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Title of Thesis: The Interrelationships between Predicted and Actual Measures of Max $\dot{V}O_2$ and Running Performance

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ABSTRACT

Title of Thesis: The Interrelationships between Predicted and Actual Measures of Max $\dot{V}O_2$ and Running Performance

William Charles Byrnes

Thesis directed by: Dr. Jay T. Kearney
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This study investigated the interrelationships between predicted Max $\dot{V}O_2$, actual Max $\dot{V}O_2$ and various running performances of individuals from three subject groups. More specifically, the study attempted to ascertain within a composite and each of three ability subgroups: (1) the relationship between actual Max $\dot{V}O_2$ and predicted Max $\dot{V}O_2$; (2) the correlations between actual oxygen uptake (L/min. and ml/kg/min.) and half-mile, mile and three-mile performance times; (3) the relationship between predicted Max $\dot{V}O_2$ (L/min. and ml/kg/min.) and performance in the half-mile, mile and three-mile run; and (4) the significance of the difference among the correlation coefficients obtained between the predicted and actual measures of oxygen uptake (ml/kg/min.) and running performance.

The research involved 33 male college students ranging in age from 18 to 25 years. Eleven volunteers were tested from each of the following three subgroups: non-physical education majors, physical education majors, and trained runners. The tests administered to each subject were actual Max $\dot{V}O_2$, predicted Max $\dot{V}O_2$ and half-mile, mile and three-mile running performances.

Actual Max $\dot{V}O_2$ was determined by an open-circuit, Douglas Bag procedure and predicted Max $\dot{V}O_2$ was obtained by application of the Astrand-Rhyming nomogram. Interrelationships were calculated utilizing the Pearson product-moment machine formula. The significance of the differences among the relationships between predicted and actual measures of Max $\dot{V}O_2$ and performance were determined by a t-test. In addition, coefficients of determination were also calculated as an alternative way to determine the compatability of the relationships between the two measures of oxygen uptake.

The analysis of the data revealed that the relationships between predicted and actual Max $\dot{V}O_2$ (L/min.) were significant within the composite and major subgroup. When Max $\dot{V}O_2$ was expressed relative to body weight, however, significant relationships were found among the non-major and major subgroups as well as the composite group. The relationships between actual Max $\dot{V}O_2$ (L/min.) and running performance were significant for the non-majors at all distances and the composite group at the mile. The expression of Max $\dot{V}O_2$ in ml/kg/min. resulted in significant relationships within the composite, non-major, and major groups.

The relationships between predicted oxygen uptake and running performance were significant for the composite group at each distance vs. Max $\dot{V}O_2$ ml/kg/min. and the trained runners at half mile (L/min.). The t value obtained for the differences among the correlation coefficients revealed significance for the trained runner sub-group at the half-mile and mile. With one exception, the relationships between actual and predicted. Max $\dot{V}O_2$ (ml/kg/min.) increased as a function of distance.

# THE INTERRELATIONSHIPS BETWEEN PREDICTED AND ACTUAL MEASURES OF MAX $\dot{V}O_2$ AND RUNNING PERFORMANCE

by
William Charles Byrnes

Thesis submitted to the Faculty of the Graduate School
at Appalachian State University in partial fulfillment
of the requirements for the degree of
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DEDICATION

This study is dedicated

to Dr. Jay T. Kearney

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The author expresses his gratitude to the advisor of this study, Dr. Jay T. Kearney, for his invaluable assistance. Appreciation for professional advice is also extended to Dr. Micheal C. Carter, Dr. Vaughan Christian, Mr. Roger Thomas, and Miss Kathy Doughty.

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TABLE OF CONTENTS

Chapter Page

DEDICATION........................................ ii

ACKNOWLEDGMENTS................................... iii

LIST OF TABLES.................................... vi

LIST OF FIGURES................................... vii

I. INTRODUCTION AND STATEMENT OF PROBLEM........... 1

A. Introduction................................... 1

B. The Problem.................................... 5

1. Statement of the Problem....................... 5

2. Scope of the Study............................. 6

3. Limitations.................................... 7

II. REVIEW OF RELATED LITERATURE.................. 8

A. Relationship between Predicted and Actually Determined Measures of Max $\dot{V}O_2$.............. 8

B. Oxygen Uptake and Its Relationship to Non-Running General Endurance Performance...... 12

C. The Relationship between Max $\dot{V}O_2$ and Running Performance.............................. 15

D. Summary........................................ 21

III. PROCEDURES.................................. 23

A. Selection of Subjects.......................... 23

B. Apparatus...................................... 24

1. Apparatus for Estimating Max $\dot{V}O_2$.......... 24

2. Apparatus Used in Determination of Actual Max $\dot{V}O_2$.................................. 26

Chapter | Page

C. Testing Procedures.............................. 29

1. Conditions.................................. 29

2. Predicted Maximum Oxygen Uptake.......... 29

3. Direct Maximum Oxygen Uptake............. 31

D. Treatment of Data............................ 34

IV. RESULTS AND DISCUSSION........................ 36

A. Descriptive Statistics...................... 36

B. Analysis of Variance........................ 38

C. Relationship between Predicted Max $\dot{V}O_2$ and Actual Max $\dot{V}O_2$.............................. 38

D. Relationships between Predicted and Actual Measures of Max $\dot{V}O_2$ and Various Running Performances.................................. 42

E. Discussion.................................... 47

1. Descriptive Statistics.................. 47

2. Analysis of Variance..................... 49

3. Relationship between Predicted Max $\dot{V}O_2$ and Actual Max $\dot{V}O_2$..................... 50

4. Relationship between Predicted and Actual Measures of Max $\dot{V}O_2$ and Various Running Performance................................ 52

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY................................ 57

A. Summary........................................ 57

B. Conclusions.................................... 59

C. Recommendations for Further Study............ 61

BIBLIOGRAPHY.............................................. 62

LIST OF TABLES

Table Page

1. Means and Standard Deviations for the Physical Characteristics of the Subjects...... 25

2. Descriptive Statistics for Predicted Max $\dot{V}O_2$, Actual Max $\dot{V}O_2$, Heart Rate during the Actual Measure and Run Times for Various Running Performances.................................. 39

3. Summary Table of ANOVA for Predicted Max $\dot{V}O_2$, Actual Max $\dot{V}O_2$, and Run Times for the Half-Mile, Mile, and Three Mile..................... 40

4. Summary Tables for Tukey's Test for Predicted Max $\dot{V}O_2$, Actual Max $\dot{V}O_2$, and Run Times for the Half-Mile, Mile, and Three Mile............... 41

5. Relationship between Predicted Max $\dot{V}O_2$, and Actual Max $\dot{V}O_2$.................................. 42

6. Relationship between Actual and Predicted Max $\dot{V}O_2$ (L/min.) and Running Performance...... 44

7. Relationship between Actual and Predicted Max $\dot{V}O_2$ (ml/kg/min.) and Running Performance.. 45

8. Coefficients of Determination and the Difference between Correlation Coefficients...... 46

LIST OF FIGURES

Figure Page

1. Apparatus for Collection of Expired Gas.............................................. 28

2. Beckman $O_2$ Analyzer Model E2 and Beckman Medical Gas Analyzer Model LB-1............... 28

# CHAPTER I

# INTRODUCTION AND STATEMENT OF THE PROBLEM

## A. Introduction

Physical fitness has become a very real concern of the American public. The general population has become increasingly aware of the value of fitness to total well-being. The components that are associated with fitness by the layman usually include such items as muscular strength and endurance, flexibility, agility, general motor ability and cardiovascular endurance. In general, the element that the public is primarily concerned with is cardiovascular or overall endurance. This component of total fitness can be evaluated by several different means. Two of the more frequently used measures are endurance performance type tests and the determination of maximum oxygen uptake (hereafter referred to as Max $\dot{V}O_2$).

Due to its utilization as a determinant or predictor of cardiovascular endurance capacity, Max $\dot{V}O_2$ has recently received increasing recognition. Textbooks dealing with physiology of exercise stress the variety of components measured by and the value of determination of maximum oxygen consumption. DeVries states that lung ventilation, pulmonary diffusion, $O_2$ and $CO_2$ transport by the blood, cardiac function, vascular adaptation, and the physical condition of the muscles involved, are evaluated by use of the Max $\dot{V}O_2$ test.[1]

For maximum exercise that lasts more than one to two minutes, Max $\dot{V}O_2$ is regarded by Morehouse and Miller as the single best indicator of cardiovascular potential.[2] Mathews and Fox also consider Max $\dot{V}O_2$ as a significant factor in cardiovascular endurance events.[3] Theoretically, these statements are based on the fact that the aerobic pathways, which are evaluated in a Max $\dot{V}O_2$ test, provide a large proportion of the energy required in cardiovascular endurance type activity. Astrand and Rodahl have attached similar importance to the measurement of Max $\dot{V}O_2$ and its relation to performance in overall endurance events.[4] The authors state that when all factors contributing to a high quality performance are present, the higher an individual's Max $\dot{V}O_2$, the better performance that can be anticipated in cardiovascular endurance tasks. Max $\dot{V}O_2$ is, therefore, the best single predictor of general endurance available.

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[1]Herbert A. deVries, Physiology of Exercise for Physical Education and Athletics, (Dubuque, Iowa: Wm. C. Brown Co., 1966), p. 157-58.

[2]Laurence E. Morehouse and Augustus T. Miller, Physiology of Exercise, (Saint Louis: C. V. Mosby Co., 1971), pp. 162-63.

[3]Donald K. Mathews and Edward L. Fox, The Physiological Basis of Physical Education and Athletics (Philadelphia: Wm. B. Saunders Co., 1971), p. 19.

[4]Per-Olof Astrand and Kaare Rodahl, Textbook of Work Physiology, (New York: McGraw-Hill Book Co., 1970), pp. 279-315.

Direct and indirect procedures for the measurement of metabolic processes, oxygen consumption, have been formulated. Direct calorimetry calculates energy output by measuring the heat produced by an individual. A subject is placed in a chamber designed to absorb all the heat produced during a given time. This method is currently not utilized by exercise physiologists due to the cumbersomeness, expense, and difficulty of operating the equipment involved.

Indirect measures of metabolic capacities are based on the relationship between oxygen consumed and heat produced. The two primary indirect procedures are the open and closed circuit systems. The open circuit procedure is generally utilized by physiologists interested in gross body performance such as cardiovascular endurance tasks. Basically, this system involves the inspiration of ambient air by the performer and the collection and analyzation of the expired air. Through the knowledge of temperature, pressures, and volumes as well as initial and final $O_2$ and $CO_2$ concentrations explicit determinations of oxygen consumption can be obtained. If an evaluation of Max $\dot{V}O_2$ is desired, the aforementioned types of data are collected while the subject is performing a strenuous bout of exercise. The most frequently used modes of exercise for these tests are successive work bouts on either a bicycle ergometer or a treadmill.

In general, the equipment necessary for the use of the open circuit procedure is expensive, sophisticated, and unavailable in many situations. For example, electronic oxygen and carbon dioxide analyses are very expensive and the replacement of fragile components can easily add to a budget. In addition, the process of obtaining Max $\dot{V}O_2$ in this manner, is relatively time consuming.

As an alternative to direct measurement, Max $\dot{V}O_2$ can also be predicted from submaximal performances on a treadmill, a bench step, or a bicycle ergometer. One of the predictive procedures which has been shown to be valid, reliable and objective is the Astrand-Rhyming nomogram.[5] The nomogram is based on the concept that a linear relationship exists between oxygen consumption and heart rate response to submaximal loads. Subjects with a greater Max $\dot{V}O_2$ produce lower heart rates in response to a particular submaximal load. Thus, by plotting heart rate response to a submaximal load, Max $\dot{V}O_2$ can be predicted with the aid of the nomogram.

The theoretical basis of the relationship between Max $\dot{V}O_2$ and cardiovascular performance and the feasibility of predicting Max $\dot{V}O_2$ have been previously investigated. However, if the predicted measures could be substituted for the directly determined measure, physical educators and coaches might find it practical to use the predicted measure in evaluating the participants in the programs

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[5] Ibid., p. 619-627.

concerned. Such an evaluation would provide an objective and accurate measure of cardiovascular fitness with a decrease in expense of time and money. It would then appear to be of interest to consider the interrelationships among actual Max $\dot{V}O_2$, predicted Max $\dot{V}O_2$, and cardiovascular performance among various subject groups.

B. The Problem

1. Statement of the Problem

The purpose of this study was to investigate the interrelationships between actual Max $\dot{V}O_2$, predicted Max $\dot{V}O_2$, and various running performances of individuals from three subject groups. More specifically, the investigation sought to ascertain:

a. The relationship between actual Max $\dot{V}O_2$ and predicted Max $\dot{V}O_2$ within a composite group and each of three individual groups of subjects.

b. The correlations between the variables actual Max $\dot{V}O_2$ (L/min. and ml/kg/min.) and half-mile, mile, and three mile performance times for a composite group and the various subject groups.

c. The relationship between predicted Max $\dot{V}O_2$ (L/min. and ml/kg/min.) and performance in the half-mile, mile, and three mile for the composite group and each individual group of subjects.

d. If the correlation coefficients obtained between the predicted and actual measures of Max $\dot{V}O_2$

(ml/kg/min.) and performance in the half-mile, mile, and three mile differed significantly for either the composite or the various subject groups.

2. Scope of the Study

The study involved 33 individuals enrolled at Appalachian State University in the spring of 1973. The subjects, who ranged in age from 18 to 25 years, were volunteers obtained from three populations. Eleven non-physical education majors (hereafter referred to as non-majors) and eleven physical education majors (hereafter referred to as majors) were selected from the non-major and major populations, respectively. As a prerequisite, majors and non-majors were not allowed to be members of a varsity team. Nine members of the Appalachian State University track team and two experienced runners formed the third group of trained distance runners. Each subject was tested twice on each of the following five measures: actual Max $\dot{V}O_2$, predicted Max $\dot{V}O_2$, and half-mile, mile, and three mile running performances. The first performance served as a learning situation for the individual involved.

Actual Max $\dot{V}O_2$ was determined by the open-circuit Douglas Bag procedure and predicted Max $\dot{V}O_2$ obtained by application of the Astrand-Rhyming nomogram. Interrelationships were calculated between the five measures utilizing the Pearson product-moment machine formula. After these interrelationships were calculated, t-tests were utilized to determine the significance of the correlation coefficients and the significance of the difference between correlation coefficients for the correlated samples. In addition, an ANOVA was applied to the differences between the three groups regarding actual Max $\dot{V}O_2$ (ml/kg/min.), predicted Max $\dot{V}O_2$ (ml/kg/min.), and performances in the half-mile, mile, and three mile runs.

3. Limitations

The data collected during the course of this investigation may have been influenced by certain uncontrollable factors such as:

a. The cooperation of the subjects in not training extra-experimentally either before or during the testing periods was essential if the data collected were to remain valid.

b. The motivation of each subject to perform maximally during the evaluation of actual Max $\dot{V}O_2$ and the various running performances was of importance and not completely controllable.

c. This study was limited to the investigation of Max $\dot{V}O_2$ as a determinant of cardiovascular endurance performance and did not evaluate other determinants such as motivation, pain tolerance, heat dissipation, and efficiency of the nervous and related homeostatic mechanisms.

CHAPTER II

REVIEW OF RELATED LITERATURE

This chapter presents a review of the literature dealing with actual Max $\dot{V}O_2$, predicted Max $\dot{V}O_2$, and their importance in relation to cardiovascular endurance performance. The chapter is divided into four sections. The first section reviews some of the studies that have compared predicted and actual measures of oxygen uptake. Investigations that ascertained the relationship between Max $\dot{V}O_2$ and general cardiovascular endurance performances are included in the second portion. The third section is concerned with the relationships between the variables Max $\dot{V}O_2$ and running performances at various distances. A very brief summary of the literature reviewed in the earlier sections is presented in the final portion of the chapter.

## A. Relationship between Predicted and Actual Measures of Max $\dot{V}O_2$

In the process of developing a nomogram that would provide a simple procedure for predicting an individual's Max $\dot{V}O_2$, Astrand and Rhyming compared measures of Max $\dot{V}O_2$ and heart rate response to submaximal levels of exercise. The subjects included

27 and 31 well-trained males and females whose Max $\dot{V}O_2$ was determined on the bicycle ergometer. Additionally, the subjects performed submaximal loads of 600 and 900 kpm/min. for females and 900 and 1200 kpm/min. for males while their heart rate responses were monitored. This heart rate response to submaximal workload data was used to develop a nomogram for the prediction of Max $\dot{V}O_2$. At higher workloads, comparisons of the values for the predicted and actually determined Max $\dot{V}O_2$ revealed that a standard error of measurement of 6.7 percent for men and 9.4 percent for women existed for two-thirds of the subject population. When the predicted values were based on the lower workloads, the standard deviation rose to 14.4 percent for men and 10.4 percent for women.[1]

Hettinger, et. al., investigated the relationships between Max $\dot{V}O_2$ and the following tests of physical work capacity: the Harvard Step Test, a modified step test in which body weight and the length of a subject's legs were taken into account, the Master Step Test, the Amplituden-Puls-Frequenz Test and the Leistungs-Pulsindex. In addition, 28 of the 96 subjects between the ages of 20 and 30 years participated in a comparison of estimated Max $\dot{V}O_2$ and actual Max $\dot{V}O_2$. Actual Max $\dot{V}O_2$ was obtained

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[1]Per-Olof Astrand and Ira Rhyming, "A Nomogram for Calculation of Aerobic Capacity from Pulse Rate during Submaximal Work," Journal of Applied Physiology, 7:218-21, September, 1954.

in a series of experiments with the bicycle ergometer. Predicted Max $\dot{V}O_2$ was determined on the basis of submaximal performance on the ergometer and application of the Astrand-Rhyming nomogram. Submaximal loads producing heart rates between 125 and 170 beats per minute were used.

Analysis of the data revealed that the mean predicted measure of Max $\dot{V}O_2$ (2.62 L/min.) was significantly higher than the mean actual measure of Max $\dot{V}O_2$ (2.38 L/min.). The authors also stated that the correlation between the two measures was statistically significant at "about" the .01 level.[2]

Glassford, et. al., using 24 male subjects between the ages of 17 and 33 years, researched the relationships between three actual and one estimated measure of Max $\dot{V}O_2$. One of the direct measures was the Astrand bicycle ergometer test of Max $\dot{V}O_2$. The indirect measure was the Astrand-Rhyming nomogram which predicts Max $\dot{V}O_2$ from heart rate response to submaximal work. Both measures were performed on a Monark bicycle ergometer at a pedal frequency of fifty revolutions per minute. The author reported an r=.65 between actual and predicted Max $\dot{V}O_2$ (L/min.). When body weight was taken into account by the expression of oxygen uptake in ml/kg/min., the

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[2]T. Hettinger, et. al., "Assessments of Physical Work Capacity," Journal of Applied Physiology, 16:153-56, 1961.

relationship determined was r=.63.[3]

DeVries also researched the relationship between predicted Max $\dot{V}O_2$ as obtained from the Astrand-Rhyming nomogram and actually measured Max $\dot{V}O_2$. The correlation ascertained between these variables was r=.74. The author also reported a standard error of prediction of ±9.3 percent. This figure is in agreement with an earlier research by Astrand and Rhyming, who reported values of 6.7 percent at 1200 kpm/min. and 14.4 percent at 900 kpm/min.[4]

In 1965, the ability of the Astrand-Rhyming nomogram to predict Max $\dot{V}O_2$ was investigated by Teräslinna, et. al. Using 31 members of the Purdue University faculty and staff who had participated in an adult fitness program, the authors reported a validity coefficient for the nomogram. Actual Max $\dot{V}O_2$ was assessed by an H. B. Falls' modification of work capacity test designed by Balke and Taylor. The means for actual and predicted oxygen uptake (L/min.) were 2.89 and 3.11, respectively. When the nomogram's age correction factor was appropriately applied, the mean predicted measure was reduced to 2.85 L/min. An analysis by the Pearson product-moment formula revealed a correlation coefficient of r=.69 between the actual and

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[3]R. G. Glassford, et. al., "Comparison of Maximal Oxygen Uptake Values Determined by Predicted and Actual Methods," Journal of Applied Physiology, 20:509-13, 1965.

[4]Herbert A. deVries, Physiology of Exercise for Physical Education and Athletics, (Dubuque, Iowa: Wm. C. Brown Co., 1966), p. 209.

estimated measure of Max $\dot{V}O_2$. The relationship increased to r=.92 when the actual measure was compared with the age corrected-estimated value.[5]

In a study designed to investigate the possibility of predicting oxygen uptake from running performance, Wiley and Shaver also researched the relationship between actual Max $\dot{V}O_2$ measured on a treadmill and predicted Max $\dot{V}O_2$ as determined by the Astrand-Rhyming nomogram. Based on the performance of 35 untrained male subjects, the authors concluded that the nomogram was a poor predictor of Max $\dot{V}O_2$ as measured on a treadmill.[6]

B. Oxygen Uptake and Its Relationship to Non-Running General Endurance Performance

In 1951, Cureton investigated all-out performance on a treadmill test and maximum oxygen consumption. The author reported that the relationship between the variables was r=.24 when gross oxygen consumption was used. When Max $\dot{V}O_2$ were expressed in ml/kg/min., the correlation obtained was r=.34.[7] Bruce investigated the relationships

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[5] P. Teräslinna, et. al., "Nomogram by Astrand and Rhyming as a Predictor of Maximum Oxygen Intake," Journal of Applied Physiology, 21:513-15, 1966.

[6] Jack F. Wiley, and Larry G. Shaver, "Prediction of Maximum Oxygen Intake from Running Performances of Untrained Young Men," Research Quarterly, 43:89-93, March, 1972.

[7] Thomas K. Cureton, Physical Fitness of Champion Athletes, Urbanna: University of Illinois Press, 1951.

of Max $\dot{V}O_2$ and three types of performance tasks on the bicycle ergometer. The 27 male subjects employed ranged in age from 18 to 41 years with a mean age of 22.55 years. The three performance tasks were: (1) continuous increasing increments in work levels, (2) a constant load of 1620 kpm/min., and (3) a constant load of 1620 kpm/min. preceded by a ten minute warm-up. The correlation coefficient between Max $\dot{V}O_2$ (L/min.) and endurance performance was r=.78. When body weight was included, the relationship dwindled to r=.30. Bruce concluded that body weight was important to performance on the bicycle ergometer and that Max $\dot{V}O_2$ was not indicative of an individual's ability to perform on the bicycle ergometer when a gross work output type of endurance exercise was involved.[8]

The relationship between Max $VO_2$ and capacity for endurance on the bicycle ergometer has also been investigated by Wilmore. The subjects, 30 male university students, were physically active but were not engaged in a systematic training program. Two continuous work capacity tests were administered to each subject. Oxygen intake values were calculated minute by minute and both the amount of work done and length of ride recorded. The relationship obtained was r=.84 when Max $\dot{V}O_2$ (L/min.) was compared to total work output. When Max $\dot{V}O_2$ was

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[8] J. R. Bruce, "The Relation of Maximal $O_2$ Intake to Performance on a Bicycle Ergometer." Master's thesis, University of California at Berkley, 1967 (microcarded).

expressed relative to body weight, the correlation between the same two variables was r=.37. By holding the influence of body weight on the endurance performance test statistically constant, the relationship between Max $\dot{V}O_2$ (ml/kg/min.) and performance was reported as r=.78. Wilmore concluded that when the influence of body weight was taken into account, a high relationship existed between any form of Max $\dot{V}O_2$ and cardiovascular endurance capacity.[9]

In 1970, variations in Max $\dot{V}O_2$ with physical activity in middle-aged men were investigated by McDonough, et. al. The oxygen uptake of 86 healthy men was determined by a treadmill procedure. One of the variations considered was the relationship between oxygen uptake and duration of a multistage treadmill test. The correlation coefficient reported by the authors for the above variables was r=.85.[10]

The relationships between estimated and predicted measures of Max $\dot{V}O_2$ and performance on the Johnson, Brouha, and Darling physical fitness test was researched by Glassford, et. al. The subjects used in the investigation were 24 male volunteers. Correlations between the actual measure of oxygen consumption of the fitness test scores (L/min. and ml/kg/min.), were r=.68 and r=.65, respectively.

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[9] Jack H. Wilmore, "Maximal Oxygen Intake and Its Relationship to Endurance Capacity on a Bicycle Ergometer." Research Quarterly, 40:203-10, March, 1969.

[10] J. R. McDonough, et. al., "Variations in Maximal Oxygen Intake with Physical Activity in Middle Aged Men," Circulation, 91:743-51, May, 1970.

Results between the estimated measure of oxygen uptake and the fitness test were r=.80 and r=.79.[11]

### C. The Relationship between Max $\dot{V}O_2$ and Running Performance

Falls, et. al., researched the validity of estimating Max $\dot{V}O_2$ from AAHPER Youth Fitness Test items. The subjects used in this study were 87 male volunteers from the Purdue University faculty and staff. With the exception of the sit ups and the medicine ball throw, the fitness test items were administered according to the AAHPER Youth Fitness Manuel. Actual Max $\dot{V}O_2$ was determined by a continuous performance on the bicycle ergometer until exhaustion or until two consecutive heart rates taken a minute apart were constant. The Pearson product-moment formula was used to correlate test items with Max $\dot{V}O_2$ expressed in L/min., ml/kg/min., and ml/kg of lean body weight/min. The coefficient for Max $\dot{V}O_2$ (L/min.) and 600 yard run-walk times was r=-.47. When body weight was included, the relationship rose to r=-.64.[12]

In a portion of a study by Doolittle and Bigbee, oxygen uptake was correlated with 600 yard run-walk times of ninth grade boys. Nine of the 153 subjects in the study were selected at random and given a continuous Max $\dot{V}O_2$

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[11]Glassford, et. al., Loc. cit.

[12]Harold B. Falls, et. al., "Estimation of Maximum Oxygen Uptake in Adults from A.A.H.P.E.R. Youth Fitness Test Items." Research Quarterly, 37:192-201, May, 1966.

test. The Spearman rank-difference method revealed a correlation of r=-.62, between oxygen uptake and 600 yard run-walk times.[13]

Drake researched the relationships between estimated Max $\dot{V}O_2$ and the following seven items of the AAHPER fitness test: speed sit-ups, standing broadjump, shuttle run, chin-ups, medicine-ball throw, fifty yard dash and 600 yard run-walk. The subjects ranged in age from 16 to 59 years. The procedures for the administration of the fitness test were taken from the AAHPER Youth Fitness Manuel. Estimated maximum oxygen uptake was determined from the Astrand-Rhyming nomogram. The relationship between Max $\dot{V}O_2$ and 600 yard run-walk times was the concern of the present investigation. Correlations of r=-.25 and r=-.27 were reported for the above variables when estimated Max $\dot{V}O_2$ was expressed in L/min. and ml/kg/min., respectively.[14]

Metz and Alexander investigated the relationship between Max $\dot{V}O_2$ and physical fitness items from the AAHPER Youth Fitness Test and the McCloy Strength Test. The 60 subjects were divided into two equal groups on the basis of age. One group consisted of 12 and 13 year old boys

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[13] T. L. Doolittle, and Rollin Bigbee, "The Twelve-Minute Run-Walk: A Test of Cardiorespiratory Fitness of Adolescent Boys." Research Quarterly, 39:491-95, October, 1968.

[14] V. Drake, et. al., "Fitness Performance Tests and Their Relationship to the Maximal Oxygen Uptake of Adults", Canadian Medical Association Journal, 99:844-48, November 1, 1968.

and the other group was composed of 14 and 15 year old boys. Oxygen consumption was determined by performance on a treadmill. The data were handled by simple and multiple correlation regression analysis. For the variables of Max $\dot{V}O_2$ (ml/kg/min.) and 600 yard run-walk times, the 12-13 year old group revealed a coefficient of r=-.66. The relationship using the same variables was r=-.27 for the 14-15 year old group.[15]

Katch determined the relationship between Max $\dot{V}O_2$ measured by a discontinuous treadmill procedure and individual differences in steady-pace endurance running test for college males. The subjects ran at an initial speed of 10 mph. and attempted to sustain this speed for 10 minutes while running performance was evaluated in terms of running time between consecutive stations of a track. An individual's endurance score was represented as the cumulative distance run after each minute. A portion of the study revealed an r=.61 between Max $\dot{V}O_2$ (ml/kg/min.) and cumulative distance after five minutes of running. Katch suggested that to obtain moderate validity for a performance measure of running endurance, subjects must attempt to maintain a speed of 10 mph. for at least five minutes.[16]

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[15]Kenneth F. Metz, and John F. Alexander, "An Investigation of the Relationship between Maximum Aerobic Work Capacity and Physical Fitness in Twelve-to-Fifteen-Year-Old Boys," Research Quarterly, 41:75-81, March, 1970.

[16]Frank E. Katch, et. al., "Relationship between Individual Differences in a Steady Pace Endurance Running Performance and Maximal Oxygen Intake," Research Quarterly, 44:206-15, May, 1973.

In 1968, an investigation of the 12 minute run-walk as an indicator of cardiovascular fitness was conducted by Doolittle and Bigbee. Utilizing nine ninth grade boys, the authors reported an r=.90 for the variables Max $\dot{V}O_2$ and 12 minute run-walk times by means of the Spearman rank-difference method. The authors concluded that the 12 minute run-walk was a valid and highly reliable measure of cardiovascular endurance performance.[17]

Gregory randomly selected 40 college males for a study involving Max $\dot{V}O_2$ and performance in the 12 minute run-walk. The oxygen uptake test was administered first to 20 subjects and the other 20 participants performed the 12 minute run, first. Between two and four days later, the participants were rotated and given the opposite test. An r=.66 resulted between Max $\dot{V}O_2$ and distance achieved in the 12 minute run. The author stated that such a relationship was not sufficient to allow the 12 minute run-walk to be substituted for a Max $\dot{V}O_2$ test.[18]

The relationship between the variables Max $\dot{V}O_2$ and endurance scores obtained from the 12 minute run was also researched by Katch. Oxygen uptake of 50 college males was determined on the bicycle ergometer. Subjects

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[17] Doolittle and Bigbee, Loc. cit.

[18] John D. Gregory, "The Relationship of the Twelve Minute Run to Maximal Oxygen Intake", Master's thesis, Mankato State College, 1970.

rode at an initial load of 900 kpm/min. for two minutes. The load was then increased in increments of 180 kpm/min. each two minutes thereafter until exhaustion. Oxygen intake was measured each minute with the highest value obtained being designated as Max $\dot{V}O_2$. The correlation of Max $\dot{V}O_2$ to 12 minute run scores was r=.54. An r=.54 was also reported between Max $\dot{V}O_2$ and independently measured endurance run scores. Based on the results of this study, the author concluded that aerobic capacity should only be considered as a partial determinant of cardiovascular endurance performance.[19]

Maksud and Coutts established norms for Cooper's 12 minute run-walk test for young males. The subjects were 80 boys ranging in age from 11 to 14 years. In a sub-sample of 17 individuals, Max $\dot{V}O_2$ was measured by a modification of the Taylor treadmill procedure. The Pearson product-moment formula was utilized to determine a coefficient of r=.65 between Max $\dot{V}O_2$ and performance.[20]

Oxygen uptake and running performance in young and middle aged males was researched by Ribisl and Kachadorian. The subjects performed the 60 yard dash, 100 yard dash,

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[19] Victor L. Katch, "The Role of Maximal Oxygen Intake in Endurance Performance." Paper presented at the National Convention of the A.A.H.P.E.R., Seattle, Washington, 1970.

[20] Michael G. Maksud, and Kenneth D. Coutts, "Application of the Cooper Twelve-Minute Run-Walk Test to Young Males." Research Quarterly, 42:54-59, March, 1971.

220 yard dash, 440 yard dash, 880 yard run, mile run, and the 2 mile run. Max $\dot{V}O_2$ was determined by an intermittent procedure on a motor driven treadmill. Within a subgroup of 11 moderately well trained, college age subjects, the correlations obtained between oxygen uptake and the performance measures increased sequentially as a function of distance. Coefficients of r=-.67, r=-.79, and r=-.85 were obtained for the relationships between Max $\dot{V}O_2$ and the half-, one-, and two-mile runs, respectively. The authors suggested that the two mile run was a valid measure of aerobic capacity.[21]

Katch utilized 35 college males, whose mean age was 21.4 years, to determine the role of Max $\dot{V}O_2$ in predicting running performance. The author ascertained an r=-.55 when the variables were two-mile performance times and maximum oxygen uptake. The conclusion drawn was that prediction of running performance required more than just measuring Max $\dot{V}O_2$. Katch suggested that psychological factors such as motivation and pain tolerance were probably important variables.

In a study concerned with predicting Max $\dot{V}O_2$ from running performance, Wiley and Shaver determined correlation coefficients between Max $\dot{V}O_2$ and running performance in the 440 yard dash, mile run, 2-mile run, and 3-mile run.

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[21] P. M. Ribisl, and W. Kachadorian. "Maximal Oxygen Intake Prediction in Young and Middle-Aged Males." Journal of Sports Medicine and Physical Fitness, 9:17-22, 1969.

Thirty-five untrained males ranging in age from 18 to 25 years served as subjects. The subjects were not allowed to practice any of the running events prior to performance. The relationships obtained between oxygen consumption (ml/kg/min.) and performance increased as a function of distance. Some of the correlations and the variables revealed were: $r=-.29$ between Max $\dot{V}O_2$ and the mile run, $r=-.47$ between Max $\dot{V}O_2$ and the 2-mile run, and $r=-.43$ between Max $\dot{V}O_2$ and the 3-mile run.[22]

D. Summary

The research presented here, comparing predicted and actual measures of Max $\dot{V}O_2$ appears to favor the possibility of substituting the estimated measure for directly determined Max $\dot{V}O_2$. Correlations between the direct measure and the Astrand-Rhyming nomogram ranged from .63 to .92 with a standard error of measurement from $\pm$6.7 to $\pm$14.4. Wiley and Shaver, however, concluded that the nomogram was a poor predictor of Max $\dot{V}O_2$ as measured on a treadmill. When Max $\dot{V}O_2$ was correlated with non-running endurance performance, investigators showed variability in their results. Authors reported relationships as low as .24 and as high as .84. The magnitude of the correlations was larger in three of the studies reviewed when Max $VO_2$ was expressed in L/min. The research indicates

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[22] Wiley and Shaver, Loc. cit.

that for a running performance to be utilized as an indicator of Max $\dot{V}O_2$, it must be primarily an aerobic event. Events such as the 12 minute run-walk, 2-mile run, and 3-mile run appear to be good indicators of cardiovascular endurance. For running performances at shorter distances, other variables appear to play a more prominent role in performance. Among these variables are psychological factors such as motivation and pain tolerance.

CHAPTER III

PROCEDURES

This chapter is concerned with the methods utilized during the collection and analysis of the data necessary to determine interrelationships between the variables: predicted Max $\dot{V}O_2$, actual Max $\dot{V}O_2$ and performance in the half-mile, mile, and three mile runs. It is divided into four sections: (a) selection of subjects; (b) apparatus; (c) testing procedures; and (d) treatment of data.

A. Selection of Subjects

A total of 60 male students attending Appalachian State University volunteered for the study. Of these, 33 satisfactorily completed all of the required tests and were actually used as subjects. The total subject population was divided into three distinct sub-populations for the purpose of subject selection. The three sub-groups each containing 11 volunteers were then selected as follows:

1. Non-majors chosen from three required physical education activities courses;

2. Majors selected from three skill and technique (methods) courses;

3. The group of trained runners was composed of

nine members of the Appalachian State University Track Team and two graduate students who were undergoing similar competitive training.

As a prerequisite, majors and non-majors were not allowed to be members of a varsity team. This protocol was used in hopes of obtaining groups representative of three varient skill levels. The means and standard deviations for the physical characteristics of the subjects are presented in Table 1, (See page 25).

B. Apparatus

1. <u>Apparatus for Estimating Max $\dot{V}O_2$</u>

Submaximal workloads for the predicted measure of Max $\dot{V}O_2$ were performed either on a Monark Bicycle Ergometer[1] or a Schwinn Ergo Metric Exerciser.[2] With the resistance established, an electric metronome was utilized to maintain the desired revolutions per minute. Stopwatches were utilized in the process of obtaining heart rate by palpation and to determine total riding time. Heart rate response to a submaximal load was then substituted into tables provided by Astrand and Rodahl[3]

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[1] Distributed by Quinton Instruments Co., Seattle, Washington.

[2] Manufactored by the Schwinn Bicycle Co., 1965 North Kostner Avenue, Chicago, Illinois 60639.

[3] Per-Olof Astrand, and Kaare Rodahl, <u>Textbook of Work Physiology</u>, (New York: McGraw-Hill Book Company, 1970) pp. 619-27.

Table 1

Means and Standard Deviations for the Physical Characteristics of the Subjects

| Characteristics | Statistic | Group | | | |
|---|---|---|---|---|---|
| | | Non-Major | Major | Trained Runner | Composite |
| Age | $\overline{X}$ | 19.1 | 20.8 | 20.9 | 20.2 |
| | s | 1.5 | 1.5 | 2.3 | 1.78 |
| Height (in.) | $\overline{X}$ | 71.20 | 70.61 | 68.48 | 70.15 |
| | s | 2.57 | 5.11 | 2.71 | 3.23 |
| Weight (lbs.) | $\overline{X}$ | 158.5 | 171.5 | 136.7 | 155.5 |
| | s | 23.9 | 22.5 | 15.5 | 25.0 |

to predict Max $\dot{V}O_2$.

2. Apparatus Used in the Determination of Direct Max $\dot{V}O_2$

Before the administration of the direct measure of oxygen consumption, gas temperature and barometric pressure were recorded. The subject was then requested to pedal a Monark Bicycle Ergometer to the cadence, 65 rpm., established by a metronome. In response to the subject's signal, an eighteen inch fan could be directed toward the participant. During the ride, the subject inhaled and exhaled through a Collins Rubber Mouthpiece, P-530[4] that was attached to a Triple "J" Valve.[5] To insure that breathing occurred only through the mouthpiece, a Collins Rubber Tipped Nose Clip, P-358[6] was placed on the subject's nose. A Collins Five Way Control Valve[7] enabled the investigator to collect an individual's expired gas at desired intervals. These collections were accomplished by means of Douglas Gas Bags.[8] Three way valves attached to each bag enabled the author to collect and hold the gas in each of the four bags utilized. The volume of ambient air flowing into the system was measured

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[4]Manufactured by Warren E. Collins, Inc., Boston, Massachusetts.

[5]Ibid.

[6]Ibid.

[7]Ibid.

[8]Ibid.

by a gasometer[9] calibrated at one cubic foot per revolution. The reading obtained from this instrument was multiplied by 28.317 to convert the volume to liters.

The collected gas was analyzed for the percentage of oxygen it contained by a Beckman $O_2$ Analyzer, Model E2.[10] Carbon dioxide content of the same gas was determined by a Beckman Medical Gas Analyzer, Model LB-1.[11] The above two instruments were calibrated before and during the testing sessions with standard gases obtained from the Air Products Co.[12] After the ride, the exhaust hose was attached to a motor blower so the flow of expired gas could be directed into the analyzers. Readings were taken after the gas in the bags being analyzed was extracted for a one minute period. The first thirty seconds cleared the system so only gas from the bag in question was flowing through the system. During the second thirty seconds, flow was directed through the oxygen and the carbon dioxide analyzers to allow the instruments to stabilize.

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[9]American Meter Co., Philadelphia, Pennsylvania.

[10]Manufactured by Beckman Instruments, Inc., Scientific Instruments Division, 2500 Harbor Blvd., Fullerton, Co. 92634.

[11]Ibid.

[12]Obtained from Air Products Co., Specialty Gases Dept., Allentown, Pennsylvania.

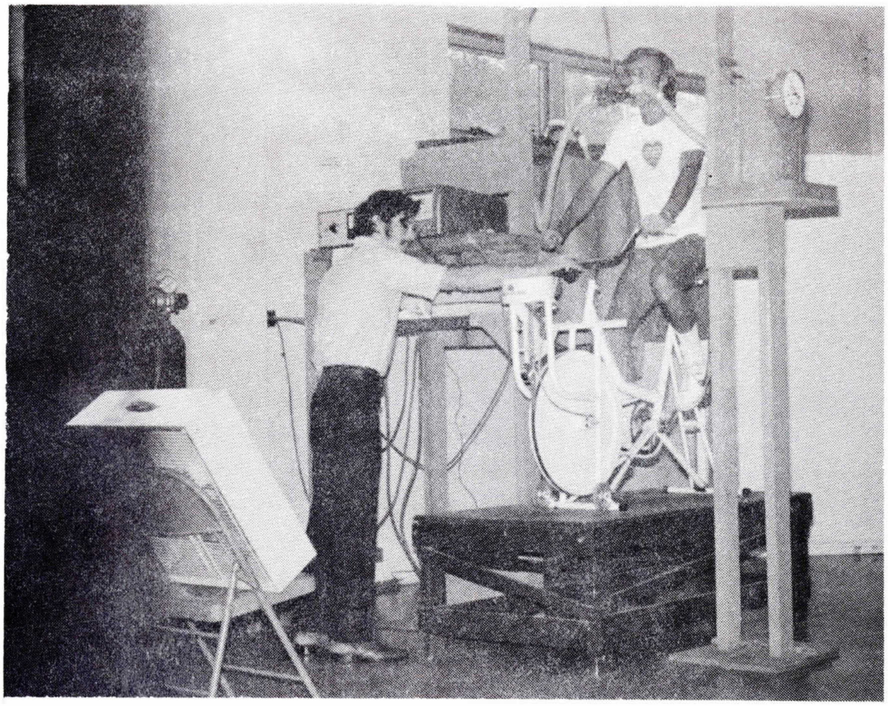

Figure 1

Apparatus for Collection of Expired Gas

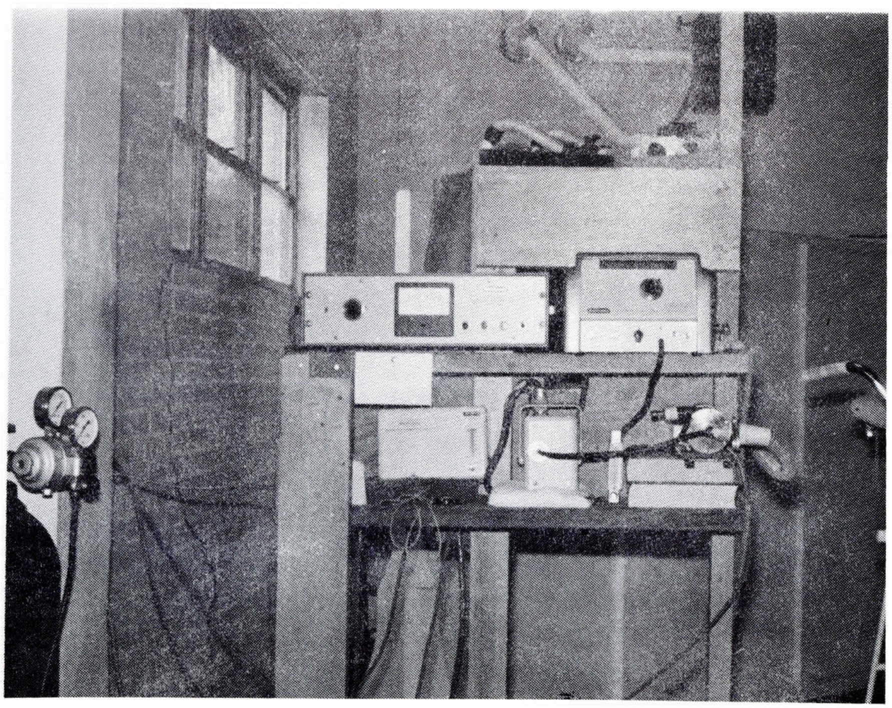

Figure 2

Beckman $O_2$ Analyzer Model E2 and Beckman Medical Gas Analyzer Model LB-1

## C. Testing Procedure

### 1. Conditions

Testing sessions were administered in the following order: (1) the predicted measure Max $\dot{V}O_2$, (2) the direct measure of Max $\dot{V}O_2$, and (3) the various running performances. The height and weight of each subject were recorded prior to the indirect measure of Max $\dot{V}O_2$. Weight was again accessed before the direct oxygen uptake was measured. All tests were performed twice with the first administration serving as a learning-familiarization situation for the individual involved. In all cases, at least one day's rest was allowed between test administrations. The author attempted to reschedule subjects at approximately the same time of day as the individual's previous test. Subjects were asked not to eat or perform any strenuous exercise for three hours before the final evaluations in each testing area.

The laboratory was not equipped with temperature or humidity controls. The heat stress factors, however, remained reasonably constant as indicated by the fact that the wet and dry bulb temperatures ranged from 69° F to 78° F and 55° F to 68° F, respectively, during the testing sessions.

### 2. Predicted Maximum Oxygen Uptake

The Bicycle Ergometer Test as described by Astrand and Rodahl was administered to all subjects. Each subject performed the test on two separate days and the first test, in addition to acting as a learning-familiarization situation, enabled the investigator to determine a workload for each subject that would elicit a heart rate response between 150 and 170 beats per minute.[13] The desirability of a heart rate response in this range has been documented by Astrand.[14]

The basic test protocol required that each subject ride the bicycle ergometer at a rate of 50 rpm for at least six minutes. Prior to performance, the seat and handle bars were adjusted to facilitate optimum pedaling efficiency. In the last twenty seconds of each minute during the ride, the investigator recorded the number of seconds it took the individual's heart to beat 30 times. The heart rate was taken by the investigator at the carotid artery or at the intercostal space between the fifth and sixth ribs in line with the left nipple. The researcher had obtained considerable experience in the use of this palpulatory procedure for the determination of heart rate prior to the initiation of this project. The time per 30 heart beats data was later converted into

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[13] Per-Olof Astrand and Kaare Rodahl, Textbook of Work Physiology, (New York: McGraw-Hill Book Co., 1970), pp. 617-27.

[14] Per-Olof Astrand and Irma Rhyming, "A Nomogram for Calculation of Aerobic Capacity from Pulse Rate during Submaximal Work", Journal of Applied Physiology, 7:218-21, September, 1954.

heart beats per minute by utilization of conversion tables provided by Astrand and Rodahl.[15]

The subject was considered to have achieved a steady state when two consecutive heart rates of the fifth and sixth minutes differed by no more than five beats per minute. If a steady state had not been reached within six minutes, the exercise was continued until such a state existed. The two heart rates that denoted a steady state were then averaged and this figure was applied to the Astrand-Rhyming nomogram[16] to determine the subject's predicted maximum oxygen uptake.

3. Direct Maximum Oxygen Uptake

In obtaining direct maximum oxygen uptake, the subject was seated on a Monark Bicycle Ergometer and the seat was adjusted so an individual's knee was close to full extension. While the apparatus was being set up, the participant was informed of the kind of performance required. The individual was told that the ride would consist of pedaling the ergometer to the beat of a metronome until the subject was unable to maintain the cadence. Information regarding workload increases every three minutes and the requirement of a two minute warning before fatigue was also provided.

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[15] Astrand and Rodahl, Loc. cit.

[16] Ibid.

Subsequent to the explanation of the procedure to be utilized, the respiratory valves were put into place. This procedure involved connecting inch and a half diameter plastic tubing to the intake and exhaust sides of the Triple "J" Valve. The tubing from the intake connection was then attached to the gasometer and tubing from the exhaust connection was fastened to the five-way control valve. The entire valve assembly and mouthpiece was suspended by rubber tubing so the height of the assembly could be adjusted to a position the subject considered confortable. When the above operation was completed, the nose clip was fastened so a subject inhaled and exhaled only through the respiratory valves.

The subject then began to pedal at a rate of 130 beats per minute, which resulted in a pedal speed of 65 revolutions per minute. A speed of between 60 and 70 revolutions per minute has been shown by previous research to be the most efficient.[17] An initial load of 390 kpm/min. served as a warm up and the first actual workload was performed at 780 kpm/min. The participant then rode in increments of three minutes.

At the end of each increment, the workload was increased by 195 kpm/min. unless a heart rate response of less than 120 beats per minute was obtained during the

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[17] Lars Hermansen, and Bengt Saltin. "Oxygen Uptake during Maximal Treadmill and Bicycle Exercise." Journal of Applied Physiology, 26:31-37, January, 1969.

last 20 seconds of an increment. In this case, the workload was increased by 390 kpm/min. The test continued until the subject was unable to maintain the required workload. The individual was instructed to give approximately a two minute warning via a hand signal before the above point was reached. The investigator monitored each participant's heart rate in a manner described under the heading, Predicted Maximum Oxygen Uptake, and verbally assisted the subject in making the "point of fatigue" decision. The first administration of this test and verbal motivation by the researcher were also utilized in an attempt to obtain a maximum effort and the desired two minute warning. The mean and standard deviation of the participant's final heart rates for the test's second administration are presented in Chapter IV. Throughout the ride, a fan was situated in front of the ergometer. This aided the evaporation and convection processes, thereby helping to maintain the body's thermal balance. During the second ride, expired gas was collected during the last minute of each increment until the termination warning was given. At this time, consecutive one minute collections were made. In some cases, however, subjects were unable to complete the last minute and partial collections of 30 or 45 seconds were used. Each bag was analyzed for oxygen and carbon dioxide content by the instruments described earlier. After all the bags were analyzed, the system was evacuated and made ready for the next subject.

4. Running Performances

All subjects ran each of the following distances twice: half-mile, mile, and three mile. Times were recorded to the nearest second with the fastest time of the two runs at each distance used as the measure of performance. Whenever possible, the researcher on the basis of the first run scheduled those individuals with similar times together for the second performance. This was done in an attempt to enhance performance and thus obtain the most representative data.

For all trials, the participants were asked to perform a maximum effort. The concept of pace was explained and examples presented. At the end of each lap, the investigator called out the time at that point and the number of laps that remained. For the three mile trials, the 440 yard all-weather track was marked off into eight 55 yard segments. Subjects were encouraged to run the whole distance as rapidly as possible and were not allowed to walk more than one-eighth (55 yards) of a lap at a time.

### D. Treatment of Data

Oxygen uptake data were obtained by using the FORTRAN program for the reduction of open-circuit data.[18] After the calculation of oxygen uptake in each bag, the highest value obtained was considered to be an individual's Max $\dot{V}O_2$. The program and resultant data were processed at

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[18]Jay T. Kearney and G. Alan Stull, "A FORTRAN Program for the Prediction of Open-Circuit Data," Research Quarterly, 42:223-28, May, 1971.

the Computer Center of Appalachian State University. The computer programs were utilized because the time spent analyzing the data was reduced and the mathematical calculations produced were exact.

Correlations were calculated by the Pearson product-moment machine formula between the following variables: direct Max $\dot{V}O_2$ (L/min.), predicted Max $\dot{V}O_2$ (L/min.), direct Max $\dot{V}O_2$ (ml/kg/min.), predicted Max $\dot{V}O_2$ (ml/kg/min.), and half-mile, mile, and three mile run times. The significance of these relationships was determined by application of a t-test. A t-test applicable for correlated samples was also utilized to determine whether or not the differences between the relationships for the predicted and actual measures of Max $\dot{V}O_2$ (ml/kg/min.) and the various running performances were significant. In addition, an ANOVA was applied to the differences among the three groups regarding direct Max $\dot{V}O_2$ (ml/kg/min.), predicted Max $\dot{V}O_2$ (ml/kg/min.), and half-mile, mile, and three mile run times.

# CHAPTER IV

# RESULTS AND DISCUSSION

This chapter is concerned with the presentation and discussion of the results of the present investigation. The material is divided into five sections. The first is concerned with descriptive statistics. Some of the descriptive statistics are analyzed in the second section to determine the significance of the differences among the means of each sub-group regarding predicted Max $\dot{V}O_2$, actual Max $\dot{V}O_2$, and the various running performances. The third deals with the relationship obtained between predicted Max $\dot{V}O_2$ and actual Max $\dot{V}O_2$. The relationships between the predicted and actual measures of oxygen uptake and the various running performances are presented in the fourth section. Finally, the results of this study are discussed and compared to other investigations.

## A. Descriptive Statistics

Means and standard deviations for predicted Max $\dot{V}O_2$, actual Max $\dot{V}O_2$, maximum heart rate during the test, and the times acquired for the various running performances are presented in Table 2. In all sub-groups as well as the composite group, predicted Max $\dot{V}O_2$ was higher than actual

Max $\dot{V}O_2$. This variation between the two oxygen uptake values was present when Max $\dot{V}O_2$ was expressed as L/min. as well as when the influence of body weight (ml/kg/min.) was taken into consideration. Values for the predicted measure (ml/kg/min.) were 48.27, 46.45, and 58.55 for the non-majors, majors, and trained runners, respectively. The values for the same groups regarding actual Max $\dot{V}O_2$ were 41.13, 41.23, and 50.54, ml/kg/min.

Inspection of oxygen uptake values reported in Table 2 revealed that predicted Max $\dot{V}O_2$ (L/min.) and direct Max $\dot{V}O_2$ (L/min and ml/kg/min.) increases sequentially as the degree of skill increases. In the case of predicted oxygen uptake (ml/kg/min.), the values obtained were 48.27, 46.25, and 58.55 for the non-majors, majors, and trained runners.

The descriptive statistics for the heart rates recorded during the actual measure of Max $\dot{V}O_2$ are also presented in Table 2. The mean value for the composite of the three sub-groups was 202.74. The mean values reported for each of the subgroups were 213.14 for non-majors, 203.00 for majors and 195.20 for trained runners.

Regarding running performances at each of the three distances, the sub-groups again showed the tendency toward improved performance as the skill level increased. This was most evident in the mile, where times of 6:18.5, 5:51.5, and 4:47.0 were reported for the non-majors, majors, and trained runners, respectively.

B. Analysis of Variance

The ANOVA summary table, Table 3, revealed that significant differences existed among the means of each of the sub-groups regarding predicted Max $\dot{V}O_2$ (ml/kg/min.), actual Max $\dot{V}O_2$ (ml/kg/min.) and the various running performances. Tukey's test was applied to determine the location of any significant differences. The summary of these analyses, reported in Table 4, reveal that the trained runners exhibited significantly higher mean values for both measures of oxygen uptake and significantly faster times at all distances than either the majors or the non-majors. Additionally, the major group was significantly better than the non-major group for the half and one mile runs. The actual differences for these runs were 12.5 and 27.0 seconds, respectively.

C. Relationship between Predicted Max $\dot{V}O_2$ and Actual Max $\dot{V}O_2$

The relationships between the predicted and actual measures of oxygen uptake, expressed in L/min. and ml/kg/min. are presented in Table 5. The magnitude of the correlations was higher when Max $\dot{V}O_2$ was expressed in ml/kg/min. for the non-majors, r=.65, majors, r=.73, and composite groups, r=.73. These correlations were all statistically significant. For the trained runners the magnitude of the relationship was greater when Max $\dot{V}O_2$ was expressed in terms of L/min. Specifically, a correlation of r=.52 resulted when oxygen

Table 2

Descriptive Statistics for Predicted Max $\dot{V}O_2$, Actual Max $\dot{V}O_2$, Heart Rate during the Actual Measure and Run Times for Various Running Performances

| Variable | Statistic | Group | | | |
|---|---|---|---|---|---|
| | | Non-Major | Major | Trained Runner | Composite |
| Predicted Max $\dot{V}O_2$ (l/min.) | $\overline{X}$ | 3.42 | 3.58 | 3.61 | 3.54 |
| | s | .72 | .54 | .54 | .59 |
| Predicted Max $\dot{V}O_2$ (ml/kg/min.) | $\overline{X}$ | 48.27 | 46.45 | 58.55 | 51.09 |
| | s | 10.65 | 7.33 | 7.53 | 9.96 |
| Actual Max $\dot{V}O_2$ (l/min.) | $\overline{X}$ | 2.91 | 3.15 | 3.09 | 3.05 |
| | s | .41 | .31 | .27 | .34 |
| Actual Max $\dot{V}O_2$ (ml/kg/min.) | $\overline{X}$ | 41.13 | 41.23 | 50.54 | 44.30 |
| | s | 7.71 | 5.38 | 4.77 | 7.40 |
| Actual Max $\dot{V}O_2$ Heart Rate | $\overline{X}$ | 213.14 | 203.00 | 195.20 | 202.74 |
| | s | 11.26 | 12.55 | 6.48 | 12.42 |
| Half-Mile[a] | $\overline{X}$ | 2:39 | 2:27.5 | 2:08 | 2:24.5 |
| | s | :15 | :09.5 | :08.5 | :17.5 |
| Mile[a] | $\overline{X}$ | 6:18.5 | 5:51.5 | 4:47 | 5:39 |
| | s | :36.5 | :23.5 | :14 | :47 |
| Three Mile[a] | $\overline{X}$ | 22:04 | 21:30.5 | 16:23.5 | 19:59.5 |
| | s | 2:14 | 1:34 | :57 | 3:03.5 |

[a]All time variables are reported in minutes and seconds to the nearest tenth of a second.

Table 3

Summary Table of ANOVA for Predicted Max $\dot{V}O_2$, Actual Max $\dot{V}O_2$, and Run Times for the Half-Mile, Mile, and Three Mile

| Source of Variance | df | SS | MS | F |
|---|---|---|---|---|
| Predicted Max $\dot{V}O_2$ (ml/kg/min.) | | | | |
| Treatment | 2 | 935.09 | 467.55 | 6.27[a] |
| Error | 30 | 2237.64 | 74.59 | |
| Total | 32 | 3172.73 | 542.14 | |
| Actual Max $\dot{V}O_2$ (ml/kg/min.) | | | | |
| Treatment | 2 | 641.97 | 320.99 | 8.66[a] |
| Error | 30 | 1111.49 | 37.05 | |
| Total | 32 | 1753.46 | 358.04 | |
| Half-Mile | | | | |
| Treatment | 2 | 1.51 | .76 | 19.00[a] |
| Error | 30 | 1.08 | .04 | |
| Total | 32 | 2.59 | .80 | |
| Mile | | | | |
| Treatment | 2 | 13.53 | 6.77 | 35.63[a] |
| Error | 30 | 5.77 | .19 | |
| Total | 32 | 19.30 | 6.96 | |
| Three Mile | | | | |
| Treatment | 2 | 215.40 | 107.70 | 38.74[a] |
| Error | 30 | 83.39 | 2.78 | |
| Total | 32 | 298.79 | 110.48 | |

[a]Significant at the .05 level.

Table 4

Summary Tables for Tukey's Test for Predicted Max $\dot{V}O_2$, Actual Max $\dot{V}O_2$, and Run Times for the Half-Mile, Mile, and Three Mile

| Variable | Mean | Actual Difference | | Critical Difference |
|---|---|---|---|---|
| Predicted Max $\dot{V}O_2$ | | | | |
| Non-major | 48.27 | | | |
| | | 1.82 | | |
| Major | 46.45 | | 12.10[a] | 9.07 |
| | | 10.28[a] | | |
| Trained runner | 58.55 | | | |
| Actual Max $\dot{V}O_2$ | | | | |
| Non-major | 41.13 | | | |
| | | .10 | | |
| Major | 41.23 | | 9.41[a] | 6.39 |
| | | 9.31[a] | | |
| Trained runner | 50.54 | | | |
| Half-Mile | | | | |
| Non-major | 2:39 | | | |
| | | :12.5[a] | | |
| Major | 2:27.5 | | :31.0[a] | :01 |
| | | :19.5[a] | | |
| Trained runner | 2:08 | | | |
| Mile | | | | |
| Non-major | 6:18.5 | | | |
| | | :27[a] | | |
| Major | 5:51.5 | | 1:31.5[a] | :27 |
| | | 1:04.5[a] | | |
| Trained runner | 4:47 | | | |
| Three Mile | | | | |
| Non-major | 22:04 | | | |
| | | :33.5 | | |
| Major | 21:30.5 | | 5:40.5[a] | 2.55 |
| | | 5:07[a] | | |
| Trained runner | 16:23.5 | | | |

[a]Significant at the .05 level.

uptake was reported in L/min.; however, with the addition of body weight, the relationship dwindled to r=.36.

Table 5

Relationship between Predicted Max $\dot{V}O_2$ and Actual Max $\dot{V}O_2$

| Units | Group | | | |
|---|---|---|---|---|
| | Non-Major | Major | Trained Runner | Composite |
| L/min. | .52 | .69[a] | .52 | .57[a] |
| ml/kg/min. | .65[a] | .73[a] | .36 | .73[a] |

[a]Significant at the .05 level.

D. Relationships between Predicted and Actual Measures of Max $\dot{V}O_2$ and Various Running Performances

Generally, the relationships between actual and predicted Max $\dot{V}O_2$ (L/min.) and performance in the half-mile, mile, and three mile, reported in Table 6, failed to reach statistical significance. In four instances, negative correlations between actual Max $\dot{V}O_2$ (L/min.) and performance were significant. Three of these relationships recorded for the non-major sub-group, were r=-.82, r=-.87, and r=-.74 for the half-mile, mile, and three mile times, respectively. The fourth significant correlation was reported for the composite group at the one mile distance. Additionally, the relationship, r=.63, between predicted Max $\dot{V}O_2$ and the half-mile performance for the trained runners was found to be significant.

When Max $\dot{V}O_2$ was expressed in ml/kg/min., the relationships for the composite group between both measures of oxygen uptake and running performance were all significant (Table 7). The magnitude of these correlations increased as a function of distance when the predicted measure was compared to performance coefficients of r=-.45 for the half-mile, r=-.56 for the mile, and r=-.67 for the three mile were obtained. The relationships between actual Max $\dot{V}O_2$ and the same variables were r=-.69, r=-.73, and r=-.75.

In order to ascertain the significance of the correlation coefficients determined between the two measures of oxygen uptake and the various running performances, a t-test for significance of the difference between two correlation coefficients for correlated samples was utilized. The results in Table 8 indicate that significant differences existed between the coefficients obtained within the trained runners group at the half and one mile distances. For the half-mile, the relationships between performance and actual and predicted measures of oxygen uptake were r=.40 and r=-.42, respectively. The corresponding coefficients for the mile were r=.22 and r=-.51.

As an alternative to this statistical test, the coefficient of determination is also presented in Table 8. Perusal of these values should suggest to the reader that, although most of the relationships were not significantly different, rather sizable differences do exist relative to the proportion of explained variance.

Table 6

Relationship between Actual and Predicted Max $\dot{V}O_2$ (L/min.) and Running Performance

| Distance | Group: Non-Major | Major | Trained Runner | Composite |
|---|---|---|---|---|
| Half-Mile | | | | |
| Actual Max $\dot{V}O_2$ | -.82[a] | .58 | -.01 | -.32 |
| Predicted Max $\dot{V}O_2$ | -.25 | .30 | .63[a] | -.04 |
| Mile | | | | |
| Actual Max $\dot{V}O_2$ | -.87[a] | .34 | -.22 | -.36 |
| Predicted Max $\dot{V}O_2$ | -.40 | .19 | .40 | -.56[a] |
| Three Mile | | | | |
| Actual Max $\dot{V}O_2$ | -.74[a] | -.03 | -.30 | -.33 |
| Predicted Max $\dot{V}O_2$ | -.45 | -.28 | -.07 | -.26 |

[a]Significant at the .05 level.

Table 7

Relationship between Actual and Predicted Max $\dot{V}O_2$ (ml/kg/min.) and Running Performance

| Distance | Group | | | |
|---|---|---|---|---|
| | Non-Major | Major | Trained Runner | Composite |
| Half-Mile | | | | |
| Actual Max $\dot{V}O_2$ | -.73[a] | -.04 | -.42 | -.69[a] |
| Predicted Max $\dot{V}O_2$ | -.40 | -.12 | .40 | -.45[a] |
| Mile | | | | |
| Actual Max $\dot{V}O_2$ | -.72[a] | -.25 | -.51 | -.73[a] |
| Predicted Max $\dot{V}O_2$ | -.50 | -.25 | .22 | -.56[a] |
| Three Mile | | | | |
| Actual Max $\dot{V}O_2$ | -.67[a] | -.37 | -.58 | -.75[a] |
| Predicted Max $\dot{V}O_2$ | -.55 | -.53 | -.30 | -.67[a] |

[a]Significant at the .05 level.

Table 8

Coefficients of Determination and the Difference between Correlation Coefficients

| Performance | Predicted Max $\dot{V}O_2$ $r_1$ | $r_1^2$ | Actual Max $\dot{V}O_2$ $r_2$ | $r_2^2$ | t $r_1 - r_2$ |
|---|---|---|---|---|---|
| Half-Mile | | | | | |
| Non-major | -.40 | .16 | -.73 | .53 | -1.649 |
| Major | -.12 | .01 | -.04 | .00 | .311 |
| Trained Runner | .40 | .16 | -.42 | .18 | 22.347[a] |
| Composite | -.45 | .20 | -.69 | .48 | -1.761 |
| Mile | | | | | |
| Non-major | -.50 | .25 | -.72 | .52 | -1.771 |
| Major | -.25 | .06 | -.25 | .06 | |
| Trained Runner | .22 | .05 | -.51 | .26 | 2.516[a] |
| Composite | -.56 | .31 | -.73 | .53 | -1.859 |
| Three Mile | | | | | |
| Non-major | -.55 | .30 | -.67 | .45 | -.602 |
| Major | -.53 | .28 | -.37 | .14 | .726 |
| Trained Runner | -.30 | .09 | -.58 | .34 | -.865 |
| Composite | -.67 | .45 | -.75 | .56 | -.201 |

[a]Significant at the .05 level.

## E. Discussion

### 1. Descriptive Statistics

Values for the predicted measure of Max $\dot{V}O_2$ (ml/kg/min.) in this study for non-majors, majors, and trained runners were 48.27, 46.45, and 58.55, respectively. Using similar sub-groups, Kearney and Byrnes[1] reported predicted values of 41.00, 43.80, and 57.29. Although there is some disagreement regarding non-majors and majors, the composite value of 51.09 obtained in this investigation is similar to the Kearney and Byrnes composite of 49.97.

Actual Max $\dot{V}O_2$ (ml/kg/min.) ranged from 41.13 for non-majors to 50.54 for trained runners. Falls revealed a Max $\dot{V}O_2$ (ml/kg/min.) of 39.46 for fairly active, young adults, much lower than the figures obtained in the present study.[2] Other authors have also investigated oxygen uptake capacity of young adults and reported values of 50.00[3], 50.60[4],

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[1]Jay T. Kearney and William C. Byrnes, "The Relationship between Running Performance and Predicted Maximum Oxygen Uptake among Divergent Ability Groups," Research Quarterly: (in print).

[2]Harold B. Falls, et. al., "Estimation of Maximum Oxygen Uptake in Adults from A.A.H.P.E.R. Youth Fitness Test Items," Research Quarterly, 37:192-201, May, 1966.

[3]Jack H. Wilmore, "Maximal Oxygen Intake and Its Relationship to Endurance Capacity on a Bicycle Ergometer," Research Quarterly, 40:203-10, March, 1969.

[4]Jack F. Wiley and Larry G. Shaver, "Prediction of Maximum Oxygen Intake from Running Performances of Untrained Young Men," Research Quarterly, 43:89-93, March, 1972.

and 57.35[5] ml/kg/min. These figures for normally active adults are comparable to the value reported for the trained runners in the present investigation. Magel and Faulkner[6], however, ascertained a Max $\dot{V}O_2$ of college varsity swimmers to be 55.00 ml/kg/min., which is similar to the value reported for trained runners herein.

In an attempt to determine whether the times recorded for non-majors and majors were representative of the particular group concerned, some of the literature dealing with similar subject populations and distances was reviewed. In this study, the non-majors' performances of 6:18.5 in the mile and 22:04 in the three mile were not in agreement with the performances of 35 untrained males in a study by Wiley and Shaver.[7] These authors revealed times of 7:40 and 25.87 for the mile and three mile, respectively. In the Kearney and Byrnes study, the following times for majors were reported for the half-mile and mile, 2:53 and 5:48[8] similar to the majors in this investigation who performed the half-mile in 2:46 and the mile in 5:51.5.

It is of interest to note the heart rate response

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[5] P. M. Ribisl and W. Kachadorian. "Maximal Oxygen Intake Prediction in Young and Middle-Aged Males." Journal of Sports Medicine and Physical Fitness, 9:17-22, 1969.

[6] John R. Magel and John A. Faulkner. "Maximum Oxygen Uptakes of College Swimmers." Journal of Applied Physiology, 22:929-33, May, 1967.

[7] Wiley and Shaver, Loc. cit.

[8] Kearney and Byrnes, Loc. cit.

patterns to the determination of actual Max $\dot{V}O_2$. The respective values for non-majors, majors, and trained runners were 213.14, 203.00, and 195.20. Theoretically, one might suggest that the probably increased efficiency of the heart associated with training facilitated optimal achievement levels of cardiac output at lower rates of contraction.

2. Analysis of Variance

The analyses of variance and subsequent post hoc tests calculated for predicted Max $\dot{V}O_2$, actual Max $\dot{V}O_2$, half-mile, mile and three mile run times resulted in significant differences among the means of the trained runner sub-group and both the major and non-major subgroups. This was as expected due to the extensive training accomplished by the runners. The lack of significance between the means for predicted Max $\dot{V}O_2$, actual Max $\dot{V}O_2$, and three mile performance concerning non-majors and majors was unexpected but partially justified when the author referred to the aerobic component of the three mile run. According to Astrand and Rodahl, a maximal performance resulting in times of either 22:04 (non-majors) or 21:30.5 (majors) was about 7 per cent anaerobic and 93 per cent aerobic.[9] Therefore, the three mile run, basically an aerobic event should have revealed no significant

[9] Per-Olof Astrand and Kaare Rodahl, Textbook of Work Physiology (New York: McGraw Hill Co., 1970), pp. 303-04.

difference between non-major and major performance since both groups were not significantly different in the measurement of predicted or actual oxygen uptake.

It would appear that the interrelations between aerobic and anaerobic components of a maximum running performance may also aid in explaining the significantly better mean times of majors over non-majors in the half-mile and mile runs. Times recorded by both groups correspond to ratios of aerobic to anaerobic components of about 1 to 1 for the half-mile and about 3 to 7 for the mile.[10] The greater anaerobic components of these tasks may have given the majors a slight advantage due to two related factors. First, the majors by nature of the curriculum were more experienced at running. The second factor was that majors may have been better prepared for the psychological components of endurance involving motivation and pain tolerance.

3. Relationships between Predicted Max $\dot{V}O_2$ and Actual Max $\dot{V}O_2$

The composite relationship between the two measures of Max $\dot{V}O_2$ (L/min.) was r=.57, similar to the coefficient of r=.63 when these variables were researched by Glassford, et. al.[11] When body weight was considered by expressing oxygen uptake in ml/kg/min., the composite correlation rose

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[10] Ibid.

[11] A. G. Glassford, et. al., "Comparison of Maximal Oxygen Uptake Values Determined by Predicted and Actual Methods," Journal of Applied Physiology, 20:609-13, 1965.

to r=.73, which was significant. This value compared favorably with relationships found by the following authors utilizing the same variables: deVries, r=.74[12], Glassford, et. al., r=.65[13], and Teräslinna, r=.69.[14]

When analyzed by sub-groups, significant correlations for the non-majors and majors revealed were r=.65 and r=.73, respectively. An r=.36 was calculated for the trained runner sub-group. The above relationships may have been affected by the small number of subjects within each sub-group.

In each of the groups, Max $\dot{V}O_2$ as predicted from the Astrand-Rhyming nomogram was less than a perfect approximation of actually determined Max $\dot{V}O_2$. This discrepancy was the greatest for the group of trained runners. It appears that in this group in particular, factors other than heart rate response to a submaximal work load are important in predicting Max $\dot{V}O_2$. On the basis of theoretical considerations, these additional factors would include arteriovenous oxygen difference, as well as cardiac and enzymatic efficiency.

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[12]Herbert A. deVries, Physiology of Exercise for Physical Education and Athletics, (Dubuque, Iowa: Wm. C. Brown Co., 1966), p. 209.

[13]Glassford, Loc. cit.

[14]P. Teräslinna, et. al., "Nomogram by Astrand and Rhyming as a Predictor of Maximum Oxygen Intake", Journal of Applied Physiology, 21:513-15, 1966.

4. Relationships between Predicted and Actual Measures of Max $\dot{V}O_2$ and Various Running Performances

In all cases, except one, the magnitude of the relationship between the oxygen uptake values and running performances was greater when the uptake was expressed relative to body weight. The sole exception, the non-major sub-group, was that actual Max $\dot{V}O_2$ (L/min.) was more highly related to running performances then when expressed as ml/kg/min.

The relationships between Max $\dot{V}O_2$ and performance in the 600 yard run-walk and the 12 minute run-walk have been investigated by a number of authors. When the variables were oxygen uptake (L/min.) and 600 yard run-walk times correlation coefficients of r=-.47[15] and r=-.25[16] were revealed. With the addition of body weight, authors found relationships of r=-.64[17], r=-.62[18], r=-.27[19], r=-.66[20] and r=-.27.[21] The magnitude of the correlations remained high,

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[15]Falls, et. al., Loc. cit.

[16]V. Drake, et. al., "Fitness Performance Tests and Their Relationship to the Maximal Oxygen Uptake of Adults", Canadian Medical Association Journal, 99:844-48, November 1, 1968.

[17]Falls, et. al., Loc. cit.

[18]T. L. Doolittle, and Rollin Bigbee, "The Twelve-Minute Run-Walk: A Test of Cardiorespiratory Fitness of Adolescent Boys," Research Quarterly, 39:491-95, October, 1968.

[19]Drake, Loc. cit.

[20]Kenneth F. Metz, and John F. Alexander, "An Investigation of the Relationship between Maximum Aerobic Work Capacity and Physical Fitness in Twelve-to-Fifteen-Year-Old Boys," Research Quarterly, 41:75-81, March, 1970.

however, when Max $\dot{V}O_2$ and 12 minute run-walk times were the variables. The relationships were r=.90[22], r=.66[23], r=.54[24], and r=.65.[25] The relationships are not exactly comparable to the results of the present investigation due to the different variables studied. Rough comparisons, however, may be made between the distances and the half- and three mile runs herein.

Previous research has revealed disagreement about the magnitude of correlations between Max $\dot{V}O_2$ (ml/kg/min.) and running performances utilized in this study. In 1969, Ribisl and Kachadorian obtained coefficients of r=-.67 for half-mile performances and r=-.79 for mile performances.[26] These figures are similar to the values reported in this study for the composite and non-major groups, regarding actual Max $\dot{V}O_2$. The composite coefficients were r=-.69 for the half-mile and r=-.73 for the mile. Non-majors correlations were r=-.73 and r=-.72 for the half-mile and

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[22] Doolittle and Bigbee, Loc. cit.

[23] John Douglas Gregory, "The Relationship of the Twelve Minute Run to Maximal Oxygen Intake," Master's thesis, Mankato State College, 1970.

[24] Victor L. Katch. "The Role of Maximal Oxygen Intake in Endurance Performance." Paper presented at the National Convention of the A.A.H.P.E.R., Seattle, Washington, 1970.

[25] Michael G. Maksud, and Kenneth D. Coutts, "Application of the Cooper Twelve-Minute Run-Walk Test to Young Males," Research Quarterly, 42:54-59, March, 1969.

[26] Ribisl and Kachadorian, Loc. cit.

mile, respectively. Wiley and Shaver investigated Max $\dot{V}O_2$ (ml/kg/min.) and performances in the mile and three mile runs. The authors reported a correlation of r=-.29 for the mile, and r=-.43 for the three mile.[27] The coefficient for the three mile was much lower than the values obtained herein for the non-majors group. The figures for three mile performances were r=-.67 for the actual measure of Max $\dot{V}O_2$ and r=-.55 for the predicted measure. For a five minute cumulative distance run, Katch utilized college males and reported an r=.61 using an actual measure of Max $\dot{V}O_2$.[28] Kearney and Byrnes found an r=-.30 for majors with the variable predicted Max $\dot{V}O_2$ (ml/kg/min.) and half-mile times compared to this study's, r=-.12.[29]

The relationships between Max $\dot{V}O_2$ (predicted and actual) and running performance increased as a function of distance for the composite group. This agreed with Astrand and Rodahl's concept of anaerobic and aerobic components of a running performance. As the distance increased, a greater requirement was placed on the aerobic capability of the runner. This trend is also in agreement with earlier

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[27] Wiley and Shaver, Loc. cit.

[28] Frank E. Katch, et. al., "Relationship between Individual Differences in a Steady Pace Endurance Running Performance and Maximal Oxygen Intake," Research Quarterly, 44:206-15, May, 1973.

[29] Kearney and Byrnes, Loc. cit.

works.[30, 31, 32] This pattern also held true for the non-majors regarding the predicted measure, the majors regarding both measures, and the trained distance runners regarding the actual measure. These relationships, however, were not significant for the majors and trained runners. For non-majors, correlations with the actual measure as the variable were significant and similar for all performances.

Low positive coefficients were obtained between runners at the half and one mile distances. An attempt to explain this apparent contradiction is based on the various types of distance runners used in the study. The author proposes that the half-milers and milers trained more anaerobically because the two distances have relatively high anaerobic components (half-mile 1:1; mile 3:7). The three milers, on the other hand, trained more aerobically for their event.

It may be that due to these differences in training, the shorter distance men, with a higher ratio of anaerobic to aerobic capacity should have been expected to exhibit superior performance in the half-mile and mile.

The analysis presented in Table 8 tends to indicate that the predicted measure of Max $\dot{V}O_2$ may be substituted for the direct measure of Max $\dot{V}O_2$ for all groups except

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[30] Ibid.

[31] Wiley and Shaver, Loc. cit.

[32] Ribisl and Kachadorian, Loc. cit.

the trained runners sub-group, since no significant differences existed between the relationships between both measures and running performances. Trained runners do not follow this pattern for the shorter running performances. The reader, however, should interpret this finding with some degree of caution. Due to the relatively small number of subjects contained within the subgroups rather substantial differences in the absolute magnitudes of obtained correlation coefficients were required to achieve statistical significance. An alternative tact that might be employed by the reader in order to determine the compatability of reported relationships is to consider the coefficients of determination; proportion of variance explained, $r^2$; in each case, and base subsequent applications on these values.

# CHAPTER V

## SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

### A. Summary

This study investigated the interrelationships between actual Max $\dot{V}O_2$, predicted Max $\dot{V}O_2$, and various running performances of individuals from three subject groups. More specifically, the study attempted to ascertain:

a. The relationship between actual Max $\dot{V}O_2$ and predicted Max $\dot{V}O_2$ within a composite group and each of three sub-groups.

b. The correlations between the variables actual Max $\dot{V}O_2$ (L/min. and ml/kg/min.) and half-mile, mile, and three mile performance times for a composite and three sub-groups.

c. The relationship between predicted Max $\dot{V}O_2$ (L/min. and ml/kg/min.) and performance in the half-mile, mile, and three mile for the composite group and each sub-group.

d. If the correlation coefficients obtained between the predicted and actual Max $\dot{V}O_2$ and running performances were significantly different.

The research involved 33 male college students who ranged in age from 18 to 25 years. Eleven volunteers were tested from each of the following three sub-groups: non-physical education majors, physical education majors, and trained runners. As a prerequisite, non-majors and majors were not allowed to be members of a varsity team. Each subject was tested twice on each of the following five measures: actual Max $\dot{V}O_2$, predicted Max $\dot{V}O_2$, and half-mile, mile, and three mile running performances. The first test administration served as a learning-familiarization situation for the individual involved.

Actual Max $\dot{V}O_2$ was determined by an open-circuit Douglas Bag procedure and predicted Max $\dot{V}O_2$ obtained by application of the Astrand-Rhyming nomogram. The running times were determined on a 440 yard all weather track by the use of a stopwatch. Interrelationships were calculated between the five measures utilizing the Pearson product-moment machine formula. The significance of the differences among the relationships between predicted and actual measures of Max $\dot{V}O_2$ and performance were determined by computation of a t-test statistic.

The correlation coefficients between actual and predicted measures of Max $\dot{V}O_2$ (L/min.) ranged from $r=.52$ to $r=.69$. These relationships were significant for the composite and majors groups. When body weight was added, the magnitudes of the same relationships were $r=.65$, $r=.73$, $r=.36$, and $r=.73$ for the non-majors, majors, trained runners, and the composite groups.

The relationships between the two measures of oxygen uptake (L/min.) and performance in the half-mile, mile, and three mile runs ranged from r=.40 to r=-.87. The correlations reported between actual Max $\dot{V}O_2$ and half-mile, mile and three mile were all significant. These values were r=-.82, r=-.87, and r=-.74, respectively. The magnitude of the relationship between predicted Max $\dot{V}O_2$ and the various running performances fluctuated from r=.63 to r=-.45. The significant relationships among this set of scores included the trained runners at the half-mile and the composite group at the one mile distance.

The relationships between actual oxygen uptake (ml/kg/min.) and all running performances were significant for the non-major and composite groups. The relationships between estimated Max $\dot{V}O_2$ (ml/kg/min.) and running performances of the composite group were also significant. The t values for the differences among the correlations obtained between the predicted and actual measures of Max $\dot{V}O_2$ (ml/kg/min.) were non-significant with two exceptions. These exceptions were the trained runners' coefficients at the half-mile and mile.

B. Conclusions

Within the limitations of this investigation, it may be concluded:

1. The relationships between actual and predicted

Max $\dot{V}O_2$ (L/min.) were significant within the composite and majors groups; however, when oxygen uptake is expressed relative to body weight, significant relationships were found among non-majors and majors as well as the composite group.

2. The relationships between actual Max $\dot{V}O_2$ (L/min.) and the half-mile, mile, and three mile performance times were significant for non-majors at all distances and the heterogenous groups at one mile. When actual Max $\dot{V}O_2$ was expressed in ml/kg/min., significant relationships were revealed for the composite, non-majors, and majors groups.

3. The relationship between predicted Max $\dot{V}O_2$ (L/min.) and performance in the half-mile was significant within the trained runner sub-group. When Max $\dot{V}O_2$ was expressed relative to body weight, the correlations between predicted Max $\dot{V}O_2$ (ml/kg/min.) and performance in the half-mile, mile, and three mile revealed significance in the heterogenous group.

4. The differences between the correlation coefficients obtained between the predicted and actual measures of Max $\dot{V}O_2$ and running performance were generally not significant. The two exceptions to this were the relationships ascertained for the trained runners at the half-mile and mile.

5. The relationship between oxygen uptake and running performance will generally increase as a function of distance.

C. Recommendations for Further Study

As a result of this investigation, the following recommendations for further study are provided:

a. A similar investigation utilizing a larger number of subjects and three skill levels such as non-participants, participants, and trained runners should be conducted.

b. An investigation into the psychological components of endurance performance, such as pain tolerance and motivation would provide additional information relative to their importance.

c. It may be of interest to conduct a similar investigation utilizing female subjects.

d. The interrelationships between predicted and actual measures of oxygen uptake as obtained on a treadmill and various running performances should be determined.

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