Surface |
|---|---|---|---|
| $\dot{V}_E$ B.E. | .282 | .173 | .217 |
| $\dot{V}_E$ T.M. | -.145 | -.065 | -.211 |
| H.R. on B.E. | .148 | .327 | .248 |
| H.R. on T.M. | .010 | .381 | .061 |
| Time on B.E. | .178 | -.247 | .132 |
| Time on T.M. | -.549* | -.320 | -.524* |

*Denotes significance for this study

during the bicycle ergometer test than during the treadmill test. However, there was no significant relationship found for this study between pulmonary ventilation and body weight, per cent body fat and body surface, respectively.

A higher relationship was obtained between per cent body fat and the length of time on the treadmill as opposed to per cent body fat and the length of time on the bicycle ergometer. These findings are expected and support the theory that the treadmill test among moderately obese subjects will raise the maximal heart rate higher than the bicycle ergometer test.

Table II also reveals a statistically significant relationship between the time on the treadmill and body weight and body surfase, respectively. All three anthropometric measurements show a higher relationship to the time on the treadmill than to the time on the bicycle ergometer. These correlation coefficients suggest that the more obese the subjects were, the less time they could run on the treadmill.

# IV. SUMMARY AND DISCUSSION

It was the purpose of this study to compare circulo-respiratory responses to weight-supported and non weight-supported exercise in moderately obese subjects. Table I shows higher mean values for treadmill exercise than bicycle exercise on every parameter considered in this study. Running on a treadmill appears to be more taxing on the circulatory and respiratory systems than riding a bicycle ergometer. An interrelationship between the lengths of time the subject ran on the treadmill, and body weight and body surface, respectively, were found to be statistically significant for this study.

It is not possible at present to explain the exact reasons for higher pulmonary ventilation, oxygen uptake and heart rates appearing in non weight-supported exercise because the study did not attempt to show cause and effect. However, when discussing the findings a few statements, arrived at through observations during the investigation, appear warranted.

There was a total body involvement of the subjects when running on the treadmill and much less body involvement when riding on the bicycle ergometer. The leg muscles were the only muscle group actively used while bicycling on an ergometer, where as the legs, arms, chest, and shoulder girdle groups were actively engaged when running on a treadmill, thus contributing to higher circulorespiratory values obtained during non weight-supported exercise.

During bicycle ergometer exercise the ability to achieve high maximum values may be inhibited because of a localized state of fatigue appearing in the leg muscles. This fatigue is believed to be a main contributing factor since many of the subjects complained of fatigue and pain in the anterior thigh (quadriceps) muscles during the latter stages and in recovery from the bicycle ergometer test.

Another factor which could affect the lower circulo-respiratory values for weight-supported work is psychological motivation. Although the investigator did not attempt to motivate the subjects on either test, it is possible that the subjects subconsciously motivated themselves. The subjects knew that when running on the treadmill they were forced to keep running or be thrown off the mill by the continuous rotation of the belt. While riding on the bicycle ergometer it was easy for subjects to discontinue the test.

In summary, the data obtained from fourteen male subjects indicates that higher circulatory and respiratory values were obtained during non weight-supported exercise than during weight-supported exercise; and, therefore, the treadmill would appear to provide a superior test of circulo-respiratory functions.

# CHAPTER V

## SUMMARY

### I. SUMMARY

It was the purpose of this study to compare circulo-respiratory responses to weight-supported and non weight-supported exercise in moderately obese subjects. The circulo-respiratory parameters considered were pulmonary ventilation, oxygen uptake and heart rates during and in recovery from exercise. The weight-supported exercise was performed by riding on a bicycle ergometer and the non weight-supported exercise was performed by running on a treadmill.

Fourteen male college students from Eastern Illinois University and Lake Land Junior College took part in the investigation. The moderately obese subjects had a mean body weight of 106.82 kilograms, a mean body fat of 20.6 per cent and a mean body surface of 2.26 square meters. All of the subjects had previous experience in bicycle riding and running in physical education classes. However, the majority of subjects in their later high school and early college years showed a marked decrease in physical activity.

The weight supported test consisted of a submaximal and maximal work load on the bicycle ergometer. Submaximal oxygen uptake and pulmonary ventilation values were determined from a 30 second sample of ventilated air after the heart rate reached 150 beats per minute. During a maximal bicycle ergometer exercise the subject worked at an increasing work load of 300 kilopound meters per minute and a pedal frequency of 63 revolutions per minute.

The non weight-supported exercise consisted of a submaximal and maximal test. The speed of the treadmill was set at five miles per hour, and the grade was raised two per cent every minute until the heart rate again rose to 150 beats per minute. Then oxygen uptake and pulmonary ventilation measurements were obtained. The maximal run was characterized by a speed of six miles per hour and a grade raise of two per cent every minute. The subjects ran for as long as possible then a 30 second sample of ventilated air revealed pulmonary ventilation and oxygen content. Heart rates during and in recovery from all the tests were observed employing a telemetry system and recorded on a electrocardiogram.

Half of the subjects were tested first on the bicycle ergometer while the other half were tested first on the treadmill. The order of testing was then alternated so that all subjects were evaluated on both tests. This procedure was employed to eliminate training or learning effect.

A t ratio test was used to describe statistically significant differences between means on the various test parameters. In addition certain interrelationships were investigated.

## II. CONCLUSIONS

Based on the findings of this investigation, the following conclusions appear warranted. In moderately obese subjects, higher circulorespiratory responses were obtained during non weight-supported exercise than during weight-supported exercise.

During a submaximal and a maximal work load, higher circulorespiratory responses can be obtained while running on a treadmill as opposed to riding a bicycle ergometer. Therefore, the treadmill would appear to provide a superior test of circulorespiratory functions.

## III. RECOMMENDATIONS

Based on this investigation the following recommendations for further study are presented:

1. A similar study employing the laws of physics, should be done in an attempt to equate the work loads on the bicycle ergometer and treadmill exercises.
2. Another study of this nature could be conducted using not only more subjects, but subjects who were more experienced in riding on a bicycle ergometer and running on a treadmill.

# BIBLIOGRAPHY

## BIBLIOGRAPHY

### A. BOOKS

Astrand, Per-Olof. Experimental Studies of Physical Working Capacity in Relation to Sex and Age. Copenhagen: Munksgard, 1952.

Astrand, Per-Olof, and Kaare Rodahl. Textbook of Work Physiology. New York: McGraw-Hill Book Company, 1970.

Consolozio, Frank, Robert Johnson, and Louis Pecora. Physiologic Measurements and Metabolic Functions in Man. New York: McGraw-Hill Book Company, 1963.

Johnson, Barry L., and Jack K. Nelson. Practical Measurements for Evaluation in Physical Education. Minneapolis: Burgess Publishing Company, 1969.

Mathews, Donald I. Measurement in Physical Education. Philadelphia: W. B. Saunders Company, 1968.

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

Scott, Gladys M., and Esther French. Measurement and Evaluation in Physical Education. Dubuque: Wm. C. Brown Company, 1959.

### B. PERIODICALS

Astrand, I. "Aerobic Work Capacity in Men and Women with Special Reference to Age," Acta Physiologica Scandinavica, II (March, 1960), 15.

Astrand, I., P. O., and A. Stunkard. "Oxygen Intake of Obese Individuals During Work on a Bicycle Ergometer," Acta Physiologica Scandinavica, L (March, 1960), 294-299.

Astrand, P. O., and B. Saltin, "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, XVI (November, 1961), 977-981.

Astrand, P. O., and B. Saltin. "Oxygen Uptake During the First Minutes of Heavy Muscular Exercise," Journal of Applied Physiology, XVI (November, 1961), 971-976.

Astrand, P. O., and I. Ryhming. "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate During Submaximal Work," Journal of Applied Physiology, VII (February, 1954), 218-221.

Astrand, P. O., and K. Rodahl. "Maximal Heart Rate During Work in Older Men," Journal of Applied Physiology, XIV (July, 1959), 562-566.

Brosek J., and A. Keys. "Body Fat in Adult Man," Physiological Review, XXXIII (1953), 245.

Chase, G. A., C. Grove, and L. B. Rowell. "Independence of Changes in Functional and Performance Capacities Attending Prolonged Bed Rest," Aerospace Medicine, XXXVII (December, 1966), 1232-1238.

Glassford, R. G., G. H. Y. Boycraft, A. W. Sedgwick, and R. B. J. Mcnab. "Comparison of Maximal Oxygen Uptake Values Determined by Predicted and Actual Methods," Journal of Applied Physiology, XX (May, 1965), 509-513.

Hermansen, Lars, and Bengt Saltin. "Oxygen Uptake During Maximal Treadmill and Bicycle Exercise," Journal of Applied Physiology, XXVI (January, 1969), 31-37.

Johnson, Robert E., and Francis Robbins, et al. "A Versatile System for Measuring Oxygen Consumption in Man," Journal of Applied Physiology, XXII (February, 1967), 377-379.

Kraus, Hans, and Ruth Hirschland. "Minimum Muscular Fitness Tests in School Children," Research Quarterly, XXV (May, 1954), 178-188.

Luft, U. C., D. Cardus, T. Lim, E. C. Anderson, and J. L. Howarth. "Physical Performance in Relation to Body Size and Composition," Annals New York Academy of Sciences, CX (April, 1963), 795-808.

Mitchell, J. H., B. J. Sproule, and C. B. Chapman. "The Physiological Meaning of the Maximal Oxygen Intake Test," Journal of Applied Physiology, XXXVII (August, 1958), 538-576.

Stenberg, J., P. O. Astrand, B. Ekblom, J. Royce, and B. Saltin. "Hemodynamic Response to Work with Different Muscle Groups, Sitting and Supine," Journal of Applied Physiology, XXII (January, 1967), 61-70.

Taylor, H. L., E. Buskirk, and A. Henschel. "Maximal Oxygen Intake as an Objective Measure of the Cardio-respiratory Performance," Journal of Applied Physiology, VIII (January, 1955), 73-80.

Wyndham, C. H., N. B. Strydom, W. P. Leary, and C. G. Williams. "Studies of the Maximum Capacity of Men for Physical Effort," Internationale Zeitschrift Fuer Angewandte Physiologie Einschliesslich Arbeitsphysiologie, XXII (March, 1960), 294-295.

## C. PROGRAMS

Brown, K. L. "A Calculation of Ventilation and Oxygen Consumption Program," (Charleston: Eastern Illinois University, February, 1971).

DiPietro, A. J., and R. J. LeDuc. "Student T-Scores for Means (Cards) Between Groups," (Charleston: Eastern Illinois University, May, 1964).

Dixon, W. J. (ed.). "Correlation with Item Deletion, BMD03D," Biomedical Computer Programs, (Berkeley: University of California Press, 1970), 160.

## D. REPORTS

Mellorowicz, H. "Chairman of Symposium on the Standardization of Ergometry," 16th World Congress of Sports Medicine, Hanover, 1960.

Weiner, J. "International Biological Programme: Guide to the Human Adaptability Proposals," I. C. S. U. Special Committee for the International Biological Programme, 1965.

## E. UNPUBLISHED MATERIALS

Kobayashi, Yoshio. "The Effects of Rope Jumping on Cardio-respiratory Fitness of High School Students," Unpublished Master's thesis, Eastern Illinois University, Charleston, Illinois, 1969.

Paul, Tom L. "A Comparison of the Energy Costs of Exercises on the Bicycle Ergometer, the Treadmill, and the Stool Step," Unpublished Doctor's dissertation, Florida State University, Tallahassee, 1965.

APPENDICES

# APPENDIX A

## WRITTEN INSTRUCTIONS TO SUBJECTS PRIOR TO TESTING

(1) Do not drink any type of liquids for at least two hours preceding the bicycle ergometer and treadmill tests. (liquids meaning water, milk, beer, solf drinks etc.)

(2) Do not eat any kind of foods for at least two hours preceding the bicycle ergometer and treadmill tests. (foods meaning meats, vegetables, snacks, etc.)

(3) Do not smoke anything for at least two hours preceding the bicycle ergometer and treadmill tests. (smoking meaning cigarettes, cigars, marijuana, etc.)

(4) Do not participate in any form of physical exercise other than normal school day activities on the day of and the preceding day of laboratory testing. (no jogging, weight lifting, basketball games, etc.)

(5) Get your normal amount of sleep on the preceding night of your tests.

(6) Follow your normal eating habits and daily activities during these times other than before your laboratory tests.

(7) Bring to the laboratory a set of workout clothing (consisting of gym shorts, athletic supporter, white socks and gym shoes). Towel and shower facilities are provided for all subjects.

# APPENDIX B

## ANTHROPOMETRIC MEASUREMENTS

| Subject | Age | Height (cm) | Weight (kg) | Thigh Girth(cm) Right | Left | Percent Body Fat | Body Surface $M^2$ |
|---|---|---|---|---|---|---|---|
| 1 | 19.9 | 173 | 86.82 | 62 | 61 | 13.9 | 2.01 |
| 2 | 28.3 | 180 | 109.09 | 63 | 63 | 22.3 | 2.29 |
| 3 | 18.2 | 181 | 100.00 | 66 | 66 | 24.2 | 2.22 |
| 4 | 19.1 | 176 | 122.27 | 78 | 78 | 25.4 | 2.36 |
| 5 | 18.9 | 189 | 118.64 | 71 | 70 | 25.4 | 2.48 |
| 6 | 21.4 | 165 | 101.36 | 68 | 68 | 21.5 | 2.08 |
| 7 | 19.2 | 177 | 110.45 | 72 | 73 | 17.3 | 2.27 |
| 8 | 19.5 | 172 | 88.64 | 64 | 64 | 18.5 | 2.01 |
| 9 | 21.4 | 179 | 110.91 | 71 | 71 | 21.1 | 2.30 |
| 10 | 22.3 | 189 | 107.73 | 63 | 63 | 15.0 | 2.37 |
| 11 | 18.9 | 187 | 117.27 | 72 | 71 | 19.9 | 2.45 |
| 12 | 18.7 | 176 | 103.18 | 70 | 70 | 19.6 | 2.20 |
| 13 | 21.1 | 192 | 108.64 | 68 | 67 | 29.6 | 2.41 |
| 14 | 20.7 | 167 | 110.45 | 74 | 75 | 24.2 | 2.17 |
| Mean | 20.5 | 178.79 | 106.82 | 69 | 69 | 20.6 | 2.26 |
| S. D. | 2.55 | 8.24 | 10.23 | 4.71 | 4.92 | 3.61 | .214 |

## APPENDIX C

### PULMONARY VENTILATIONS
### (Liters/Min S.T.P.D.)

| Subject | $\dot{V}_E$ $PWC_{150}$ | | $\dot{V}_E$ $PWC_{max}$ | |
|---|---|---|---|---|
| | B.E. | T.M. | B.E. | T.M. |
| 1 | 57.44 | 74.99 | 94.89 | 122.57 |
| 2 | 50.85 | 65.42 | 119.44 | 109.24 |
| 3 | 66.70 | 75.98 | 94.27 | 125.20 |
| 4 | 96.36 | 94.20 | 134.06 | 133.94 |
| 5 | 39.83 | 61.92 | 93.21 | 113.39 |
| 6 | 43.57 | 57.51 | 92.61 | 94.76 |
| 7 | 61.20 | 72.03 | 91.45 | 121.90 |
| 8 | 49.24 | 57.02 | 93.20 | 110.43 |
| 9 | 74.33 | 87.92 | 84.85 | 101.92 |
| 10 | 82.88 | 90.13 | 107.52 | 146.70 |
| 11 | 46.27 | 63.94 | 92.19 | * |
| 12 | 60.97 | 70.74 | 114.28 | 146.47 |
| 13 | 62.84 | 82.79 | 96.58 | 88.95 |
| 14 | 83.60 | 87.80 | 97.55 | 122.36 |
| Mean | 62.45 | 74.39 | 99.72 | 117.65 |
| S.D. | 16.15 | 12.03 | 13.45 | 16.71 |

*Data Not Available

APPENDIX D

OXYGEN UPTAKES
(S.T.P.D.)

| Subject | B. K. $PWC_{150}$ (lt/m) | B. K. $PWC_{150}$ (ml/kg/m) | B. K. $PWC_{max}$ (lt/m) | B. K. $PWC_{max}$ (ml/kg/m) | T. M. $PWC_{150}$ (lt/m) | T. M. $PWC_{150}$ (ml/kg/m) | T. M. $PWC_{max}$ (lt/m) | T. M. $PWC_{max}$ (ml/kg/m) |
|---|---|---|---|---|---|---|---|---|
| 1 | 2.34 | 27.00 | 2.97 | 34.20 | 2.89 | 33.32 | 3.91 | 45.01 |
| 2 | 2.10 | 19.21 | 3.27 | 30.02 | 2.78 | 30.02 | 3.52 | 32.28 |
| 3 | 2.56 | 25.58 | 2.89 | 26.95 | 2.93 | 29.32 | 3.99 | 39.91 |
| 4 | 2.89 | 23.64 | 3.17 | 25.94 | 3.28 | 26.83 | 4.03 | 32.99 |
| 5 | 1.92 | 16.18 | 3.12 | 26.34 | 2.75 | 23.14 | 4.29 | 36.20 |
| 6 | 1.87 | 18.45 | 2.90 | 28.59 | 2.58 | 25.42 | 3.17 | 31.23 |
| 7 | 2.80 | 25.38 | 3.78 | 34.18 | 3.30 | 29.91 | 4.40 | 39.85 |
| 8 | 2.18 | 24.56 | 2.88 | 32.53 | 2.17 | 24.44 | 3.51 | 39.57 |
| 9 | 2.88 | 25.94 | 3.14 | 28.34 | 3.32 | 29.93 | 3.61 | 32.53 |
| 10 | 2.74 | 25.43 | 3.02 | 28.07 | 3.35 | 31.10 | 4.39 | 40.72 |
| 11 | 2.20 | 18.74 | 3.29 | 28.02 | 3.08 | 26.22 | * | * |
| 12 | 2.52 | 24.46 | 3.58 | 34.66 | 3.00 | 29.11 | 4.84 | 46.92 |
| 13 | 2.19 | 20.24 | 3.19 | 29.39 | 3.26 | 30.03 | 2.40 | 22.12 |
| 14 | 2.81 | 25.46 | 3.15 | 28.53 | 3.57 | 32.35 | 4.45 | 40.26 |
| Mean | 2.54 | 22.87 | 3.29 | 29.84 | 3.14 | 28.33 | 4.08 | 36.89 |
| S. D. | .56 | 3.40 | .70 | 2.79 | .91 | 2.97 | 1.52 | 6.35 |

* Data Not Available

APPENDIX E

MAXIMUM HEART RATES FROM $PWC_{max}$
(Beats/min)

| Subject | Maximum Recordings | |
|---|---|---|
| | B. E. ($PWC_{max}$) | T. M. ($PWC_{max}$) |
| 1 | 182 | 190 |
| 2 | 184 | 192 |
| 3 | 185 | 203 |
| 4 | 182 | 195 |
| 5 | 200 | 208 |
| 6 | 188 | 198 |
| 7 | 180 | 191 |
| 8 | 188 | 193 |
| 9 | 184 | 191 |
| 10 | 168 | 186 |
| 11 | 197 | 189 |
| 12 | 190 | 209 |
| 13 | 192 | 192 |
| 14 | 175 | 183 |
| Mean | 185 | 194 |
| S. D. | 7.42 | 7.99 |

# APPENDIX F

## RECOVERY HEART RATES FROM $PWC_{max}$
(Beats/min)

| Subject | :30 | | 1:00 | | 1:30 | | 2:00 | | 3:00 | | 4:00 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BE | TM | BE | TM | BE | TM | BE | TM | BE | TM | BE | TM |
| 1 | 167 | 156 | 129 | 140 | 119 | 124 | 127 | 116 | 114 | 108 | 110 | 108 |
| 2 | 159 | 162 | 130 | 137 | 122 | 129 | 112 | 117 | 112 | 117 | 103 | 102 |
| 3 | 168 | 174 | 140 | 160 | 130 | 144 | 118 | 137 | 98 | 130 | 95 | 127 |
| 4 | 160 | 175 | 145 | 162 | 129 | 150 | 119 | 137 | 119 | 122 | 119 | 121 |
| 5 | 171 | 186 | 165 | 175 | 151 | 152 | 139 | 148 | 118 | 135 | 119 | 135 |
| 6 | 164 | 169 | 145 | 154 | 140 | 145 | 131 | 137 | 122 | 125 | 121 | 119 |
| 7 | 152 | 168 | 132 | 150 | 124 | 132 | 113 | 122 | 110 | 114 | 117 | 109 |
| 8 | 174 | 172 | 160 | 151 | 141 | 138 | 138 | 129 | 128 | 119 | 128 | 116 |
| 9 | 160 | 170 | 138 | 139 | 130 | 130 | 125 | 110 | 109 | 102 | 120 | 110 |
| 10 | 150 | 152 | 132 | 145 | 130 | 132 | 129 | 130 | 120 | 122 | 127 | 120 |
| 11 | 174 | 160 | 152 | 148 | 148 | 137 | 132 | 128 | 128 | 117 | 122 | 117 |
| 12 | 140 | 177 | 139 | 150 | 120 | 130 | 116 | 116 | 102 | 103 | 110 | 98 |
| 13 | 161 | 153 | 140 | 123 | 130 | 116 | 122 | 112 | 118 | 101 | 110 | 107 |
| 14 | 143 | 155 | 130 | 145 | 122 | 133 | 118 | 125 | 112 | 117 | 106 | 113 |
| Mean | 160 | 166 | 141 | 148 | 131 | 135 | 124 | 126 | 115 | 116 | 114 | 114 |
| S. D. | 10.34 | 9.88 | 20.86 | 12.03 | 9.83 | 9.63 | 8.44 | 10.78 | 8.38 | 9.91 | 8.47 | 9.4 |

Recovery from $PWC_{max}$ Test

# APPENDIX G

## MAXIMUM RIDING AND RUNNING TIMES
(Minutes and Seconds)

| Subject | B.E. | T.M. |
|---|---|---|
| 1 | 7:15 | 4:50 |
| 2 | 7:25 | 2:50 |
| 3 | 7:05 | 4:15 |
| 4 | 7:10 | 3:25 |
| 5 | 7:35 | 4:00 |
| 6 | 7:00 | 3:40 |
| 7 | 10:45 | 4:05 |
| 8 | 6:55 | 4:40 |
| 9 | 7:10 | 2:25 |
| 10 | 7:35 | 4:40 |
| 11 | * | * |
| 12 | 9:50 | 5:35 |
| 13 | 7:35 | 2:55 |
| 14 | 7:55 | 4:10 |
| Mean | 8:20 | 4:23 |
| S.D. | 10:77 | 9:41 |

* Data Not Available

# VITA

The writer was born in the city of Taylorville, Illinois on February 13, 1945. It was after he moved to Pana, Illinois, that he first became interested in athletics. While attending Pana Senior High School, he was awarded six varsity letters in football and basketball, the "Most Valuable" football player trophy, the "Free Throw" award, president of the Letterman's Club, and captain of the football and basketball teams.

After accepting a football athletic scholarship, he enrolled at Upper Iowa University with a major in Physical Education. Starting four seasons on conference championship football teams, the writer served as captain, was named to the All-Conference team, and broke two all-time pass-receiving records at the University. He received the Bachelor of Science Degree in the spring of 1967.

Actual experience in the field of physical education was achieved while teaching and coaching football and track at Solon High School, Solon, Iowa, in the school year 1967-68.

The following two years he served with the 82nd Airborne Division of the United States Army. He was awarded the "Outstanding Trainee Award" for physical conditioning, military leadership, and knowledge of military functions.

The writer was awarded a Graduate Assistantship at Eastern Illinois University during the school year 1970-71. Among his duties were teaching service classes at Lake Land Junior College.

The writer has accepted a position as head football and wrestling coach and physical education instructor at Hamlet High School, Hamlet, North Carolina.