Validation of the Original and Modified YMCA Cycle Ergometer Tests

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VALIDATION OF THE ORIGINAL AND MODIFIED YMCA CYCLE ERGOMETER TESTS

by

Joel V. Blakeman

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Health,
Physical Education and Recreation

Western Michigan University
Kalamazoo, Michigan
April 1996
ACKNOWLEDGEMENTS

I would like to take this opportunity to express my thanks to my committee chair, Dr. Patricia Frye, and members, Dr. Roger Zabik and Dr. Mary Dawson, for their unending guidance and support throughout the development of this study. Without their selfless time commitment, motivation, and assistance, the completion of this thesis would have been impossible. I cannot express in words my feelings for what they have done for me. I respect you as professors, mentors, and now as my friends.

I would also like to thank my 46 subjects who endured at least three cycling testing sessions. Without their time commitment and assistance this thesis would not be possible.

Lastly, I dedicate this thesis to my parents, Vernon and Janet Blakeman, for their support and commitment in my development as a person. Without their encouragement, guidance, and love, I would not be where I am today.

Joel V. Blakeman
VALIDATION OF THE ORIGINAL AND MODIFIED YMCA CYCLE ERGOMETER TESTS

Joel V. Blakeman, M.A.
Western Michigan University, 1996

The problem of the study was to determine if a 3-point estimation procedure for the YMCA cycle ergometer submaximal test (YMOD) provided a more valid predictor of maximal oxygen consumption (VO2 max) than the recommended 2-point estimation YMCA procedure for male and female college students ages 18 to 25 years. Apparently healthy subjects (n = 21 females; n = 25 males) completed the ACSM maximal cycle ergometer test, the YMCA test, and the YMOD test. The reliability estimates of modified YMCA max scores, R = .39, was higher than the reliability estimate from the YMCA, R = -.80. ANOVA results indicated that the means of the VO2 max estimates from the YMOD made by regression equation (YMOD-R) and visually (YMOD-V) were not significantly different, and the Pearson correlation between these variables was r = .99. ANOVAs indicated that there was no significant effect of testing order, F(2, 80) = 0.05, p > .05, and that the mean VO2 max estimates from the YMCA, the YMOD, and the ACSM tests were not significantly different, F(2, 80) = 2.97, p > .05. However, the correlations between the ACSM test and the submaximal tests were very low and not statistically significant (p > .05). Therefore, the predictions of VO2 max from the YMCA, YMOD-R, and YMOD-V estimates of VO2 max were found to be unsatisfactory.
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CHAPTER I

INTRODUCTION

Historical Background

During the era of Muscular Christianity in the 1850s, a movement was made toward physical fitness. During this time period, the Young Men's Christian Association (YMCA) was founded. In the YMCA philosophy, the concepts of the body, mind, and spirit are integrated. The YMCA has always emphasized physical fitness, but it was not until the 1960s that plans for a national fitness program emerged. At that time 50 experts from the fields of physical fitness, physiology, and sports medicine drafted a national physical fitness program (Golding, Myers, & Sinning, 1989).

For their national fitness program, the YMCA developed fitness tests, norms, and certifications for physical fitness specialists to administer the tests. In the early 1970s, the YMCA addressed the needs of women and established new guidelines for cardiac rehabilitation, weight reduction, back exercises, school health, and other areas. Then the YMCA established and revised norms and guidelines. The revisions were completed and announced in 1982, when the program, Y's Way to Physical Fitness, was introduced.

The physical fitness test battery produced by the YMCA has two evaluation divisions: (1) medical and (2) fitness. The physical fitness evaluation is composed of five separate components, one of which is a cardiorespiratory evaluation. The YMCA's
cardiorespiratory endurance test is performed on a cycle ergometer. The cycle ergometer test is used to predict the maximum working capacity, referred to as maximal oxygen uptake (VO2 max), of an individual by measuring his or her response to submaximal work. The estimation of the VO2 max in the YMCA test is based on the assumption that the relationship between the exercise intensity and oxygen consumption is linear, an assumption that has been used widely as the basis for estimating aerobic fitness (Morehouse & Miller, 1976). Two heart rate (HR) points are used in the procedure for estimating VO2 max values. It was proposed that using the line of best fit based on 3 HR points, rather than the recommended 2-point method, would give a more accurate estimate of VO2 max values.

Statement of the Problem

The problem was to determine if a 3-point estimation procedure for the YMCA cycle ergometer submaximal test provided a more valid predictor of VO2 max than the recommended 2-point estimation procedure for male and female college students between the ages of 18 and 25 years.

Delimitations

The following delimitations were established for this study:

1. Participants were 50 college student volunteers (25 males and 25 females) 18 to 25 years of age.

2. All participants were classified as apparently healthy, according to American
College of Sports Medicine (ACSM) guidelines (ACSM, 1995).

3. The YMCA test using the 2-point estimation procedure (Golding et al., 1989) and a modification of the same test, using a 3-point estimation procedure (YMOD), were performed for submaximal estimates of VO2 peak.

4. A maximal graded exercise cycle ergometer protocol (ACSM) was used for estimating the criterion VO2 max values (ACSM, 1995).

5. HR was measured with a Polar heart rate monitor (model 61210) for the submaximal test.

6. VO2 max was measured using the Quinton Q-Plex 1 metabolic cart.

7. HR and electrocardiogram (ECG) readings were measured by the Bosch (model 502A) ECG machine.

8. All testing occurred in the Exercise Physiology Lab in the Student Recreation Center, Western Michigan University.

Limitations

This study was limited by the following:

1. Only apparently healthy college-aged students participated in the study, so generalization about the validity of the procedures cannot be made to other populations.

2. The psychological effects resulting from the unusual environment, especially because of the mouthpiece and metabolic cart on the maximal test, could affect subjects' maximal values so that they are underestimates of their true VO2 max values.

3. On the ACSM test some subjects did not attain a respiratory exchange rate (R)
of 1.15 or a plateau in VO2, therefore VO2 max values had to be estimated by VO2 peak values.

Assumptions

The following assumptions have been made about this study:

1. The subjects gave their best effort on each test.

2. The dependent variables were accurately and consistently measured.

3. The random assignment of subjects to testing order could control for any possible learning effect that might occur in the second and third tests.

Hypotheses

The following hypotheses were established for this study:

1. The YMCA test provided a valid estimate of VO2 max.

2. The modified YMCA test, using a 3-point estimation procedure, provided a more accurate estimate of VO2 max than the YMCA test that uses a 2-point estimation procedure.

Definitions of Terms

The following terms were operationally defined for this study:

1. Maximal oxygen consumption (VO2 max): The point at which the oxygen consumption plateaus and shows no further increase with additional workload is referred to as VO2 max (McArdle, Katch, & Katch, 1991).
2. Peak oxygen consumption (VO2 peak): When the generally accepted criteria for the attainment of VO2 max are not met, or test performance appears limited by local factors rather than by central circulatory dynamics, the term VO2 peak is usually used. VO2 peak refers to the highest value of oxygen consumption measured during a graded exercise test (McArdle et al., 1991).

3. YMCA cycle ergometer submaximal test, using a 2-point estimation procedure (YMCA): The recommended procedure for estimating VO2 max is to plot two HRs between 110 and 150 beats per minute (bpm) during a graded exercise test. The estimated VO2 max value is formed by connecting the two HR points with a line representing the estimated maximal HR on a prepared grid and reading the estimated VO2 max at that intersection (Golding et al., 1989).

4. The modified YMCA cycle ergometer submaximal test, using a 3-point estimation procedure (YMOD): The modified procedure for estimating VO2 max is to plot three HRs between 110 and 150 bpm during a graded exercise test. The estimated VO2 max is found by plotting the line of best fit on the same grid as the traditional YMCA test and reading the estimated VO2 max value at the intersection of the line with the line representing the estimated maximal HR.
CHAPTER II

REVIEW OF LITERATURE

Introduction

Submaximal tests were developed to estimate VO2 max values without the risk, expense, and time commitment of actually performing a maximal test. Submaximal tests can be administered at a fitness club or lab to an apparently healthy (ACSM, 1995) individual with a limited possibility of adverse effects to the testee. The cost to administer the submaximal test is limited to the initial investment of an arm ergometer, cycle ergometer, or treadmill; a sphygmomanometer and stethoscope; and a stopwatch. The set-up, subject preparation, and administration times for the submaximal test are much lower than for a maximal test. A qualified technician can administer a submaximal test to apparently healthy people to estimate VO2 max values or chart the progress of a subject's fitness level.

Physiological Response to Fitness Testing

Maximal Oxygen Consumption

VO2 max is considered by many exercise scientists to be the most valid measurement of aerobic or cardiovascular fitness (Powers & Howley, 1994). The term,
VO2 max, refers to the point at which the oxygen consumption plateaus and shows no further increase with additional workload. VO2 max values can be measured indirectly by submaximal tests or directly by maximal tests, using metabolic carts that calculate VO2 max from expiratory gas samples. Estimations of VO2 max in healthy individuals can be altered by exercise conditions. Within limits, higher values are obtained when larger muscle masses are involved in the exercise testing. VO2 max values for inclined treadmill running are higher than for horizontal treadmill running, running values exceed leg cycle ergometer values, and leg cycle ergometer values are higher than arm ergometer values (ACSM, 1995).

Submaximal testing is used to estimate VO2 max values. In healthy individuals, there is a linear relationship between HR and oxygen consumption (VO2). This relationship is most linear between HR values of 110 bpm and 150 bpm. As the HR rises, there is an increase in VO2, which reaches a plateau just prior to achievement of VO2 max. Generally, in terms of accuracy, scores based upon submaximal test values are within 10% to 20% of the individual's actual VO2 max values (Powers & Howley, 1994).

VO2 max depends on several essential processes: (a) pulmonary ventilation, (b) alveolar-arterial gas exchange, (c) cardiac output, (d) blood flow redistribution, and (e) oxygen utilization by skeletal muscle. VO2 max and its determinants can be influenced by several variables, including gender, body size, environmental conditions, and various cardiopulmonary diseases. VO2 max can be expressed in absolute terms, and when it is, the magnitude of VO2 max increases in proportion to body size. VO2 max can also be expressed in relative terms. The relative value reflects the individual's ability to provide
oxygen (measured in milliliters) in relation to body weight (usually expressed in kilograms).

Absolute VO2 max values for healthy young adults range from about 2 L/min to about 6 L/min; in relative terms, the values range from 30 to 90 ml · kg⁻¹ · min⁻¹ or more. These values vary according to individual differences in muscle mass, body composition, gender, level of maturity, state of training, and heredity (MacDougall, Wenger, & Green, 1991). For a normal, healthy, 20-year-old female these values range in absolute terms from 1.8 to 2.3 L/min; in relative terms they range from 32 to 38 ml · kg⁻¹ · min⁻¹. In a normal, healthy, 20-year-old male these values range in absolute terms from 2.7 to 3.2 L/min; in relative terms they range from 36 to 44 ml · kg⁻¹ · min⁻¹ (MacDougall et al., 1991).

**Maximal Heart Rate**

A percentage of maximal heart rate (MHR) is often used as a criterion for the termination of a submaximal test. The formula, MHR = 220 - Age, is used to predict MHR (ACSM, 1995). Generally, the percentage chosen ranges from 65% to 85% of predicted MHR. For a maximal test, MHR is useful to help estimate when the termination of the test will occur.

**Borg Scale**

The Borg rating of perceived exertion (RPE) scale has been found to be a valuable and reliable indicator of exercise intensity (ACSM, 1995). The Borg RPE scale was
developed to allow the exerciser to subjectively rate his or her general fatigue level. The original RPE ratings were based on a numerical scale that ranged from 6 to 20, according to the exerciser's exertion level. The number on the RPE scale approximated the subject's HR multiplied by 10. The revised RPE scale is based on a numerical scale that ranges from 0 to 10. The revised RPE scale is a simplified version of the original RPE scale that provides the subject with more easily understood terminology, thereby providing the tester with more valid information. Often used in conjunction with a graded exercise test, RPE correlates highly with HR and measures of exercise such as VO2 (ACSM, 1995). One major benefit of the RPE scale is that it provides exercisers of all fitness levels with an easily understood guideline and pragmatic form for controlling exercise intensity.

Exercise Specificity

VO2 max exercise test values can be affected by the modality in which the test was administered. Exercise specificity has a pronounced influence on physical performance and the physiological response in physical activities, such as aerobic fitness and strength training. Exercise causes the body to make specific physiological adaptations to the primary form of exercise (Powers & Howley, 1994). This specific response to physical activity can affect VO2s in both submaximal and maximal tests.

Continuous Versus Discontinuous Test Protocols

Continuous protocols consist of progressive stages of increased work intensities with no rest intervals. In discontinuous protocols, work and rest intervals are alternated.
Due to the number of rest intervals in discontinuous protocols, a plateau in VO2 with increasing exercise intensity (VO2 max) occurs more often than in continuous protocols, in part because the subject does not experience the degree of local fatigue associated with continuous protocols (ACSM, 1995).

**Graded Exercise Testing Equipment**

A graded exercise test (GXT) should be performed in a controlled environment. In order to achieve the highest VO2 max value, the modality for the maximal GXT should match the subject's preferred form of exercise. The cost and time commitment for a maximal GXT are much greater than for a submaximal GXT test. The equipment involved for performing a maximal GXT is expensive to purchase and operate. Generally, maximal GXTs are performed in a clinical setting under the supervision of a qualified technician or physician. They are also used for individuals who do not fit into the "apparently healthy" (ACSM, 1995) screening category.

**Metabolic Cart**

A metabolic cart directly analyzes expired respiratory gases during fitness testing. Direct analysis of expired respiratory gases yields the most accurate determination of VO2 max (ACSM, 1995). The metabolic cart is a valid and reliable piece of equipment for VO2 testing. For an accurate analysis, a mouthpiece is inserted into the subject's mouth and attached to flexible tubing that transports expired gases to the metabolic cart. A nose clip is attached to the subject's nose to ensure that all gas exchange takes place at the mouth.
**Electrocardiograph**

Electrical activity around the heart creates an electrical field throughout the body. The sequence of electrical events prior to and during each cardiac cycle can be detected as a voltage change by electrodes placed on the skin surface. The graphic records of the heart's activities are called electrocardiograms (ECGs). ECGs provide an effective means for monitoring HR objectively during exercise and are a valuable tool for detecting abnormalities in heart function. During exercise, the ECG can be measured with a single bipolar lead, but a full 12-lead arrangement is preferred (McArdle et al., 1991).

**Cycle Ergometer**

VO2 max tests can be performed on treadmills, cycle ergometers, arm ergometers, and a variety of other equipment. There are two types of cycle ergometer: (1) electrically braked and (2) mechanically braked. The electrically braked cycle ergometer produces the desired workload by adjusting pedal resistance in relation to pedal frequency. As pedal frequency increases, pedal resistance decreases to produce the desired workload. On the mechanically braked cycle ergometer, the pedal resistance must be adjusted manually in relation to the desired pedal frequency, e.g., 50 rpm or 60 rpm. The Monark (Stockholm, Sweden) cycle ergometer is one example of a mechanically braked ergometer. As friction increases, the amount of work required to turn the wheel increases (MacDougall et al., 1991).
There are numerous submaximal and maximal cycle ergometer tests. The YMCA cycle ergometer test is an example of a submaximal test. The ACSM cycle ergometer test is an example of a maximal test. The purpose of a submaximal test is to estimate the VO2 max value without the cost, time commitment, and possible risk to the subject that are associated with maximal tests.

YMCA Cycle Ergometer Submaximal Test

The YMCA cycle ergometer test (Golding et al., 1989) was developed to estimate maximal working capacity, or VO2 max, by measuring the response to submaximal work. The YMCA cycle ergometer submaximal test is based on the assumption that the relationship between exercise intensity and VO2 is linear, and this linearity has been widely used as a basis for determining VO2 max (Golding et al., 1989). The YMCA cycle ergometer test results reflect the cardiorespiratory response of an individual to increased workloads. The test is discontinuous in nature; it allows for rest intervals. The VO2 max estimated score from the cycle ergometer test is one of eight criteria used to formulate the Physical Fitness Evaluation Profile (Golding et al., 1989). The Physical Fitness Evaluation Profile is organized into 8 different categories ranging from very poor to excellent. These categories represent the percentile rank within each age and gender grouping. Physical fitness rating is used to determine the type, duration, frequency, and intensity level of exercise for the individual's exercise program. The YMCA cycle ergometer predicted
VO2 max 50th percentile (Golding et al., 1989) for men 18 to 25 years of age in relative terms is 45.0 ml \cdot kg^{-1} \cdot min^{-1}. The predicted 50th percentile for VO2 max values for females 18 to 25 years of age in relative terms is 40.0 ml \cdot kg^{-1} \cdot min^{-1}.

A validation study of the YMCA submaximal cycle ergometer protocol (Grossman, Dwyer, Kaminsky, & Whaley, 1994) showed relatively modest correlations between the measured and predicted VO2 max scores. The test-retest reliability estimates of the YMCA protocol in the Grossman et al. study ranged from $r = .71$ to $r = .75$. In 17 of 43 trials, the researchers were unable to estimate the VO2 max values using the age-predicted HR max. Because of the reliability estimates and the high percentage of cases for which VO2 max estimates could not be determined, the researchers cautioned against the use of this protocol for predicting VO2 max.

**ACSM Cycle Ergometer Maximal Test**

The ACSM cycle ergometer maximal test (ACSM, 1995) was developed to measure VO2 max values. The ASCM cycle ergometer maximal test is continuous in nature. The values achieved during the cycle ergometer test reflect the cardio-respiratory response of an individual during workloads of increasing intensity. Analysis of expired gases during such a test yields the most accurate determination of VO2 max (ACSM, 1995).

The 50th percentile for VO2 max (ACSM, 1995) for men 20 to 29 years of age in relative terms is 42.29 ml \cdot kg^{-1} \cdot min^{-1}. The 50th percentile for VO2 max values for females 20 to 29 years of age in relative terms is 35.20 ml \cdot kg^{-1} \cdot min^{-1}. Maximal GXTs
are highly reliability and are used as a gold standard against which submaximal test protocols are evaluated (Howley & Franks, 1992).
CHAPTER III

METHODS AND PROCEDURES

Introduction

The purpose of this study was to validate the YMCA cycle ergometer test and determine if a modified YMCA (YMOD) version would be a better indicator of VO₂ max values. This chapter includes six sections: (1) human subjects approval, (2) subject selection, (3) instrumentation, (4) testing procedures, (5) scoring procedures, and (6) statistical analysis.

Human Subjects Approval

Approval to conduct this study was required by Western Michigan University's Human Subjects Institutional Review Board (HSIRB). The appropriate forms were submitted by the investigator to the HSIRB. After the proposal was reviewed by the full board and revisions were resubmitted, the board granted approval for this study (Appendix A).

Subjects

This study involved 50 apparently healthy college students (25 males and 25 females) 18 to 25 years of age, who volunteered to participate in the study. The
volunteers were required to participate in at least three testing sessions.

Recruitment

The 50 subjects were recruited from the Western Michigan University student population. Recruitment fliers (Appendix B) were posted in the Exercise Physiology Laboratory in the Student Recreation Center building. Announcements were made in Physical Education General (PEGN) classes and Physical Education Professional classes (PEPR) classes. Potential subjects could sign up, telephone, e-mail, or contact the researcher in person to obtain additional information and to volunteer. After the initial contact, volunteers were scheduled for a time to fill out the required screening forms for eligibility to participate.

Screening

Before the students were accepted as participants, they had to meet these requirements: (a) satisfactory completion of a health screening questionnaire (Appendix C), (b) be classified as apparently healthy on the ACSM guidelines (ACSM, 1995), and (c) be able to participate in three exercise testing sessions. If a volunteer, during the screening process, was found to have any current or predisposed condition(s) for which participation in the study could affect the health of the volunteer or the results of the study, he or she was disqualified. Once selected, subjects were informed of the procedures and potential risks associated with their participation and asked to read and sign an approved informed consent form (Appendix D) prior to testing.
Instrumentation

Submaximal Tests

The following instruments were used to gather data during the submaximal tests:
(a) the Monark (Stockholm, Sweden) cycle ergometer; (b) a Polar (Port Washington, NY) heart rate monitor, Model 61210, for HR readings; and (c) a stethoscope and sphygmomanometer for taking blood pressure readings.

Maximal Test

The following instruments were used to gather data during the maximal test: (a) the Monark (Stockholm, Sweden) cycle ergometer; (b) the Quinton (Seattle, WA) Q-Plex 1 metabolic cart for respiratory gas collection and analysis; (c) a stethoscope and sphygmomanometer for taking blood pressure readings; and (d) a Bosch (Berlin, Germany) electrocardiograph, Model 502A, with a monitor for HR and ECG readings.

Testing Procedures

A trained technician administered both the YMCA and modified YMCA cycle ergometer submaximal tests and the ACSM maximal cycle ergometer test. The technician followed all safety guidelines posted in the Exercise Physiology Laboratory.

General Testing Procedures

The following guidelines were followed for each test administration:
1. The Monark cycle ergometer was calibrated daily.

2. The subject had to maintain a cadence of 50 rpm or 18 kph.

3. The seat height was adjusted for each individual so that the leg extended to 175° at the bottom of the crank turn.

4. The subject was taught or reminded how to use the RPE scale.

5. The subject's name, age, height in meters, weight in kilograms, and estimated MHR (220 - Age) were recorded.

6. Before the ACSM maximal graded exercise test, the Quinton Q-Plex 1 was warmed up and calibrated, and the ECG machine was turned on.

7. After the testing session was completed, a cool down of riding at no resistance was performed until the subject's HR was below 120 bpm, at which time the subject stopped pedaling.

YMCA Cycle Ergometer Submaximal Test

These specific procedures were followed for the YMCA test:

1. The Polar HR monitor was fastened around the subject's chest, and the receiver display watch was attached to his or her wrist.

2. The sphygmomanometer was placed on the subject's upper left arm.

3. A resting HR and blood pressure (BP) were recorded.

4. A 5-min warm up on the cycle ergometer, set with no resistance, was administered to each subject.

5. The workloads for each stage are indicated in Appendix E. The workloads were
increased until two recorded HRs from two successive stages were between 110 and 150 bpm, at which time the test was terminated.

6. Each stage of the test has a 3-min estimated time limit. If the HRs varied by more than 5 bpm between readings, the stage was extended for an additional minute or until a stable value was obtained.

7. BP and RPE readings were recorded at 1 min 30 s of each stage.

8. HR readings were recorded at the 2-min and 3-min points in each stage.

**Modified YMCA Cycle Ergometer Submaximal Test**

These specific procedures were followed for the YMOD test:

1. The 3-point estimation modification of the YMCA cycle ergometer submaximal test was administered exactly as the 2-point method except for the workloads.

2. At Stage 1, the workload was set at 150 kgm.

3. At Stage 2, if the HR in the 3rd min of Stage 1 was (a) less than 80 bpm, the workload was set at 750 kgm; (b) between 80 and 89 bpm, the workload was set at 600 kgm; (c) between 90 and 100 bpm, the workload was set at 450 kgm; or (d) greater than 100 bpm, the workload was set at 300 kgm.

4. At all additional stages, the workloads were increased by 75 kgm until recorded HRs from two successive stages were between the 110 and 150 bpm guideline, at which time the test was terminated.
ACSM Cycle Ergometer Maximal Graded Exercise Test

These specific procedures were followed for the ACSM test:

1. The sphygmomanometer was placed on the subject's left arm.

2. The subject was connected to the ECG machine at four points using wires attached to surface electrodes: (1) upper right chest, (2) upper left chest, (3) right mid-chest, and (4) left mid-chest. The ECG machine was checked for correct operation.

3. A resting HR and blood pressure were taken.

4. Each stage had a 2-min time limit.

5. For each stage, blood pressure and RPE readings were recorded at 1 min 30 s, and HRs were recorded at 2 min.

6. Before the initial stage, the subject attached a nose clip and inserted the mouthpiece that was connected to the metabolic cart. Recording of respiratory gases was done automatically by the Quinton Q-Plex 1 at 20-s intervals.

7. Termination of the maximal test could occur under the following conditions: (a) The subject achieved VO2 max, (b) the subject requested termination, (c) the subject exhibited one of the absolute or relative indicators from the ACSM guidelines (ACSM, 1995), or (d) the subject's R value exceeded 1.15.

Scoring Procedures

YMCA Cycle Ergometer Submaximal Test

The following procedures were used to estimate VO2 max values. The first two
HRs between 110 bpm and 150 bpm were plotted on the scoring grid (Appendix F). A line was drawn to connect the points. A horizontal line at the estimated MHR was drawn across the top of the grid. At the intersection of the observed HR line and the estimated MHR line, a vertical line was drawn down to the baseline. The estimated VO2 (liters per minute) was read from the point at which the vertical line crossed the baseline. For each subject the estimated VO2 was multiplied by 1000 and divided by the subject's body weight (in kilograms) to express the estimated VO2 max in milliliters per kilogram per minute (ml · kg⁻¹ · min⁻¹).

**Modified YMCA Cycle Ergometer Test**

The following procedures were used to estimate VO2 max values. The first three HRs between 110 bpm and 150 bpm were plotted on the scoring grid (Appendix F). A line of best fit was determined using both a regression formula (YMOD-R) and a visual estimate (YMOD-V). A horizontal line at the estimated MHR was drawn across the top of the grid. At the intersection of the line of best fit and the estimated MHR line, a vertical line was drawn down to the baseline. The estimated VO2 (liters per minute) was read from the point at which the vertical line crossed the baseline. For each subject the estimated VO2 was multiplied by 1000 and divided by the subject's body weight to express the estimated VO2 max in milliliters per kilogram per minute.

**Statistical Analysis**

All the data gathered were entered into the computer for statistical analysis. The
BMDP statistical package (Dixon, Brown, Engelman, & Jennrich, 1990) was used for data analysis. The descriptive statistics for subject characteristics and the cycle ergometer scores were obtained from the BMDP 2D programs. Intraclass reliability estimates and the test of order effects were calculated from repeated-measures ANOVAs run on BMDP 2V. Split-plot factorial analyses, Gender x Test Types, were conducted, using BMDP 2V, to test for significance of differences in the VO2 max estimates between YMOD-R and YMOD-V and among the three different cycle ergometer protocols, ACSM, YMCA, and YMOD-R. Regression analyses, using BMDP 2R, were used to calculate intercorrelations and to determine if YMCA or YMOD scores provided a better estimate of the VO2 max scores on the ACSM test. The level of significance was set at .05 for all tests.
CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The problem in this study was to determine if a 3-point estimation procedure for the YMCA submaximal cycle ergometer test provided a more valid predictor of VO2 max than the recommended 2-point estimation procedure for male and female college students between 18 and 25 years of age. In this chapter the results are presented and discussed in the following order: (a) descriptive characteristics of the subjects, (b) test-retest reliability estimates for the cycle ergometer tests, (c) order effects, (d) differences in VO2 max estimates among tests, and (e) prediction of VO2 max from the submaximal tests.

Results

Descriptive Characteristics of the Subjects

In this section, the descriptive statistics for the subjects' characteristics (Table 1) and their cycle ergometer performances are presented. Note that there were 46 participants in the study, 21 females and 25 males. There were 50 subjects originally, but 4 of the females failed to complete all three tests, so they were eliminated from the study. The means for height and weight were higher for males (71.5 in. and 179.1 lb) than for
females (65.3 in. and 134.0 lb). The mean ages of males (21.4 yr) and females (21.3 yr) were similar. The standard deviations for height and age were similar for males (2.9 in and 1.8 yr) and females (3.0 in and 1.8yr). The standard deviation for weight was much larger for males (28.2 lb) than for females (16.1 lb), and the ranges for weight also indicated greater variability for males (137 lb) than for females (59 lb).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Gender</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>High</th>
<th>Low</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (in.)</td>
<td>Females 21</td>
<td>65.3</td>
<td>3.0</td>
<td>69</td>
<td>59</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Males 25</td>
<td>71.5</td>
<td>2.9</td>
<td>76</td>
<td>66</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Weight (lb)</td>
<td>Females 21</td>
<td>134.0</td>
<td>16.1</td>
<td>160</td>
<td>101</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Males 25</td>
<td>179.1</td>
<td>28.2</td>
<td>260</td>
<td>123</td>
<td>137</td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>Females 21</td>
<td>21.3</td>
<td>1.8</td>
<td>25</td>
<td>18</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Males 25</td>
<td>21.4</td>
<td>1.8</td>
<td>25</td>
<td>18</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

The descriptive statistics for VO2 max estimates on the cycle ergometer tests are presented in Table 2. The modified YMCA test was scored in two ways, resulting in two different VO2 max estimates, YMOD-R and YMOD-V. YMOD-R refers to the VO2 max estimates derived from the line of best fit based on a regression equation. YMOD-V refers to VO2 max estimates derived from a line of best fit that was determined visually.
The mean VO2 max estimates were similar for males and females for all tests except the ACSM test, for which males (45.09 ml·kg⁻¹·min⁻¹) had higher VO2 max scores than females (41.14 ml·kg⁻¹·min⁻¹). The standard deviations were similar for males and females for the YMCA (14.88 for males and 15.88 for females) and ACSM (6.23 for males and 6.42 for females) but were different for the YMOD-R and YMOD-V, in which males were more homogeneous (11.29 ml·kg⁻¹·min⁻¹ and 10.78 ml·kg⁻¹·min⁻¹, respectively) than females (13.65 ml·kg⁻¹·min⁻¹ and 13.64 ml·kg⁻¹·min⁻¹, respectively).

Table 2

Means and Standard Deviations for Cycle Ergometer Tests

| Test   | Females | | | Males | | | Total | | |
|--------|---------|---|---|-------|---|---|-------|---|
|        | N  | M  | SD | N  | M  | SD | N  | M  | SD |
| YMCA   |    |    |    |    |    |    |    |    |    |
|        | 21 | 46.59 | 15.88 | 24 | 48.76 | 14.88 | 45 | 47.75 | 15.35 |
| YMOD-R | 21 | 42.95 | 13.65 | 22 | 42.65 | 11.29 | 43 | 42.79 | 12.35 |
| YMOD-V | 21 | 43.48 | 13.64 | 22 | 42.56 | 10.78 | 43 | 43.01 | 12.12 |
| ACSM   | 21 | 41.14 | 6.42  | 25 | 45.09 | 6.23  | 46 | 43.29 | 6.31  |

Note. All scores reported are in milliliters of oxygen per kilogram of body weight per minute. The number of subjects included in the means was different for each test, because VO2 max estimates could not be calculated for 1 male on the YMCA test and 3 males on the YMOD test.
Test-Retest Reliability Estimates for the Cycle Ergometer Tests

In Table 3 the test and retest scores from the three cycle ergometer tests are provided. These represent the scores for subjects who repeated one of the tests for the purpose of estimating stability reliability. Note that only 8 subjects repeated the YMCA test, 2 repeated the YMOD test, and 3 repeated the ACSM test. For the YMCA test, differences between the test and retest scores ranged from a low of 0.9 ml·kg⁻¹·min⁻¹ for Subject 15 to a high for Subject 19 of 23.1 ml·kg⁻¹·min⁻¹. The modified YMCA test scores varied the most, 13.0 ml·kg⁻¹·min⁻¹ and 31.6 ml·kg⁻¹·min⁻¹ for the 2 subjects, Subject 7 and Subject 28, respectively. For Subject 28, the retest score was about half the original test score. The most consistent test-retest scores were from the ACSM test, for which score differences ranged from only 3.1 ml·kg⁻¹·min⁻¹ for Subject 8 to 0.0 ml·kg⁻¹·min⁻¹ for Subject 30.

In Table 4 the ANOVA summaries are presented for the intraclass reliability estimates for the three cycle ergometer tests. These ANOVAs were based on a Subjects x Trials design. The intraclass correlation formula was $R = (MS_A - MS_w)/MS_A$. This formula is appropriate if there is no significant difference between the trial means or if there is a significant difference between the trial means and the difference is attributed to measurement error (Baumgartner & Jackson, 1995). The highest reliability was for the ACSM test, $R = .95$, and the lowest was for the YMCA test, $R = -.80$. 
Table 3
Test-Retest Scores for Reliability Estimates of Cycle Ergometer Tests

<table>
<thead>
<tr>
<th>Subject #</th>
<th>YMCA</th>
<th>YMOD-R</th>
<th>ACSM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test Retest</td>
<td>Test Retest</td>
<td>Test Retest</td>
</tr>
<tr>
<td>1</td>
<td>33.3</td>
<td>34.8</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>35.9</td>
<td>55.5</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>36.1</td>
<td>48.7</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>27.6</td>
<td>39.2</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>41.6</td>
<td>45.7</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>40.2</td>
<td>41.1</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>32.7</td>
<td>55.8</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>50.2</td>
<td>39.6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>32.6</td>
<td>19.6</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>63.8</td>
<td>32.2</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>51.3</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td></td>
<td>46.7</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td>42.0</td>
</tr>
</tbody>
</table>

Note. All scores are reported in milliliters of oxygen per kilogram of body weight per minute.
### Table 4
ANOVA for Intraclass Reliability of Cycle Ergometer Tests

<table>
<thead>
<tr>
<th>Source^</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>R^b</th>
</tr>
</thead>
<tbody>
<tr>
<td>YMCA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Among</td>
<td>324.00</td>
<td>7</td>
<td>46.29</td>
<td>0.56</td>
<td>-.80</td>
</tr>
<tr>
<td>Within</td>
<td>667.76</td>
<td>8</td>
<td>83.47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>YMOD-R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Among</td>
<td>479.61</td>
<td>1</td>
<td>479.61</td>
<td>1.64</td>
<td>.39</td>
</tr>
<tr>
<td>Within</td>
<td>583.78</td>
<td>2</td>
<td>291.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACSM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Among</td>
<td>60.50</td>
<td>2</td>
<td>30.25</td>
<td>18.41*</td>
<td>.95</td>
</tr>
<tr>
<td>Within</td>
<td>4.93</td>
<td>3</td>
<td>1.64</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^Sources are among subjects (A) and within subjects (W) in a Subjects x Treatments design. ^bIntraclass reliability estimates were determined by $R = (MS_A - MS_w)/MS_A$. *p < .05.

**Order Effects**

Because of a concern about whether learning might have influenced subjects' performances, subjects were randomly assigned to a testing order for the YMCA, YMOD, and ACSM tests. Of the 46 subjects, 16 were assigned the order, YMCA, YMOD, and ACSM; 18 were assigned the order, YMOD, ACSM, and YMCA; and 12
were assigned the order, ACSM, YMCA, and YMOD. To test for an order effect, the test scores were grouped according to whether a test was administered on the first, second, or third testing session, regardless of which test procedure was administered during that session.

In Table 5 the VO2 max means and standard deviations for the three test sessions are presented by gender. The test session mean scores for males and females were similar. The largest difference was in the third test, in which the mean VO2 max scores was greater for males (47.38 ml · kg⁻¹ · min⁻¹) than for females (41.55 ml · kg⁻¹ · min⁻¹). Although it appeared that VO2 max means for females increased slightly across the three test sessions and VO2 max means for males decreased slightly across the three test sessions, there was no significant Gender x Order interaction, $F(2, 80) = 1.24, p = .29$ (see Table 6). The test for order effect indicated no significant differences between VO2 max scores for the three testing sessions, $F(2, 80) = 0.05, p = .95$. There was also no significant gender effect, $F(1, 40) = 0.61, p = .44$.

Differences in VO2 max Estimates Among Tests

An ANOVA was conducted to compare the mean VO2 max estimates between the two scoring procedures for the YMOD test, YMOD-R and YMOD-V. The ANOVA summary is presented in Table 7. The Gender x Estimation Method interaction was not significant, $F(1, 41) = 2.33, p = .13$. There was no significant difference in VO2 max estimates between males and females, $F(1, 41) = 0.03, p = .87$. The difference between estimation methods was not significant, $F(1, 41) = 1.24, p = .87$. Because the YMOD-R
### Table 5

Means and Standard Deviations for Testing Sessions

<table>
<thead>
<tr>
<th>Test Session</th>
<th>Females</th>
<th></th>
<th>Males</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>First</td>
<td>45.96</td>
<td>16.56</td>
<td>43.95</td>
<td>9.30</td>
</tr>
<tr>
<td>Second</td>
<td>43.18</td>
<td>11.86</td>
<td>45.22</td>
<td>10.22</td>
</tr>
<tr>
<td>Third</td>
<td>41.55</td>
<td>8.41</td>
<td>47.38</td>
<td>15.31</td>
</tr>
</tbody>
</table>

**Note.** For both females and males, n = 21, because the 4 males who had missing data on the YMCA or YMOD tests were excluded from the analysis. All scores are reported in milliliters of oxygen per kilogram of body weight per minute.

### Table 6

ANOVA for Order of Test Administration by Gender

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (G)</td>
<td>120.46</td>
<td>1</td>
<td>120.46</td>
<td>0.61</td>
<td>.44</td>
</tr>
<tr>
<td>Subject Within G</td>
<td>7837.99</td>
<td>40</td>
<td>195.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order (O)</td>
<td>12.25</td>
<td>2</td>
<td>6.13</td>
<td>0.05</td>
<td>.95</td>
</tr>
<tr>
<td>G x O</td>
<td>322.67</td>
<td>2</td>
<td>161.34</td>
<td>1.24</td>
<td>.29</td>
</tr>
<tr>
<td>Subjects Within G x O</td>
<td>10378.02</td>
<td>80</td>
<td>129.73</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
and YMOD-V scores were not significantly different, only the YMOD-R scores were compared to the YMCA and ACSM scores to see if there was a significant difference in VO2 max scores determined by different tests. The ANOVA results for differences in VO2 max estimate among YMCA, YMOD-R, and ACSM tests are presented in Table 8.

Table 7

ANOVA for Differences in VO2 max Estimates Between YMOD Estimation Methods by Gender

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (G)</td>
<td>7.99</td>
<td>1</td>
<td>7.99</td>
<td>0.03</td>
<td>.87</td>
</tr>
<tr>
<td>Subjects Within G</td>
<td>12528.84</td>
<td>41</td>
<td>305.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimation Method (E)</td>
<td>1.05</td>
<td>1</td>
<td>1.05</td>
<td>1.24</td>
<td>.27</td>
</tr>
<tr>
<td>E x G</td>
<td>1.97</td>
<td>1</td>
<td>1.97</td>
<td>2.38</td>
<td>.13</td>
</tr>
<tr>
<td>Subjects Within E x G</td>
<td>34.66</td>
<td>41</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The ANOVA results in Table 8 indicated there was no significant interaction for test type (YMCA, YMOD-R, and ACSM) by gender, $F(2, 80) = 0.60$, $p = .55$, and no significant difference between genders, $F(1, 40) = 0.61$, $p = .44$. The VO2 max means were somewhat different, but the differences were not statistically significant, $F(2, 80) = 2.97$, $p = .06$. 

Table 8

ANOVA for Differences in VO2 max Estimates Among Maximal and Submaximal Tests by Gender

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (G)</td>
<td>120.46</td>
<td>1</td>
<td>120.46</td>
<td>0.61</td>
<td>.44</td>
</tr>
<tr>
<td>Subjects Within G</td>
<td>7837.99</td>
<td>40</td>
<td>195.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Type (T)</td>
<td>729.68</td>
<td>2</td>
<td>364.84</td>
<td>2.97</td>
<td>.06</td>
</tr>
<tr>
<td>T x G</td>
<td>147.79</td>
<td>2</td>
<td>73.90</td>
<td>0.60</td>
<td>.55</td>
</tr>
<tr>
<td>Subjects Within T x G</td>
<td>9835.47</td>
<td>80</td>
<td>122.94</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predictions of VO2 max From the Submaximal Tests

Correlations

In Table 9 the intercorrelations of the VO2 max scores, as well as subject characteristics, are reported for all subjects who had complete data for all tests (n = 21 for both females and males). In this analysis, a missing score on either the YMCA test or the YMOD test eliminated the subject from all correlations.

Because gender was a dichotomous variable, all correlations involving this variable are point-biserial correlations. All other correlations are Pearson product-moment correlations. The highest correlation was between YMOD-R and YMOD-V, r = .9952. The second highest correlation was between height and weight, r = .8017. There are also
high correlations of gender with weight and height, $r_{pb} = .7317$ and $r_{pb} = .7351$, respectively. Correlations with ACSM that were statistically significant (one-tailed $p < .05$) included gender, $r_{pb} = .3331$, height, $r = .2784$ and the YMCA test, $r = .2973$.

The correlations in Table 10 were developed using data for all subjects who had scores for both tests being correlated. In this analysis, a missing score on either the YMCA test or the YMOD test eliminated the subject only from the correlations involving

### Table 9

<table>
<thead>
<tr>
<th></th>
<th>Gender*</th>
<th>WT</th>
<th>HT</th>
<th>Age</th>
<th>YMCA</th>
<th>YMOD-R</th>
<th>YMOD-V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (WT)</td>
<td>.7317*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (HT)</td>
<td>.7351*</td>
<td>.8017*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>.0403</td>
<td>.1647</td>
<td>.0853</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YMCA</td>
<td>.0856</td>
<td>.0637</td>
<td>.1256</td>
<td>.0369</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YMOD-R</td>
<td>-.0402</td>
<td>.0806</td>
<td>.0178</td>
<td>.2973*</td>
<td>.1282</td>
<td></td>
<td></td>
</tr>
<tr>
<td>YMOD-V</td>
<td>-.0593</td>
<td>.0559</td>
<td>.0161</td>
<td>.2483</td>
<td>.1440</td>
<td>.9952*</td>
<td></td>
</tr>
<tr>
<td>ACSM</td>
<td>.3331*</td>
<td>.1094</td>
<td>.2784*</td>
<td>.1042</td>
<td>.2973*</td>
<td>.2295</td>
<td>.2326</td>
</tr>
</tbody>
</table>

Note. $N = 42$; only 21 females and 21 males had complete data.

*Correlations of variables with the dichotomous variable, gender, are point-biserial correlations.

$p < .05$
that test. The only correlation that was significant, either statistically \((p < .05)\) or practically, was the correlation between YMOD-R and YMOD-V, \(r = .9943\). The correlation between ACSM and YMCA that was statistically significant \((r = .2973, p < .05)\) when \(n = 42\) (see Table 9) was not significant for \(n = 45, r = .2373, p > .05\). The correlations of the ACSM scores with YMOD-R and YMOD-V \((r = .2058 \text{ and } r = .2150, \text{ respectively})\) scores with ACSM were greater than the correlations of YMCA scores with YMOD-R and YMOD-V \((r = .1282 \text{ and } r = .1440, \text{ respectively})\).

Table 10

<table>
<thead>
<tr>
<th>Conditions</th>
<th>YMOD-R</th>
<th>YMOD-V</th>
<th>YMCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>YMOD-V</td>
<td>.9943*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>((n = 43))</td>
<td></td>
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<tr>
<td>YMCA</td>
<td>.1282</td>
<td>.1440</td>
<td></td>
</tr>
<tr>
<td></td>
<td>((n = 42))</td>
<td>((n = 42))</td>
<td></td>
</tr>
<tr>
<td>ACSM</td>
<td>.2058</td>
<td>.2150</td>
<td>.2373</td>
</tr>
<tr>
<td></td>
<td>((n = 43))</td>
<td>((n = 43))</td>
<td>((n = 45))</td>
</tr>
</tbody>
</table>

Note. The number of subjects included in the means was different for each test, because VO2 estimates could not be calculated for 1 male on the YMCA test and 3 males on the YMOD test.

\*\(p < .05\).
Regression Analysis

The correlations in Table 10 were used to establish the prediction equations of the ACSM VO2 max scores from the VO2 max estimates from the YMCA and YMOD-R and YMOD-V tests. The prediction equations and the corresponding ANOVAs calculated to test their significance are presented in Table 11. It was obvious that the formulas for prediction of VO2 max varied only slightly. More importantly, none of the F ratios indicated that a significant amount of variability in VO2 max scores was explained by the submaximal test estimates. The amount of variability explained, R^2, ranged from 4.2% to 5.6%.

Discussion

Subjects

Fifty students (25 males and 25 females) volunteered for the research study. Of the original 50 students, 46 students (25 males and 21 females) completed at least three tests. The 4 females who failed to complete three tests were eliminated from the study. Subjects were eliminated for several reasons: (a) illness, (b) unexplained failure to attend their scheduled testing sessions, and (c) time conflicts with their work schedule.

If a subject's line of best fit could not be plotted on the grid because the slope of the line was not steep enough for the line to intersect with the estimated MHR line, a VO2 max value of 99.9 ml · kg^-1 · min^-1 was written on his or her data sheet to indicate missing data. This situation occurred for one YMCA submaximal test and three modified
Table 11
Regression Equations and Their Tests of Significance

### Original YMCA Test

Predicted VO2 max = 0.10(YMCA) + 38.48

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>107.74</td>
<td>1</td>
<td>107.74</td>
<td>2.57</td>
<td>.0563</td>
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<tr>
<td>Residual</td>
<td>1805.19</td>
<td>43</td>
<td>41.98</td>
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</table>

### From Modified YMCA Test-Regression Technique

Predicted VO2 max = 0.11(YMOD-R) + 38.62

<table>
<thead>
<tr>
<th>Source</th>
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<th>df</th>
<th>MS</th>
<th>F</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
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<td>71.17</td>
<td>1.81</td>
<td>.0423</td>
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<tr>
<td>Residual</td>
<td>1609.37</td>
<td>41</td>
<td>39.09</td>
<td></td>
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</tr>
</tbody>
</table>

### From Modified YMCA Test-Visual Technique

Predicted VO2 max = 0.11(YMOD-V) + 38.31

<table>
<thead>
<tr>
<th>Source</th>
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<th>df</th>
<th>MS</th>
<th>F</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
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<td>1</td>
<td>71.70</td>
<td>1.99</td>
<td>.0462</td>
</tr>
<tr>
<td>Residual</td>
<td>1602.83</td>
<td>41</td>
<td>39.09</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
YMCA submaximal tests. This decreased the number of scores for each test as indicated. The subject loss of 8.9% was not as great as might have been expected. In the study by Grossman et al. (1994), VO2 max estimates from the YMCA test could not be obtained for 17 of 43, or 39.5% of their subjects. In a practical setting, the inability to get an estimated VO2 max from the YMCA test would be a real drawback, because it would be impossible for those who had just completed the test to be given adequate feedback about their fitness status.

Test-Retest Reliability Estimates for the Cycle Ergometer Tests

All subjects were asked to complete three cycle ergometer tests, one for each method. Selected subjects were asked to complete a fourth test to check for reliability of the test scores. If the subjects were able to complete the fourth cycle ergometer test, reliability estimates were calculated on their data using intraclass correlations calculated from a Subjects x Trials ANOVA. There were 8 subjects who repeated the YMCA submaximal test, 2 who repeated the YMOD submaximal test, and 3 who repeated the ACSM maximal test. The number of subjects who repeated these tests was low, therefore the reliability estimates must be viewed with this limitation in mind. The reliability estimate for the YMCA test ($R = -0.80$) was very low. There was more variability within subjects than there was between subjects. This showed the YMCA test did not provide reliable scores. The reliability estimate for the modified YMCA test ($R = 0.39$) was low, but it was still better than the reliability estimate for the YMCA test. The reliability estimate for the ACSM test ($R = 0.95$) indicated that the ACSM test was a very reliable
test, but as indicated previously, caution must be taken in the interpretation of this result because only 3 people repeated the ACSM test.

Reliability estimates should be at least .80 to .85 for the test to be interpreted as having adequate reliability (Baumgartner & Jackson, 1995). Therefore, only the ACSM test from this study could be considered to be reliable. The finding that the reliability of the YMCA test is low is consistent with the findings of Grossman et al. (1994). They found reliability estimates for the YMCA test between $r = .71$ and $r = .75$. Because the maximal validity that can be obtained for a test is dependent on the test's reliability (Baumgartner & Jackson, 1995), the validity estimates of the YMCA test might be expected to be low as a result of the findings of both the Grossman et al. study and the current study.

Order Effects

One factor that can affect reliability of test scores is the order in which tests are taken. An ANOVA procedure was performed to see if subjects' estimated VO2 max values were getting significantly better on the second or third trial, possibly as a learning effect or a result of becoming accustomed to the cycling. Although the order of the tests was randomly assigned, which should minimize order effect, the researcher wanted to see if one occurred. An ANOVA based on a Gender x Order design, in which the three different sessions (first, second, or third) represented the repeated measure, was conducted. The mean for the first session represented the mean VO2 max score for all subjects during their first visit to the lab, regardless of whether the YMCA, YMOD, or
ACSM test was administered during that session. The means for the second and third sessions were calculated in a similar manner. The main effect for order was not statistically significant, which meant that mean VO2 max scores for the second and third testing sessions were not significantly different from the mean VO2 max for the first testing session. This result indicated that the concern over a possible order effect was unfounded.

Another source of variability that could have decreased the reliability of test scores was time of day at which the tests were taken. Although no formal statistical analysis was completed for this possibility, time of day should not have been a significant factor, because 96% of the subjects performed each test on the 2nd and 3rd testing days within 2 hours of the time of the original test.

Differences in VO2 max Estimates Among Tests

ANOVA results indicated that the VO2 max estimates obtained from regression and visual scoring procedures for the modified YMCA test were not significantly different. This means that the visual determination of the line of best fit could be used in place of the statistically derived estimate. There is no need for practitioners to be trained to calculate and plot the exact regression line. The extra time needed for those calculations could make the scoring procedure too complicated, and ultimately, reduce the number of practitioners who would choose to administer the modified YMCA test, even if it did produce a VO2 max estimate better than the current YMCA estimate. Because the YMOD-R and YMOD-V means were not significantly different, only one of
the values, YMOD-R, was chosen to represent the submaximal VO2 max scores in subsequent difference tests.

The differences in mean VO2 max scores from the ACSM, YMCA, and YMOD-R tests were compared in Table 8, using a Gender x Test Type split-plot factorial ANOVA design. The first noticeable point was that mean VO2 max scores were not significantly different between genders. The VO2 max scores for the males and females were quite similar, as seen in Table 2. Mean VO2 max estimates for males in this study ranged from 42.6 to 48.8 ml·kg⁻¹·min⁻¹. Mean VO2 max estimates for females in this study ranged from 41.1 to 46.6 ml·kg⁻¹·min⁻¹. Males' scores were higher than females' scores on the YMCA and ACSM test, but were essentially the same on the modified YMCA test.

For ages 20 to 29 years, the median VO2 max scores from the ACSM test were 42.3 ml·kg⁻¹·min⁻¹ for males and 35.2 for ml·kg⁻¹·min⁻¹ (ACSM, 1995). MacDougall et al. (1991) reported VO2 max ranges of 36 to 44 ml·kg⁻¹·min⁻¹ for 20-year-old males and 32 to 38 ml·kg⁻¹·min⁻¹ for 20-year-old females. The norms for ages 18 to 25 years on the YMCA test (Golding et al., 1989) indicated median VO2 max estimates for males and females were 45 and 40 ml·kg⁻¹·min⁻¹, respectively. In the current study, the mean VO2 max estimates for males were consistent with the norms reported in all three sources. However, the mean VO2 max estimates for all tests for females were higher than the norms reported in all three sources. This indicates that the females in this study were probably much more fit than the typical 18 to 25-year-old females.

The VO2 max estimates for the YMCA and YMOD-R tests were not shown to be significantly different from the mean VO2 max score on the ACSM test, although the
probability level for this comparison was .06, very close to the .05 level of significance chosen for this study. According to Powers and Howley (1994), the VO2 max estimates based on the submaximal tests are generally within 10% to 20% of the actual VO2 max values. Means for the YMCA, YMOD-R, and YMOD-V tests in the current study (see Table 2) all are within this guideline, but they are all overestimates of the VO2 max scores from the ACSM test. This result could be affected somewhat by the estimation of VO2 max scores from VO2 peak scores on the ACSM test for subjects who did not demonstrate a plateau in VO2 scores or did not reach an R value of 1.15. However, practitioners should probably warn their clients on the strong possibility that both the YMCA test and the modified YMCA test provide overestimations of the actual VO2 max scores.

Predictions of VO2 Max From the Submaximal Tests

The Pearson correlation for the YMCA and the ACSM tests (r = .2373, p < .05) indicated that only 6% of the variability in the VO2 max scores from the ACSM test could be explained by the YMCA test scores. The correlations for the YMOD-R (r = .2058) and YMOD-V (r = .2150) with the ACSM scores explained 4% and 5% of the variability, respectively. The regression equations to estimate the VO2 max scores on the ACSM test were nearly identical when the YMCA, YMOD-R, and YMOD-V tests were used as the predictors. This would indicate that the VO2 max scores from the tests are interchangeable as predictors of the VO2 max scores from the ACSM tests. However, the ANOVAs to test the significance of these estimates were not significant, as would be
expected from the low Pearson correlations of these tests with the ACSM test.

These values indicated that, despite the lack of a significant difference in group means between both the original and modified YMCA test and the ACSM test, neither of the submaximal tests, YMCA or modified YMCA, was a good predictor of the VO2 max values. Therefore, the hypotheses that the YMCA test provided a valid estimate of VO2 max and that the modified YMCA test provided a more accurate estimate of VO2 max than the YMCA test were both rejected.
CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The problem was to determine if a 3-point estimation procedure for the YMCA cycle ergometer submaximal test provided a more valid predictor of VO2 max than the recommended 2-point estimation procedure for male and female college students between the ages of 18 and 25 years. In order to determine this, data were obtained from 46 subjects. The subjects performed the two submaximal cycle ergometer tests, YMCA and modified YMCA, and the ACSM maximal cycle ergometer test. The study took place in the Exercise Physiology Laboratory at Western Michigan University. A descriptive analysis was conducted on the subjects' characteristics and their VO2 max estimates on the cycle ergometer tests. ANOVAs for reliability estimates and for differences in VO2 max estimates between the ACSM, YMCA, and modified YMCA tests were conducted. Regression analysis was used to determine which submaximal test provided a better estimate of the VO2 max scores from the ACSM maximal cycle ergometer test. BMDP statistical software was used to perform all analyses. The level of significance was set at .05 for all tests.
Findings

The significant findings of the study were as follows:

1. The reliability estimate of the ACSM test, $R = .95$, was higher than the reliability estimates of the YMCA and modified YMCA tests, $R = -.80$ and $R = .39$, respectively.

2. The reliability estimate of the modified YMCA test, $R = .39$, was higher than the reliability estimate of the YMCA test, $R = -.80$.

3. No significant testing order effect was found, $F(2, 80) = 0.05$, $p = .27$.

4. No significant difference was found in the estimated VO2 max scores between the regression scoring method and the visual scoring method, $F(1, 41) = 1.24$, $p = .27$.

5. No significant difference in VO2 max scores was found between males and females, $F(1, 40) = 0.61$, $p = .44$.

6. No significant differences were found in the estimated VO2 max scores among the ACSM, YMCA, and modified YMCA tests, $F(2, 80) = 2.97$, $p > .05$, although it was observed that all submaximal tests resulted in mean VO2 max scores that were overestimates of the VO2 max scores from the ACSM test.

7. The correlations of ACSM VO2 max scores with the VO2 max estimates from the YMCA ($r = .2373$) and the modified YMCA, scored by the regression method ($r = .2058$) and by the visual method ($r = .2150$), were not significant, $p > .05$.

8. The regression equations for predicting VO2 max scores from the YMCA and the modified YMCA tests were similar, but none of the equations accounted for a
significant (p < .05) amount of variability in the VO2 max scores, F (1, 43) = 2.57 for the YMCA, F (1, 41) = 1.81 for the YMOD-R, and F (1, 41) = 1.99 for the YMOD-V.

Conclusions

The findings led the investigator to suggest the following conclusions:

1. The YMCA submaximal cycle ergometer test did not provide a valid estimate of VO2 max.

2. The modified YMCA test estimate using a 3-point procedure appeared to be more reliable than the YMCA test that used a 2-point estimate procedure, but neither test provided an accurate estimate of VO2 max.

Recommendations

The following are recommendations for further research:

1. Use an ECG instead of a HR monitor to determine HRs, or record HRs for a 10-s interval and use the mean HR to determine the VO2 max estimate.

2. When using the YMCA and modified YMCA submaximal tests go beyond the recommended 110 to 150 bpm range to estimate additional plot points for estimating VO2 max.

3. Administer three or more submaximal tests and use the middle score, or the mean of two or more middle scores, to estimate VO2 max.

4. Test a large randomly selected group of females to see if the VO2 max estimates in this study or those reported in the literature review are more accurate.
Appendix A

Human Subjects Institutional Review Board Approval
Date: December 13, 1995

To: Joel Blakeman

From: Richard Wright, Chair

Re: HSIRB Project Number 95-11-13

This letter will serve as confirmation that your research project entitled “Validation of the YMCA cycle ergometer test” has been approved, as revised, under the full category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you must seek specific approval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: December 13, 1996

xc: Patricia Frye, HPER
Appendix B

Recruitment Flier
Graduate assistant Joel Blakeman is looking for volunteers to participate in his master's thesis research. The study will be a validation study of the YMCA's cycle ergometer submaximal test. The study requires 50 volunteers (25 males and 25 females) between the ages of 18 and 25 years. As a volunteer, you will be required to participate in at least three fitness tests: (1) a YMCA cycle ergometer submaximal test, (2) a modified YMCA cycle ergometer submaximal test, and (3) the ACSM cycle ergometer maximal test. A group of 10 subjects from each of the tests will be required to complete a retest on that test to confirm the reliability of the test. A random order selection process will be established to determine what cycle ergometer test you will participate in first and whether you will be asked to complete a retest on one of the fitness tests.

Prospective participants will be asked to complete a questionnaire on their current health history to determine if they will be able to participate. If you are accepted as a subject, you must read and signed an informed consent form before participating. Your commitment would involve at least three 30-min sessions, and possibly a fourth if you are selected for a reliability group. Each subject will be given at least 48 hours rest between tests. All sessions will take place in the Exercise Physiology Laboratory, Room 1055 at the Student Recreation Center.

The tests will involve cycling on a Monark cycle ergometer at 50 rpm for 9 to 18 min. All tests involve increasing workloads according to pre-established test protocols. During the YMCA and modified YMCA cycle ergometer submaximal tests, your heart rate, blood pressure, and perceived level of exertion (RPE) for each stage will be recorded. For the ACSM cycle ergometer test, your heart rate, blood pressure, RPE, electrocardiograph readings, and respiratory exchange (VO2) will be monitored and recorded.

You have the option of voluntarily terminating your involvement in the study for any reason. Your participation or performance during the study will not have any effect on your academic evaluation in any way. All test information will be kept confidential, and you will be able to receive a copy of your test results upon request. If you are between 18 and 25 years old and are interested in getting more information or volunteering for the study, please fill out the information below or contact me by e-mail (95BLAKEMAN@WMICH.EDU) or phone (345-4699). Thank you.

<table>
<thead>
<tr>
<th>Name</th>
<th>Phone Number</th>
<th>Name</th>
<th>Phone Number</th>
</tr>
</thead>
</table>

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Appendix C

Health Screening Questionnaire
SUBJECT SCREENING FORM

Code Number: __________________

Please answer 'yes' or 'no' to the following questions.

1. Do you smoke?
2. Do you have diabetes?
3. Have you been told that you have high blood pressure or do you take blood pressure medication?
4. Has a member of your immediate family (parent or sibling) suffered from coronary or other atherosclerotic disease before the age 55?
5. Have you been told that you have a high blood cholesterol level?
6. Are you taking any medication, prescribed or over the counter? What are you taking?
7. Is there any possibility that you are pregnant (women only)?
8. Are you taking any of the following drugs?
   - Beta Blockers
   - Alpha Blockers
   - Amphetamines
   - Antidrenergic Agents
   - Nitrates and Nitroglycerin
   - Calcium Channel Blockers
   - Cocaine
   - Digitalis
   - Diuretics
   - Peripheral Vasodilators
   - Marijuana
   - Angiotensin-Converting Enzyme
   - Antiarrhythmic Agents
   - Sympathomimetic
   - or Antihyperlipidemic Agents
9. Have you experienced chest pains, shortness of breath, tightness in the chest, or fainting spells?
10. Do your ankles swell?
11. Do you have varicose veins?
12. Do you have a systemic infection?
13. Do you have mononucleosis?
14. Are you or have you been recently ill?
15. Do you have an injury that may be aggravated by exercise?
16. Do you have arthritis?
17. Do you experience extreme shortness of breath, especially with exercise?

Failure to answer any of these questions will result in elimination from the study. If a potential subject answers 'yes' to two or more items, 1-5, he or she does not qualify as 'apparently healthy' according to American College of Sports Medicine Guidelines (ACSM, 1995). Only 'apparently healthy' subjects will be eligible to participate in the study. An individual judgment will be made concerning participation of potential subjects answering yes to items 6-17. The judgment will be based on the potential impact of exercise on that particular. Individuals with cardiovascular disease, those with known symptoms of cardiovascular disease, or those possessing more than two known major factors or orthopedic injuries that require medical treatment during the past year or that are chronic enough to warrant exclusion will also be eliminated.
Appendix D

Informed Consent Form
I have been invited to participate in a research project entitled "Validation of the YMCA Cycle Ergometer Test." I understand that this research is intended to determine if a 3-point estimation procedure for the YMCA cycle ergometer submaximal provides a more valid predictor of maximal oxygen consumption than the 2-point procedure. I further understand that this project is Joel Blakeman's master's thesis in the department of Health, Physical Education, and Recreation at Western Michigan University.

My consent to participate in this project indicates that I will attend at least three 15- to 30-min sessions. These sessions will take place in the Exercise Physiology Laboratory, room 1055, in the Student Recreation Center. These sessions will involve: (1) YMCA cycle ergometer submaximal test, (2) YMCA modified cycle ergometer submaximal test, and (3) the American College of Sports Medicine (ACSM) cycle ergometer maximal test. In the first session, I will be familiarized with the Borg's rating of perceived exertion (RPE) scale, all testing procedures, and will participate in one cycle ergometer test. In the second and third sessions, I will participate in one of the remaining two tests, one in each session. I understand that I may be asked to participate in a fourth test, for establishing intraclass reliability. The order of testing will be done randomly.

As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or treatment will be made available to me except as otherwise specified in this consent form. I understand that there may be some potential risk of injury, such as muscle soreness or possible heart attack. However, appropriate measures will be taken to minimize these risks. The investigators and assistants in the data collection are all CPR and First Aid trained. Emergency response procedures are also posted in the Exercise Physiology Laboratory where all testing will take place. I also understand that I may terminate my involvement with this research for any reason at anytime without prejudice or affecting my academic evaluation in any way.
I may benefit from my participation by knowing my maximal oxygen consumption (VO2 max) for cycling. I may also gain insight as to time and equipment involved for taking a maximal or submaximal graded exercise test. I may also gain knowledge as to the importance of exercise participation and its affect on VO2 max.

I understand that all the information collected from me is confidential. My name will only appear on my data recording form and no individual names will be printed on any papers or reports other than this form, which will be seen only by the investigators and those helping to test. All data will be retained for a period of 3 years in a locked file controlled by the principal investigator. At the conclusion of the study, I will be able to receive a copy of my results upon request.

If I have any questions or concerns about this study I may contact Joel Blakeman at 387-2690 (office) or 345-4699 (home) or Dr. Frye at 387-2676. I may also contact the chair of the Human Subjects Institutional Review Board at 387-8293 or the Vice President for Research at 387-5926. I affirm that I am between the ages of 18 and 25 years old and free of any known cardiorespiratory disease. My signature below indicates that I understand the purpose and requirements of the study and that I agree to participate.

Signature

Date
Appendix E

YMCA Workloads
YMCA Guide to Setting Workloads on the Cycle Ergometer

<table>
<thead>
<tr>
<th>1st Workload</th>
<th>150 kgm 0.5 KP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rates (HR)</td>
<td>&lt; 80</td>
</tr>
<tr>
<td>2nd Workload</td>
<td>750 kgm</td>
</tr>
<tr>
<td>Workload</td>
<td>2.5 Kp</td>
</tr>
<tr>
<td>3rd Workload</td>
<td>900 kgm</td>
</tr>
<tr>
<td>Workload</td>
<td>3.0 Kp</td>
</tr>
<tr>
<td>4th Workload</td>
<td>1050 kpm</td>
</tr>
<tr>
<td>Workload</td>
<td>3.5 Kp</td>
</tr>
</tbody>
</table>

Directions:
1. Set the first workload at 150 kgm/min (0.5).
2. If HR in the third minute is
   - less than (<) 80, set the second workload at 750 kgm (2.5 Kp);
   - 80-89, set the second workload at 600 kgm (2.0 Kp);
   - 90-100, set the second workload at 450 kgm (1.5 Kp);
   - greater than (>) 100, set the second workload at 300 kgm (1.0 Kp);
3. Set the third and fourth (if required) workloads according to the workloads in the columns below the second workloads.
Appendix F

YMCA and Modified YMCA Scoring Grid


