4-2002

Development of a Submaximal Test to Predict VO_2MAX Using an Elliptical Trainer

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DEVELOPMENT OF A SUBMAXIMAL TEST TO PREDICT VO_2 MAX USING AN ELLIPTICAL TRAINER

by

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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 2002

ACKNOWLEDGEMENTS

Although I initially planned to pursue my Master's Degree in the latter portion of my life, I am truly grateful for the opportunity, knowledge, and personal gratification this experience has provided. I would first like to thank my thesis chair, Dr. Timothy Michael, for your continuing guidance, suggestions, and putting up with all of my questions. Thank you to Dr. Roger Zabik and Dr. YaunLong Liu as well for your assistance with revisions, data and regression analysis, confidence in me, and for serving on my committee. A special thank you to Dr. Mary Dawson, for believing in me and pushing me throughout my entire college career. I would not be here today without you.

I would also like to deeply thank my colleagues, Georgios Hajiefremides, M.A. and Amy Geib, M.A. who have helped me every inch of the way with my research. Thank you for your support, assistance in data collection, and for your friendship. Also, thank you to the other graduate assistants who aided in the data collection and to all of my subjects who agreed to participate in my study.

Finally, thank you to my family for your endless love, patience, hope, and faith in me. I will miss you when I leave, but you are always with me in my heart.

Alicia C. Armour

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Western Michigan University, 2002

The study attempted to determine whether an elliptical trainer is a valid exercise devise for the use in submaximal exercise testing to predict VO_2 max. Each subject performed two maximal treadmill exercise tests (Bruce Protocol), and three submaximal elliptical trainer exercise tests. The graded exercise test (GXT) had the following features: (a) 3-minute stages, (b) incremental increases in resistance of three levels between stages, and (c) a cycling (step) rate of 100 per minute. The variables measured in the study were: (a) VO_2 max, (b) HR, (c) RPE, and (d) workload expressed in watts. HR and watts were measured every minute of each stage, and then averaged. Overall RPE was measured on the second minute of each stage. From the variables measured, a multiple linear regression analysis was conducted using the enter method on SPSS version 10.0. Three Models were chosen for further analysis. From this analysis a final formula, Model C, was created in order to predict VO_2 max, providing similar R, R^2, and SEE values (0.724, 0.525, and 4.867 respectively) to standard submaximal exercise tests. The regression formula for Model C was: $VO_2 \text{ max} = 71.14 - 11.875x_1 + 2.362x_2 - 0.273x_3$ (x_1=gender where 1=male, 2=female; x_2 = termination stage, and x_3 = weight in kg).

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CHAPTER I

INTRODUCTION

New exercise machines are designed, marketed, presented, and purchased every year. Each machine promises a better, more efficient workout. As these new machines emerge, researchers begin to examine them to see if the machines do all that is promised, as well as test them for other purposes, such as exercise testing. Since exercise testing began, many modalities have been used for both submaximal and maximal exercise tests.

The protocol used in the clinical setting is generally maximal exercise testing using a motorized treadmill. A maximal exercise test measures or predicts maximal oxygen consumption (VO_2 max) at the end of an exhaustive incremental or graded exercise bout (Pivarnik, Dwyer, & Lauderdale, 1996). Maximal oxygen consumption is dependent on the ability of the oxygen transport system to deliver blood to the body and for the cells to utilize the oxygen (Noonan & Dean, 2000). Test termination criteria for VO_2 max are: (a) plateau in VO_2, (b) ± 10 beats per minute of age predicted maximal heart rate, (c) RQ ≥ 1.15, (d) blood lactate > 4 mmol. If an individual is unable to reach a plateau or does not reach their maximum because musculo-skeletal or pulmonary limitations then their test results would be considered invalid (Noonan & Dean, 2000).

Many clinical specialists agree that maximal exercise testing is not always the best alternative for many individuals (Gill, DiPictro, & Krumholz, 2000). For example, in an elderly population it is harder for subjects to reach their maximum exercise level due to musculo-skeletal problems or vascular problems (Froelicher, Fearon, Ferguson, Morise, Heidenreich, West, & Atwood, 1999).

Submaximal exercise testing gives patients and subjects an estimate of their VO_2 maximum without extreme strain or exertion. There are two types of submaximal exercise testing, predictive and performance. Predictive submaximal testing will estimate a patient's maximal aerobic capacity (Noonan & Dean, 2000). Performance submaximal exercise testing measures a person's response to standardized physical activity that is typical of everyday life situations (Noonan & Dean, 2000). A submaximal exercise test overcomes many of the limitations of maximal testing such as pain and fatigue (with the exertion required in a maximal test). Submaximal testing can also be used to make diagnoses and assess the functional limits of patients, as well as to determine the outcome of interventions such as exercise programs. It also provides information on the body's exercise response (Noonan & Dean, 2000). Many health professionals today agree that more submaximal exercise test protocols are needed (Noonan & Dean, 2000).

Modalities often used today for exercise testing include the treadmill and bicycle ergometer. Each machine has its advantages and disadvantages. A new machine popular in most fitness centers today, the elliptical trainer, combines the movement and advantages of the treadmill and bicycle ergometer. With the combined advantages, and elimination of the disadvantages, the elliptical trainer is a wonderful alternative for exercise testing.

A disadvantage when using treadmills for submaximal exercise tests is subject weight limit restrictions. Weight limits for treadmills range from 250 to 350 pounds. The treadmill is also a weight bearing exercise, thus is high-impact. This high-impact can cause extra pain for subjects with vascular problems, arthritis, joint problems, surgery patients, and orthopedic patients. One study found that the treadmill has as much as two times the ground reaction forces as does the elliptical trainer. This supports the argument that use of the elliptical trainer may provide less injury (Porcari, Zedaker, Naser, & Miller, 1998). Other researchers have stated that the high impact aerobic activities, such as jogging, can cause forces equal to 24 times a person's body weight due to the body becoming airborne. These forces are absorbed in the foot, then move up into the ankle, knee, hip or back, many times resulting in injury (Porcari et al., 1998). The treadmill also causes problems for people who struggle with gait irregularities, as well as the danger of someone falling off the treadmill during the test itself (Neiman, 1999). Treadmills are more expensive and require more maintenance than cycle ergometers, take up more space, and are less portable (Neiman, 1999). Another disadvantage to the treadmill is the measurement of heart rate and blood pressure can be more difficult due to the noise created by the treadmill.

Cycle ergometers are the most commonly used modality for submaximal exercise testing today. Cycle ergometer tests have an advantage because they have no weight restrictions. They are low impact, and require mostly legwork. Cycle ergometers are reasonable in price, and very portable. They also take up little space in a lab or clinical setting. Work produced by cycle ergometers is measured in watts or kiloponds·m·min^{-1}, therefore, power can be measured directly (Neiman, 1999).

Some disadvantages to cycle ergometer tests are leg fatigue and noise level. The cycle ergometer concentrates on the quadricep muscle group, causing early leg fatigue resulting in inaccurate data (Lehmann, Schmid, Ammer, Schomig, & Alt, 1997). Cycles also can be very noisy and create a large amount of artifact on the electrocardiogram (ECG) reading (Froelicher, Grauer, Hizon, & Travalino 1998). This noise also makes measurement of heart rate (HR) and blood pressure (BP) more difficult (Froelicher et al., 1998). Cycle ergometers are used more often than arm ergometers due to the small number of protocols available for arm ergometer tests.

Generally, arm ergometer tests are administered when a patient has severe peripheral vascular disease, and are unable to use their legs for specific periods of time (Shephard, Allen, & Benade, 1968). Also, if the patient is uncomfortable and has a hard time pedaling, the arm ergometer is a better alternative for testing.

Statement of the Problem

Since both treadmills and cycle ergometers have many disadvantages that may tend to outweigh the advantages, the option of using an elliptical trainer for submaximal exercise testing may be a good alternative modality. This machine combines the strengths of the two most popular modalities. It is low-impact, uses all muscle groups in the legs, and is extremely quiet (Blaf, 1998). The study was conducted to determine whether a Precor® EFX^{TM} 546 elliptical trainer submaximal exercise protocol would provide a valid test for the prediction of VO_2 max.

Significance of the Problem

As previously stated, when administering submaximal exercise testing, the standard modalities used are treadmill and cycle ergometers. Each has advantages and disadvantages. Most exercise physiologists today prefer treadmill protocols due to better performance rates. In one specific study the exercise tolerance time of the subjects was 9% higher on the treadmill (Lehmann et al., 1997). With this increase in exercise tolerance time subjects could exercise at a larger workload and exercise duration causing higher peak values (Lehmann et al., 1997). Subjects exercise tolerance time on treadmill tests is longer due to the use of all muscle groups in the legs, versus isolated muscle groups on the cycle (Lehmann et al., 1997). Some populations also function better on the treadmill because walking and running is a more natural movement than cycling.

Precor EFX® elliptical trainers are the most popular elliptical trainers in fitness centers today. They take up less space and are more user friendly than most other modalities (Blaf, 1998). Elliptical trainers were designed to provide the movement of running or walking, but without the impact (Lochridge, 2000). Each user has the option of moving forward or backward in a circular motion (Lochridge, 2000). Adjustments on the Precor EFX® elliptical trainer range from 1% to 20% of incline and resistance settings from 1 to 20 (Blaf, 1998). The monitor on the machine displays MET level, which is the metabolic equivalent (Blaf, 1998). This allows the user to monitor their effort level at any time. There are no weight restrictions on the elliptical trainer and it produces very little noise (Blaf, 1998). With the small amount of noise and the high use of elliptical trainers in fitness facilities, it makes the elliptical trainer a good option for submaximal exercise testing. Therefore, the purposes of this study were to: (a) determine whether an elliptical trainer protocol to produce a prediction equation to predict VO_2 max would provide a valid exercise test; and (b) determine whether the elliptical trainer protocol will provide an alternative modality for submaximal exercise testing that has similar results in comparison to standard tests.

Purpose

The purposes of this study were the following:

1. To design a valid submaximal elliptical trainer protocol to predict VO_2 max.

2. To design a submaximal exercise test with similar results in comparison to standard exercise tests to provide an alternative modality for testing.

Research Problem

The following research problem was tested: The elliptical trainer submaximal exercise protocol will provide a valid test for the prediction of VO_2 max.

Delimitations

The delimitations of the study were the following:

1. The study was limited to 51 male and female Western Michigan University (WMU) students in Exercise Science and Physical Education major classes, and Student Recreation Center participants.

2. The participants were between the ages of 18 and 31, low risk according to American College of Sports Medicine (ACSM) guidelines, who reported exercising two to three times per week, and had no history of musculo-skeletal injury (ACSM, 2000).

3. All measurements, treadmill and elliptical tests were conducted in the WMU Student Recreation Center rooms 1050-1060.

4. The data collected were VO_2, HR, BP, ECG, RPE, watts, weight, height, body mass index (BMI), and age.

Limitations

The following were limitations of the study:

1. The subjects who participated in the study were not randomly selected; therefore this research may not represent the general population.

2. Subjects performed three trials on separate days with various rest periods between trials, which may have affected the results.

Assumptions

The following assumptions were made in this study:

1. Subjects followed all pretest guidelines.

2. Subjects were adequately warmed up at the time the trials were conducted.

3. Subjects performed to the best of their ability during each trial session.

4. Subjects understood the RPE charts and reported their levels consistently and accurately throughout the study.

5. The equipment used throughout the study was calibrated precisely.

Definitions

The following terms were defined for the study:

1. *Cycle/arm ergometer*: stationary bike/arm cycle.

2. *Elliptical Trainer*: a cross-training exercise machine that is low-impact and moves the lower extremities in the motion of an ellipse (Blaf, 1998).

3. *Electrocardiogram* (ECG, EKG): monitors electrical impulses/voltage produced by cardiac muscle.

4. *MET*: one MET is equal to the resting oxygen consumption of the reference average human age; 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$ (Demaree, Powers, & Lawler, 2001).

5. *Rate of perceived exertion* (RPE): A rating scale from 6 (no exertion) to 20 (maximal exertion), which can be used to determine relative exercise intensity (Brooks Fahey, & White, 1996).

6. *Submaximal exercise test*: a test where the subject exercises until they reach a goal of 75%-85% of their maximal heart rate.

7. *Oxygen consumption* (VO_2): the rate at which oxygen is consumed during exercise (Neiman, 1999).

8. *Maximal oxygen consumption* (VO_2 max): the greatest rate (or rate) at which oxygen can be consumed during exercise (Neiman, 1999).

CHAPTER II

LITERATURE REVIEW

The elliptical trainer, one of the most popular exercise machines used in fitness centers today, is currently being tested for all of the potential benefits as well as for the possibility of fitness testing. Specifically examining the Precor® elliptical trainer, research has shown that elliptical trainer sales have increased 300 percent between 1996 and 1997, and are competing for space with standard bikes and treadmills (Florez, 1998). One of the most popular reasons for the increased sales of the elliptical trainer would be the cross training workout participants get with little impact or stress on the body (Alper, 1998). The option of a beneficial, low impact workout permits a wide range of users to use the elliptical trainer including moderate exercisers, rehab patients, deconditioned individuals, or athletes (Precor, 1996). Most researchers study similar topics when evaluating the reliability and validity of a specific machine and protocol for exercise testing. The topics included in this study were: elliptical trainer: a low impact modality; elliptical trainer: a valid modality; oxygen consumption, comparison of submaximal and maximal exercise testing; developing submaximal exercise tests; and developing regression equations for fitness testing.

Elliptical Trainer: A Low Impact Modality

Each machine has specific mechanics, mechanical advantages, and therefore they produce different results and benefits. Designers of exercise equipment want to provide a safe, effective machine that can be used with most populations. However, due to the movement mechanics of the machines, some populations cannot use certain modalities. The elliptical trainer, however, is low impact, provides fluid movement, which reduces impact-related injury in joints and muscles (Precor, 1998). The movement of the elliptical trainer, in an ellipse, provides a crosstraining workout through a broad range of motion, promoting proper body posture and stability (Precor, 1998). The elliptical trainer provides 40% more gluteal involvement than standard exercise machines (Bates, 1996). The elliptical trainer also offers increased quadriceps exercise, specifically the rectus femoris, vastus lateralis, and vastus medialis muscles in the quadriceps (Bates, 1996). It also supplies exceptional hip extension and flexion, as well as increased knee range of motion. Specifically, the positioning of the knee significantly reduces the potential for shear force damage (Bates, 1996). Not only does the elliptical trainer provide a better workout, but the options of forward and backward movement complement each other by granting a cross training workout. The reverse motion places an emphasis on hamstring work, while forward motion promotes gluteal effort (Bates, 1996).

One of the main appeals to the elliptical trainer for submaximal exercise testing is it's low impact feature. Several studies (Porcari et al., 1998; Bates, 1996; Porcari, Foster, & Schneider, 2000) have been conducted analyzing the ground reaction forces (GRF) on different exercise machines. One study in particular compared the elliptical trainer to treadmill walking and running, stationary cycling, and stepping (Porcari et al., 1998). The purpose of the study was to examine the physiological responses to exercise on the elliptical trainer to each of the standard exercise modalities. The results from the study showed that the elliptical trainer showed no significant difference in oxygen consumption (VO_2), heart rate (HR), and Kcals, between the elliptical trainer and treadmill running. However, the results in comparison to the other exercise modalities were much higher on the elliptical trainer (Porcari et al., 1998). The study also showed that the GRF of the elliptical trainer as less than half of the treadmill run (Porcari et al., 1998). The decrease in GRF suggests to researchers that the elliptical trainer provides the same benefits of exercise and testing on the treadmill, with a decreased risk for injury (Porcari et al., 2000).

Elliptical Trainer: A Valid Modality

Many researchers have found that elliptical trainer users have VO_2 results equal to those on treadmills, and while working at the same level in terms of aerobic capacity, the users perceived the workout to be less strenuous (Kravitz, Wax, Mayo, Daniels, & Charette, 1998). Other current studies found when evaluating VO_2 on the elliptical trainer, that the values were comparable to treadmill running, and significantly higher than all other standard exercise modalities (Porcari et al., 2000). Another study conducted at the University of Mississippi found similar results and concluded that elliptical training provided a satisfactory metabolic challenge for cardiovascular fitness (Kravitz et al., 1998). In another study of a comparison between a treadmill and an elliptical trainer, where VO_2 was analyzed, no significant difference was found. Thus, making the elliptical trainer a valid mode of exercise for cardiorespiratory exercise and endurance (Pecchia, Evans, Edwards, & Bell, 1999). Other research found that when conducting graded exercise tests (GXT) on the elliptical trainer and treadmill, comparable peak responses occurred, indicating that the elliptical trainer is a suitable modality for exercise testing (Wiley, Mercer, Chen, & Bates, 1999).

Oxygen Consumption

Knowledge of oxygen consumption (VO_2) as a response to exercise is beneficial for various reasons, including diagnostic testing and prescription, evaluation of cardiorespiratory fitness, motivation, information on health status, and general knowledge (McConnell, 2001). The best measure of cardiovascular and respiratory endurance is the direct measurement of oxygen uptake during maximal exercise through lab testing. Measurements should be specific to the sport practiced by the individual being tested because of unique adaptations that occur (Neiman, 1999). The most commonly used method of measuring VO_2 is open-circuit spirometry (Powers & Howley, 1994).

Open-circuit spirometry collects and analyzes the inspired and expired gases that move through the mouth of the subject during exercise. Air is directed through the mouth using a one-way valve (Demaree et al., 2001). The volume of inspired oxygen (O_2) is measured by using a dry gas meter, turbine, or pneumatic. On the expired side, gas fractions are sampled and measured by O_2 and carbon dioxide (CO_2) analyzers. The voltages are converted to digital information using the Haldane transformation of the Fick equation (Demaree et al., 2001). After the metabolic cart samples, measures, and converts the information it calculates oxygen consumption (VO_2, VO_2 max). Most researchers analyze exercise responses using this equipment to measure VO_2 along with ECG equipment to monitor heart rate and electrical conduction of the heart.

Comparison of Submaximal and Maximal Testing

The most reliable measure of aerobic capacity is maximal oxygen consumption (VO_2 max) in standard exercise testing (Hollenburg & Tager, 2000). Maximal oxygen consumption (VO_2 max) defines the pumping ability of the heart, providing useful information for physicians, exercise physiologists, physical therapists, and many other individuals in the medical profession (ACSM, 2001). When testing for VO_2 max, subjects are exercised to exhaustion (Nieman, 1999). The following criteria are used to determine whether an individual has reached true VO_2 max: (a) plateau in VO_2, (b) ± 10 beats per minute of age predicted maximal heart rate, (c) RQ ≥ 1.15, (d) blood lactate > 4 mmol (ACSM, 2001). This form of maximal graded exercise testing (GXT) serves several purposes including: diagnostic purposes (heart disease), cardiorespiratory functional capacity, response to exercise conditioning or rehabilitation programs, and for motivational purposes (Nieman, 1999). However, most average individuals who participate in GXTs seldom reach their true VO_2 max (Hollenburg & Tager, 2000). Instead, they reach their peak oxygen consumption. GXTs are often too strenuous and require too much impact for many populations (Hollenburg & Tager, 2000). Lab measurements of VO_2 max is expensive and time-consuming, requiring highly trained personnel and therefore it is not practical for most testing situations (Neimen, 1999). An alternative to maximal GXTs is submaximal exercise testing.

Submaximal exercise testing measures physiological responses to exercise, including VO_2, heart rate, and blood pressure, where the participant exercises up to a set heart rate, generally 75-85% of their age predicted maximum heart rate (MHR) (Nieman, 1999). Submaximal exercise tests assume that: (1) heart rate, oxygen uptake, and workload have a linear relationship, (2) maximal heart rate at a given age is the same for everyone, (3) oxygen uptake at a given workload is uniform (McConnell, 2001). Oxygen uptake at any given workload can vary 15% between individuals (Neiman, 1999).

Using the data collected during the test, maximal oxygen consumption (VO_2 max) can be predicted by using a linear regression formula specific to the protocol used. The reasoning behind submaximal exercise testing is to reduce subjectivity error, increase the population use of the protocol, and to provide a more safe, practical, and appropriate mode of determining aerobic capacity (VO_2 max) (Hollenburg & Tager, 2000).

Designing Submaximal Exercise Tests

Before designing a submaximal graded exercise test (GXT), the following items should be taken into consideration: (a) legal consideration, (b) physician involvement, (c) preparation for the test, (d) screening tools, (e) population restrictions, (f) documentation, (g) contraindications, and (h) emergency procedures. The following equipment should be used for a submaximal GXT: (a) the testing modality, (b) perceived exertion chart, (c) clock, (d) metronome, (e) sphygmomanometer, (f) stethoscope, (g) scale, (h) calculator, and (i) first aid kit (ACSM, 2001). Physiological variables measured during submaximal GXTs include HR and BP. It is recommended that an ACSM-certified person administer the GXT. When low risk participants are tested, a physician is not required. However, when testing people classified high risk, a physician should supervise the test (Neiman, 1999).

Submaximal GXTs can be single stage or multi stage to estimate VO_2 max from HR measurements. It is recommended that either an ECG, HR monitor, or stethoscope be used to determine HR. HR can be affected by environment, dietary, and behavioral factors. In order to ensure a valid and reliable estimate, these factors must be controlled. The test modality should be consistent with their primary choice of physical activity (ACSM, 2000).

Standard submaximal GXTs such as the YMCA cycle ergometer test or Balke treadmill test follow similar design. Most submaximal GXTs consist of 3-minute stages. Usually the test's stages have an stepwise increase in workload of 25 watts, 150 kg·m·min^{-1}, or 0.5 kiloponds. Heart rate is generally monitored and recorded every minute of each stage, specifically the second and third minute of each stage, where a steady state is more likely to have been achieved. Blood pressure, when monitored, is measured at the latter portion of the stage (ACSM, 2000). Test termination for the YMCA submaximal cycle ergometer test is two heart rates in two different stages in the range of 110-150 beats per minute (bpm) or 120-170 bpm. Termination criteria for the Balke submaximal treadmill test is when the participant reaches 75% or 85% of their age predicted maximal heart rate (APMHR). The YMCA cycle ergometer test and Balke treadmill test follow general procedures of sumaximal exercise testing according to ACSM guidelines (ACSM, 2000).

Although many submaximal GXTs have been developed on standard exercise equipment such as treadmills and cycle ergometers, there are a few protocols that exist for new exercise equipment such as the elliptical trainer. As previously stated, elliptical trainers are one of the most popular exercise machines used today (Florez, 1998). With such a wide and common form of cardiovascular exercise, a protocol for submaximal exercise testing could be extremely beneficial. As mentioned above, when considering submaximal testing, the test modality for GXTs should be consistent with the individual's primary choice of activity. With this in mind, a protocol was established for submaximal testing on the elliptical trainer. Following standard tests and ACSM guidelines, the design as previously mentioned was created. The protocol was developed and consisted of 3-minute stages with a maximum of 10 stages. Stages 1-7 had a workload increase of three levels in resistance beginning at resistance two, where grade remained constant at level 10. At stage 8, resistance remained constant at level 20, due to the maximal resistance level being achieved, and incline increased to 13, 17, and 20 respectively with each stage increase. The set cadence was 100 strides per minute with hand placement on the handrails with a light grip consisting of 2-3 fingers or palms only on the handrail to ensure proper form and use. Termination criteria were as follows: (a) participant reached 75% of their APMHR, (b) participant could no longer maintain the cadence, (c) participant requested to stop. All other termination criteria followed were according to ACSM guidelines (ACSM, 2000).

Developing Regression Equations for Fitness Testing

Multiple linear regression is frequently used with data that includes three or more variables where one variable is dependent upon two or more variables (Vincent, 1995). For the purpose of this study, multiple linear regression was chosen due to the large number of independent variables measured to predict VO_2 max. Some advantages to using multiple linear regression, in comparison to bivariate linear regression, are the following: (a) multiple regression provides a lower standard of error of estimate (SEE), (b) provides information to determine which independent variables contribute to the prediction and which do not (Vincent, 1995). Each of the coefficients give weight to the independent variables and prediction of the dependent variable, in this case VO_2 max (Vincent, 1995).

There are many types of regression, three specific types of multiple regression are as follows: (a) standard, (b) hierarchial, (c) stepwise. Standard regression produces one equation with all the variables and constants. Hierarchial regression provides an equation with a hierarchial order for inclusion of independent variables. The third form of regression, stepwise, is a series of equations, starting with a bivariate equation, which adds additional equations in a step-by-step order of adding independent variables to the equation (Vincent, 1995). It is suggested that the ratio of subjects to independent variables be no less than 5:1 (Vincent, 1995).

In a study conducted on a nonexericse prediction equation of VO_2 peak, the Statistical Package for the Social Sciences (SPSS) was used to develop four prediction models using multiple linear regression analysis. The variables measured and analyzed in the study included: (a) percent body fat, (b) self-reported exercise frequency, and (c) body mass index. Each model's validity was tested by applying each equation to the cross-validation data (Erdmann, Hensley, Dolgener, & Graham, 1999). A subgroup analysis was conducted by computing the SEE values to validate accuracy of the regression formulas (Erdmann et al., 1999). Results from this study supported the validity of nonexercise testing for predicting VO_2 peak in all groups with the exception of highly fit 11 to 14-year-old boys. The study also found the accuracy of the prediction formulas to be consistent with other nonexercise prediction models (Erdmann et al., 1999).

In another study multiple regression was used to evaluate gender and ethnicity as possible sources of prediction bias (Quail, Vehrs, & Jackson, 1999). When both variables were added to the regression formula, a significant increase in correlation and added variance of measured VO_2 max was observed. The formula produced from this study was found to provide an increasingly accurate prediction of VO_2 max (Quail, Vehrs, & Jackson, 1999).

In summary, the purpose of this study was to determine whether an elliptical trainer protocol would produce an alternative modality for submaximal exercise testing which has similar predictiveness in comparison to standard tests. The purpose was also to determine whether an elliptical trainer protocol to produce a prediction equation to predict VO_2 max would provide a valid exercise test.

CHAPTER III

METHODS AND PROCEDURES

The following methods and procedures are presented in this chapter: (a) selection of subjects, (b) screening and initial testing, (c) instrumentation, (d) design, (e) testing procedures, and (f) statistical analysis.

Selection of Subjects

This study was approved by the WMU Human Subject Institutional Review Board prior to all testing (Appendix A). The subjects were male and female WMU students recruited from Exercise Science and Physical Education major classes, and Student Recreation Center (SRC) participants (Appendix B). The only subjects who participated in the study were classified as low risk by ACSM guidelines, between the ages of 18-35 years, who exercised 2-3 times per week, and were free of musculo-skeletal injury (ACSM, 2000). The subjects attended five sessions with a minimum of 24 hours and maximum of 48 hours between tests. All sessions were held in the SRC, Rooms 1050-60. All subjects were screened prior to participation in the study (Appendix C). All subjects were required to read and sign a consent form prior to participation in the study (Appendix D).

Screening and Initial Testing

During the initial screening, all subjects were provided information regarding pre-test guidelines. The guidelines according to ACSM before each test were: (a) avoid food, alcohol, or caffeine or using tobacco products for at least 3 hours before testing; (b) avoid exercise or strenuous activity the day of the test; (c) drink plenty of fluids over the 24-hour period before the test to ensure proper hydration; (d) clothing worn for the test should permit freedom of movement and include walking or running shoes (ACSM, 2000). At the initial meeting, testing protocol(s) were discussed, a demonstration was given on the elliptical trainer, and all subjects were given the opportunity to try the elliptical trainer as well as the treadmill prior to testing to avoid learner error. After the initial screening each subject was contacted to sign up for days and times for testing.

All subjects were required to fill out a subject screening form completely (Appendix C). All subjects were instructed to read and sign a consent form prior to participating in the study after passing the initial screening (Appendix D). During each session evaluation of the subject's health and fitness was monitored through observation and data collection in order to protect the subjects.

Prior to data collection, subjects prepared their muscles and joints for exercise by warming up in a 10-15 minute time period using their own personal protocol and modality. Subjects performed two standard GXTs on the treadmill. The protocol used for the treadmill GXT was the Bruce Protocol (Appendix E). During the tests HR, ECG, blood pressure (BP), VO_2, and ratings of perceived exertion (RPE) overall

(Appendix F) were monitored. Subjects completed the VO_2 max test on two different days with a minimum of 24 hours and a maximum of 48 hours between the two tests. VO_2 max and HR max from the highest test were used in the study.

Instrumentation

The following equipment was used in this study: for ECG recording and heart rate measurement, the Marquette Cardiosoft, GE Marquette Medical Systems, Milwaukee, WI was used with Graphic Controls 8105 electrodes (4 lead). All VO_2 data and metabolic information were recorded on the Sensormedics metabolic cart, model Vmax 229 LV Lite, Yorba Linda, CA. The mouthpieces used in this study were Hans Rudolph, Inc. model 1.375, Kansas City, MO. The blood pressure equipment consisted of a Welch Allyn blood pressure cuff, model Tycos, Arden, NC and an IMCO Caliber Aneroid sphygmomanometer, model 72-130-011, Daytona Beach, FL. A Polar heart rate monitor model 61214, was used to evaluate HR during the elliptical trainer exercise. The Elliptical Trainer used in this study was model EFX™ 546, Precor® Inc., Bothel, WA. A Quinton Instruments model 643, Seattle, WA was used during the treadmill testing. The metabolic cart was calibrated using the following equipment: a Hans Rudolph, Inc. 3 liter Calibration Syringe, model 5530, Kansas City, MO was used for volume calibration. Known concentration of gases were used to achieve gas analyzer calibration. A chart with Borg's RPE scale was used to record perceptual responses, seen in Appendix F (ACSM, 2000).

Design

The purpose of this study was through multiple linear regression, to derive a regression equation to estimate VO_2 max by using an elliptical submaximal exercise protocol. The predictive variables used in this study are presented in Table 1.

Table 1

Predictive Variables Recorded

Descriptive Variables	Exercise Variables
Weight (kg)	Termination Stage (stage number)
Height (cm)	Average overall RPE for the termination stage
BMI ($kg{\cdot}m^{-2}$)	Average HR (bpm) for the termination stage
Age (yr.)	Average watts for the termination stage
Gender (1=males, 2=females)	Average HR for Stage 2 (bpm)
	Average HR for Stage 3 (bpm)
	Average watts for Stage 2
	Average watts for Stage 3
	Average overall RPE for Stage 2
	Average overall RPE for Stage 3

Note. The dependent variable recorded in this study was VO_2 max.

The protocol included 3-minute stages with a stride frequency set constant at 100 strides per minute. The increases in resistance levels or incline came on the third minute of each stage. This resulted in an increase of approximately 21 to 25 watts per stage. Table 2, presented on the next page, shows the submaximal elliptical trainer protocol used in the study.

As stated previously, each subject who volunteered and was cleared through the screening process, signed-up for five sessions, two sessions for VO_2 max data collection, and three sessions for the GXT on the elliptical trainer. During the submaximal tests HR and RPE were measured and recorded. The test was terminated when: (a) the subject reached 75% of his/her age predicted maximum heart rate, (b) if the subject asked to stop or there was a malfunction with equipment, and (c) for any general indications for stopping an exercise test listed by ACSM guidelines (ACSM, 2000). Using the highest VO_2 max value from the maximal treadmill test, a linear regression formula was produced from variables measured during the elliptical GXT to predict VO_2 max.

Table 2

Submaximal Elliptical Trainer Protocol

Stage	Crossramp Inclination	Resistance
1	10	2
2	10	5
3	10	8
4	10	11
5	10	14
6	10	17
7	10	20
8	13	20
9	17	20
10	20	20

Testing Procedures

Prior to testing each subject warmed up for approximately 10-15 minutes, using their own personal protocol and modality. The graded exercise test (GXT) was designed with the following features: (a) 3-minute stages, (b) incremental increases in resistance of three levels between stages (which is equivalent to an average of 25 watts), and (c) a cycling (step) rate of 100 per minute. HR and watts were measured every minute of each stage, and then averaged. Overall RPE was measured on the second minute of each stage. Means for HR, watts, and overall RPE for each stage were found by averaging the three trials. Termination of the test occurred when the subject's heart rate reached 75% of his/her age predicted maximum heart rate. This protocol was repeated on three separate days. The total sessions for each subject were five sessions, consisting of two sessions of VO_2 max testing and three sessions to complete the GXT on the elliptical trainer.

Statistical Analysis

The statistical analysis chosen for this study was multiple linear regression using SPSS version 10. The highest VO_2 max recorded from the treadmill tests was used as the dependent variable for the multiple linear regression analysis. The SPSS enter method was used for the regression formula. A logical approach was taken at first with the regression analysis, where variables that were known to have relationships with VO_2 max were entered into the regression formulas (i.e. RPE, HR, and workload expressed in watts). The variables entered into the initial analyses were also chosen based upon variables previously used in regression analyses found in the literature review. After initial analyses were conducted, a statistical approach was taken where correlations between variables were computed (Appendix G) and further regression analyses were formed. The combination of independent variables that contributed to the prediction of VO_2 max (dependent variable) were included in the final regression formula based upon the R, R^2, and SEE values.

CHAPTER IV

RESULTS

The purpose of this study was to design a submaximal exercise test to predict VO_2 max using an elliptical trainer exercise protocol. The dependent variable and predictive variables used in this study were presented in Table 1. From the variables measured, a multiple linear regression analysis was conducted, and then a formula was determined in order to predict VO_2 max. The results presented in the chapter are as follows: (a) subject demographics, (b) Model A variable labels, (c) Model A linear regression formula, (d) Model B variable labels, (e) Model B linear regression formula, (f) Model C variable labels, (g) Model C linear regression formula, and (h) model summary.

Subject Demographics

The demographics of participants from this study are presented in Table 3. Males and females are combined as a total sample group.

Linear Regression Analysis

Model A contains 12 variables, which are listed in Table 4. Model B contains 8 variables, which are presented in Table 5. Model C contains 3 variables, which are presented in Table 6. The R, R^2, and SEE values for Model A, Model B, and Model C linear regression formulas are presented in Table 7.

Table 3

Subject Demographics

	n	Minimum	Maximum	Mean	SD
VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$)	51	33.40	60.20	46.41	6.85
MHR (bpm)	51	154.00	214.00	187.70	11.37
Weight (kg)	51	49.09	104.55	71.93	13.88
Height (cm)	51	152.40	190.50	171.38	10.96
BMI ($kg \cdot m^{-2}$)	51	17.40	34.12	24.40	3.00
Age (yr.)	51	18.00	31.00	21.40	2.81

Through the enter method, a regression formula containing 12 variables was computed to predict VO_2 max (Model A). As previously stated, the variable labels for Model A are listed in Table 4.

Table 4

Model A Variable Labels

Label	Variable
x_1	Termination Stage (stage number)
x_2	Average HR for the termination stage (bpm)
x_3	Average watts for the termination stage
x_4	Average overall RPE for the termination stage
x_5	Average HR for Stage 2 (bpm)
x_6	Average HR for Stage 3 (bpm)
x_7	Average watts for Stage 2
x_8	Average watts for Stage 3
x_9	Average overall RPE for Stage 2
x_{10}	Average overall RPE for Stage 3
x_{11}	BMI ($kg \cdot m^{-2}$)
x_{12}	Weight (kg)

The initial regression formula (Model A) for predicting VO_2 max while using a submaximal elliptical trainer protocol was as follows:

Model A

$$VO_2 \text{ max} = 145.611 + 2.284x_1 - 0.180x_2 + 0.106x_3 - 2.228x_4 + 0.819x_5 - 0.925x_6 - 0.405x_7 - 0.174x_8 - 0.937x_9 + 1.128x_{10} - 0.258x_{11} + 0.280x_{12}.$$

Through the enter method, another regression formula containing 8 variables was computed to predict VO_2 max (Model B). The variables labels for Model B are listed in Table 5.

Table 5

Model B Variable Labels

Label	Variable
x_1	Age (yr.)
x_2	Termination Stage (stage number)
x_3	Average HR for the termination stage (bpm)
x_4	Average watts for the termination stage
x_5	Average overall RPE for the termination stage
x_6	BMI ($kg \cdot m^{-2}$)
x_7	Gender (1=males, 2=females)
x_8	Weight (kg)

The second regression formula (Model B) for predicting VO_2 max while using a submaximal elliptical trainer protocol was as follows:

Model B

$$VO_2 \max = 102.74 - 0.144x_1 + 2.323x_2 - 0.171x_3 + 0.0016x_4 - 0.301x_5 - 0.107x_6 - 10.842x_7 - 0.278x_8.$$

Through the enter method, a third regression formula containing three variables was computed to predict VO_2 max (Model C). The variable labels for Model C are listed in Table 6.

Table 6

Model C Variable Labels

Label	Variable
x_1	Gender (1=males, 2=females)
x_2	Termination Stage (stage number)
x_3	Weight (kg)

The final regression formula (Model C) was chosen for the prediction of VO_2 max while using the submaximal elliptical trainer protocol:

Model C

$$VO_2 \text{ max} = 71.14 - 11.875x_1 + 2.362x_2 - 0.273x_3.$$

The R, R^2, and SEE values for Models A, Model B, and Model C linear regression analyses are presented in Table 7.

Table 7

Model Summary

Model	R	R^2	SEE
A	0.770	0.593	5.009
B	0.740	0.547	5.027
C	0.724	0.525	4.867

CHAPTER V

DISCUSSION

The intention of this study was to design a submaximal elliptical trainer exercise test to predict VO_2 max. All subjects were tested maximally on two separate occasions to obtain a VO_2 max value, and were tested three times using the submaximal elliptical trainer protocol. The predictive variables used in this study were presented in Table 1. From the data collected, three linear regression models were derived. The following areas are presented in this chapter: (a) variables used in the regression formulas, (b) variables excluded from the regression analysis, (c) correlation coefficients and SEEs, (d) conclusions, and (e) future recommendations.

Development of Regression Formulas for Predicting VO_2 max

The enter method on SPSS was used for the regression analysis in this study. The regression analysis was performed to determine the predictiveness of the variables examined in this study as they were applied to VO_2 max. From the analysis, three final regression equations were formed, models, A, B, and C using 12, eight, and three variables respectively. As previously stated, a different approach was taken during the formation of the regression analysis. The first approach taken was logical, where the variables entered into the regression analysis were variables known to predict VO_2 max such as HR, RPE, and work output expressed in watts. The variables entered into the initial analyses (refer to Tables 4 and 5) were also chosen based upon use in previous studies found in the literature review. This approach was carried out, and two initial models were formed, Model A and Model B. These two models were initially chosen based upon the R, R^2, and SEE values (as seen in Table 7).

After reanalyzing Models A and B, and computing correlations between predictive variables (refer to Table G_1), a statistical approach was taken. Models A and B were reanalyzed based upon the significance of each variable as well as the standard error of the mean. From the statistical analysis, a new model was formed, Model C, which was chosen as the final regression analysis for prediction of VO_2 max (Table 6). Model C was selected for the final analysis due to its R, R^2, and SEE values (as seen in Table 7), and it's simplicity. Model C had three variables in comparison to Model A, which contained 12 variables, and Model B with eight variables (refer to Tables 4, 5, and 6).

The variables that were most predictive in Model A were: (a) weight, (b) BMI, (c) termination stage, (d) average HR for stage 2, (e) average watts for stage 2, (f) average overall RPE for stage 2, (g) average HR for stage 3, (h) average watts for stage 3, (j) average overall RPE for stage 3, (k) average HR for the termination stage, (l) average watts for the termination stage, (m) average overall RPE for the termination stage. Variables that were most predictive in Model B were: (a) weight, (b) BMI, (c) age, (d) gender, (e) termination stage, (f) average HR for the termination stage, (g) average watts for the termination stage, and (h) average overall RPE for the termination stage. The most predictive variables used in Model C were: (a) gender, (b) termination stage, and (c) weight.

Models A and B contained the following variables: (a) weight, (b) BMI, (c) termination stage, (d) average HR for the termination stage, (e) average watts for the termination stage, and (f) average overall RPE for the termination stage. The submaximal elliptical exercise test developed for this study was a multistage protocol where intensity was accurately controlled and increased throughout the stages, which were represented by a stage number. According to Wilmore & Costill (1994), when intensity is controlled HR can be used to predict VO_2 during submaximal exercise, which signifies a direct relationship between HR, intensity, and VO_2. RPE values are also highly correlated with HR and intensity (ACSM, 2000).

After analyses were computed for Models A and B, a significant correlation (refer to Table G_1) between average watts at termination, and average overall RPE at termination was found. A significant correlation (Table G_1) was also found between average HR at termination and VO_2 max. Due to these relationships the average HR and overall RPE for the termination stage were used in the regression analyses. The load expressed in watts on the EFX™ 546 is based upon resistance and subject's weight (Precor, 1998). The analyses for Models A and B showed a significant correlation (as seen in Table G_1) between VO_2 max and weight, and VO_2 max and watts. A significant correlation (Table G_1) between termination stage and VO_2 max was also found. BMI (weight/height^2) was added to the regression analysis on the basis of it's relationship to weight and use to predict body fat (refer to Table G_1). It is known that individuals that are overweight with high BMI values tend to have low fitness levels and therefore lower VO_2 max levels. Erdmann et al. (1999) used BMI as an variable in the regression analysis to predict VO_2 max, and suggested that it is a predictor when height and weight data is available. Therefore, average watts for the termination stage, weight, and BMI were also entered into the regression analyses. It is for these reasons that average HR, watts, and overall RPE values for the termination stage were used in the regression analyses, and termination stage number was also chosen for the analyses.

Model A

In the regression analysis for Model A the following variables were also entered: (a) average HR for stage 2, (b) average watts for stage 2, (c) average overall RPE for stage 2, (d) average HR for stage 3, (e) average watts for stage 3, and (f) average overall RPE for stage 3. Early statistical analysis of the data suggested that the variable that correlated highly with VO_2 max was average HR for stage 3. From these analyses, averages of each variable for stage 3 were entered into the equation. ACSM (2000) also suggests that the use of HR from two submaximal exercise intensities could be used to predict a maximal heart rate, maximal exercise intensity, and therefore predict VO_2 max.

The final analysis for Model A indicated a significant correlation (refer to Table G_1) between average HR for stage 3 and VO_2 max, and average HR for stage 2 and VO_2 max. A significant correlation (Table G_1) between the average HR for stage

2, the average HR for stage 3, average watts for stage 2, and average watts for stage 3 was found with average watts for the termination stage and average HR for the termination stage. Given the correlations found (as seen in Table G_1), when the average HR for stage 2 and average HR for stage 3 were added into the analysis, higher R and R^2 values were produced. Also, in previous studies it was stated that the use of two heart rates within a given range could estimate VO_2 max (Maud & Foster, 1995). Therefore, average HR for stage 2 and average HR for stage 3 were included in the final regression analysis for Model A.

Although no significant correlation (refer to Table G_1) was found between VO_2 max and average watts for stages 2 and 3, and average overall RPE for stages 2 and 3, R and R^2 values (Table 7) in the analysis increased when these variables were entered into the equation. Decreases in SEE values (Table 7) were also found when the previously mentioned variables were added to the equation. It is for these reasons that average watts for stage 2, average overall RPE for stage 2, average watts for stage 3, and average overall RPE for stage 3 were added in the final regression analysis for Model A.

Model B

Model B also contained the following variables in the regression analysis: (a) age and (b) gender. Although age was not significantly correlated (refer to Table G_1) with VO_2 max, an increase in R and R^2 values (Table 7) were found when added to the equation. A lower SEE value (as seen in Table 7) was also found with the addition of age to the equation. When comparing VO_2 max and gender, a significant correlation (Table G_1) was found between VO_2 max and gender, as well as an increase in R and R^2 values. Researchers in this study speculate that the significant correlation between VO_2 max and gender (refer to Table G_1) is due to the differences in weight between males and females, and the effect it has on the work output expressed in watts. As stated earlier, the work output expressed in watts on the EFX™ 546 is determined by weight and resistance level. Most of the males participating in this study were significantly heavier than females, and therefore produced higher work output values. Therefore, the difference between genders significantly increases. It is for these reasons that age and gender were added to the regression analysis in Model B.

Model C

As mentioned above, Model C contained the following variables in the regression analysis: (a) gender, (b) termination stage, and (c) weight. A significant correlation was found between gender and VO_2 max, termination stage and VO_2 max, and weight and VO_2 max (Table G_1). Researchers in this study speculate that the significance of gender could be due to the weight differences between males and females. Also mentioned previously, weight can generally be associated with fitness level, displaying an indirect relationship where the increase in weight dictates a lower aerobic capacity (VO_2 max). Although termination stage is a categorical variable, it is determined by a set termination HR, which is dictated by increase in workload. As stated in published literature, HR and workload have a direct relationship with VO_2

max (Willmore & Costill, 1994). Thus, the basis for the use of termination stage in the regression analysis for Model C.

Similar in R and R^2 values were found in comparison to Models A and B, and SEE value decreased (refer to Table 7). It is for these reasons that only gender, termination stage, and weight were used in the final regression analysis, Model C.

Variables Excluded from the Regression Analyses

The following variables were not included in the final regression analysis for Model A or Model B: (a) height, (b) average HR for stage 1, (c) average watts for stage 1, and (d) average overall RPE for stage 1. Although a significant effect (Table G_1) was found between height and VO_2 max in this study, it was excluded from the final regression analysis for Model A, B and C due to practicality. There was no supporting literature found for the use of height in regression analyses for the prediction of VO_2 max (Quail, Vehrs, & Jackson, 1999; Erdmann et al., 1999; Maud & Foster, 1995). Height does not increase the force applied to a surface or the work output on an exercise machine. Height is a categorical variable, which expresses surface area, and has been found to have no significant effect on force (Kreighbaum & Barthels, 1996). Also, the EFX™ 546 is a low-impact modality, which significantly reduces GRF as stated in previous chapters (Bates, 1996).

When analyzing the data between stages 1 and 2 for average HR and average overall RPE, no significant difference (refer to Table G_1) was found between the two values. For most subjects, the values for average HR and overall RPE in stages 1 and

2 remained similar or slightly decreased. Although the average watts increased between stages 1 and 2, no significant physiological increases (Table G_1) were found between stages. The data analysis from this study suggests a curvilinear relationship between resistance level and HR on the EFX™ 546, which would reflect the slow increase in HR during the initial stages of the test. As stated previously, HRs remained similar or slightly decreased, which suggests that workloads on the elliptical trainer increase exponentially, resulting in a curvilinear effect on HR. Therefore, it was concluded that average watts for stage 1 had no significant effect (as seen in Table G_1) on the prediction of VO_2 max. It is for these reasons that average HR for stage 1, average watts for stage 1, and average overall RPE for stage 1 were excluded from the final analyses of Model A and Model B.

Model A

In addition to the variables mentioned above, gender and age were also excluded from the final regression analysis of Model A. Model A was the first linear regression analysis to produce R and R^2 values acceptable for a prediction equation (refer to Table 7). The variables used in the analysis were chosen based upon previously stated information. In order to maintain a less complicated analysis, gender and age were not added to the regression formula for Model A, which already contained 12 variables.

Model B

In addition to the variables mentioned earlier, the following variables were excluded from the final regression analysis for Model B: (a) average HR for stage 2, (b) average watts for stage 2, (c) average overall RPE for stage 2, (d) average HR for stage 3, (e) average watts for stage 3, and (f) average overall RPE for stage 3. These variables were excluded from the regression analysis in Model B to simplify the formula. The variables used in Model A were all variables from the termination stage with the addition of age and gender. This regression analysis produced similar R and R^2 values to Model A, with four less variables (as seen in Table 7). The R and R^2 values for Model B were acceptable for a prediction model (Table 7) (Maud & Foster, 1995).

Model C

All variables except the three variables entered into the equation were excluded from the regression analysis for Model C. Although variables used in Models A and B showed significant correlation (refer to Table G_1), the variables with the highest significance overall in comparison to VO_2 max were gender, termination stage, and weight. This provides the most simplistic regression formula out of all of the models provided, with similar R, R^2, and SEE values to Models A and B (refer to Table 7). A recent study conducted by Larsen, George, Alexander, Fellingham, Aldana, and Parcell (2002) contained almost the same variables in a regression formula for the prediction of VO_2 max from walking, jogging, or running. The variables entered in the regression analysis were gender, body mass (weight) and elapsed exercise time. Similar R and R^2 values were also found in comparison to the results from this study (Larsen et al., 2002). Therefore, Model C was chosen as the final regression formula to be used for the prediction of VO_2 max for the submaximal elliptical exercise test.

Correlation Coefficients and SEEs

The results from this study are supported by similar correlation coefficients and SEEs reported for similar standard submaximal GXTs with the coefficients ranging from 0.72 to 0.77, and SEEs ranging from 4.87 to 5.03 $ml \cdot kg^{-1} \cdot min^{-1}$ (Maud & Foster, 1995). Therefore, the validity of Model C for the prediction of VO_2 max from a submaximal elliptical exercise test is supported as well.

Conclusions

In conclusion, the investigators found that the Precor® EFX™ 546 Elliptical Trainer is a valid instrument for submaximal exercise testing. It produced a high correlation between termination stage and VO_2 max, from which VO_2 max can be predicted using a regression formula (Franklin, 2000). Termination stage is based upon a HR termination of 75% APMHR, and an incremental increase of workload for each stage. The estimate of VO_2 max from the prediction equation used in this study is within the standard submaximal estimates of VO_2 max, which is an SEE ± 5.0 $ml \cdot kg^{-1} \cdot min^{-1}$ (Morrow, Jackson, Disch, & Mood, 1995). The results from the prediction equation produced R and R^2 values within the acceptable range in comparison to standard submaximal exercise tests (Maud & Foster, 1995). The variables entered into the prediction equation were almost identical to the variables used in a recent study by Larsen et al. (2002). Therefore, the prediction equation and protocol used in this analysis are valid for submaximal exercise testing to predict VO_2 max.

Recommendations for Future Studies

The following are recommendations for future studies or research on the submaximal elliptical trainer protocol:

1. Although the sample size used in this study was small, the results were encouraging for further research.

2. A greater sample size in future studies may produce higher R and R^2 values.

3. A cross-validation study is suggested for future research on the submaximal elliptical trainer protocol.

4. A test-retest study should be carried out to test the reliability of the submaximal elliptical trainer protocol.

Appendix A

Human Subject Institutional Review Board
Approval Forms

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board
PROJECT APPROVAL REVIEW FORM

Western Michigan University's policy states that "the HSIRB's review of research on a continuing basis will be conducted at appropriate intervals but not less than once per year." In compliance with that policy, the HSIRB requests the following information:

PROJECT TITLE: Physiological and Biomechanical Assissment of Two Different Elliptical Trainers
HSIRB Project Number: 00-10-05
Date of Review Request: 09/17/00 Date of Last Approval: 10/20/00

PRINCIPAL INVESTIGATOR OR ADVISOR
Name: Mary L. Dawson
Department: HPER Electronic Mail Address: mary.dawson@wmich.edu

(1) CO-PRINCIPAL OR STUDENT INVESTIGATOR
Name: Roger Zabik
Department: HPER Electronic Mail Address: roger.zabik@wmich.edu

(2) CO-PRINCIPAL OR STUDENT INVESTIGATOR
Name: Tim Michael
Department: HPER Electronic Mail Address: tim.michael@wmich.edu

1. The research, as approved by the HSIRB, is completed.
   ☐ Yes (Continue with items 5-7 below.) ☒ No (Continue with items 2-5 below.)
2. Have there been changes in Principal or Co-Principal Investigators? ☐ Yes ☒ No
   (If yes, provide details on an attached sheet.)
3. Is the approved protocol still accurate and being followed with respect to:
   (If no to any item below, provide the details on an attached sheet.)
   a. Procedures ☒ Yes ☐ No
   b. Subjects ☒ Yes ☐ No
   c. Design ☒ Yes ☐ No
   d. Data collection ☒ Yes ☐ No
4. Has any instrumentation been modified or added to the protocol? ☐ Yes ☒ No
   (If yes, attach new instrumentation or indicate the modifications made.)
5. Have there been any adverse events which need to be reported to the HSIRB? ☐ Yes ☒ No
   (If yes, provide details on an attached sheet.)
6. Current total number of subjects enrolled: 30 Current number of subjects in the control group: 0
7. Provide copies of the consent documents signed by the last two subjects enrolled in the project. Cover the signature in such a way that the name is not clear but there is evidence of signature. If subjects are not required to sign the consent document, provide a copy of the most current consent document being used. **(Remember** to include a clean original of the consent documents to receive a renewed approval stamp.)

Mary L. Dawson 9-14-01
Principal Investigator/Faculty Advisor Signature Date

Roger M Zabik Tim M. Michael 9-14-01
Co-Principal or Student Investigator Signature Date

Approved by the HSIRB:

Mary Lagerwey 9-18-01
HSIRB Chair Signature Date

Revised 5/98 WMU HSIRB
All other copies obsolete.

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board
PROJECT APPROVAL REVIEW FORM

Western Michigan University's policy states that "the HSIRB's review of research on a continuing basis will be conducted at appropriate intervals but not less than once per year." In compliance with that policy, the HSIRB requests the following information:

PROJECT TITLE:
HSIRB Project Number:
Date of Review Request: Date of Last Approval:
PRINCIPAL INVESTIGATOR OR ADVISOR
Name:
Department: Electronic Mail Address:
(1) CO-PRINCIPAL OR STUDENT INVESTIGATOR
Name: George Hajiefremides
Department: HPER Electronic Mail Address: giorgiohaji@hotmail.com
(2) CO-PRINCIPAL OR STUDENT INVESTIGATOR
Name: Alicia Armour
Department: HPER Electronic Mail Address: alicia.armour@wmich.edu

1. The research, as approved by the HSIRB, is completed.
   ☐Yes (Continue with items 5-7 below.) ☐No (Continue with items 2-5 below.)
2. Have there been changes in Principal or Co-Principal Investigators? ☐Yes ☐No
   (If yes, provide details on an attached sheet.)
3. Is the approved protocol still accurate and being followed with respect to:
   (If no to any item below, provide the details on an attached sheet.)
   a. Procedures ☐Yes ☐No
   b. Subjects ☐Yes ☐No
   c. Design ☐Yes ☐No
   d. Data collection ☐Yes ☐No
4. Has any instrumentation been modified or added to the protocol? ☐Yes ☐No
   (If yes, attach new instrumentation or indicate the modifications made.)
5. Have there been any adverse events which need to be reported to the HSIRB? ☐Yes ☐No
   (If yes, provide details on an attached sheet.)
6. Current total number of subjects enrolled: Current number of subjects in the control group:
7. Provide copies of the consent documents signed by the last two subjects enrolled in the project. Cover the signature in such a way that the name is not clear but there is evidence of signature. If subjects are not required to sign the consent document, provide a copy of the most current consent document being used. (**Remember** to include a clean original of the consent documents to receive a renewed approval stamp.)

✎ ____
Principal Investigator/Faculty Advisor Signature Date

✎ Alicia Armour 9·13·01
Co-Principal or Student Investigator Signature Date
Hajiefremides 9·13·01

Approved by the HSIRB:

✎ Mary Lagerwey 9-18-01
HSIRB Chair Signature Date

Revised 5/98 WMU HSIRB
All other copies obsolete.

Appendix B

Subject Recruitment Forms

Memo

To: All HPER faculty and staff

From: Giorgio Haji, Alicia Armour

Re: Thesis and data collection

Date: September 17, 2001

Hello everyone! The semester is on its way and we have favors to ask of all of you. If you would be so kind as to read the attached Subject Recruitment form in all of your classes for us and have the students write their names and numbers on the provided form. All forms may be placed in Haji's mailbox (4th floor SRC). We are willing to speak in your classes if you prefer us to do so. We are hoping to begin collecting data by the end of the month and continue through October. Haji needs about 30 subjects and Alicia needs at least 50. If you have questions about either thesis you can ask Haji, Alicia, Dr. Michael, Dr. Zabik, or Dr. Dawson. Thank you for your time and cooperation.

Subject Recruitment Script

Drs. Dawson, Michael, and Zabik are in need of volunteers to participate in a research project that they are conducting titled *Physiological and Biomechanical Assessment of Two Different Elliptical Trainers.* The study will involve subjects between 18-35 years of age who are "low risk" according to ACSM's risk classification. Volunteers will complete a paper/pencil health risk appraisal form to qualify to participate in this study. Participation in this study involves one of the following:

1. Using the elliptical trainer with the moveable handlebars and with the stationary handlebars at a low, medium, and medium high resistance settings (settings 5, 10, and 15 on the Precor Elliptical Trainers). Participation in this phase of the study will involve four, 45-minute sessions.
2. Using the elliptical trainer at a low, medium, and medium high resistance settings (settings 5, 10, and 15 on the Precor Elliptical Trainers) and at three grades; level, low, and medium (settings 5, 10, and 15 on the Precor Elliptical Trainers). Both a backward and a forward cycling motion will be studied. Participation in this phase of the study will involve three, 45-minute sessions.
3. Exercising on the elliptical trainer as the workloads, every 3 minutes, become more difficult. The exercise session will stop when heart rate gets to about 160 bpm (the average heart rate for most normal aerobic workouts). Your VO_2 max will also be measured. Participation in this phase of the study involves five sessions; two, 45-minute sessions to test VO_2 max and three, 30-minute sessions of a graded exercise test using the elliptical trainer.

You have the option to voluntarily terminate your involvement in the study for any reason. Your participation during the study will not have any effect on your status as a student at Western Michigan University. All test information will be kept confidential. If you are between the ages of 18-35 years of age, exercise 2-3 times per week, and are interested in getting more information or volunteering for the study, please print your name and phone number below or contact Dr. Dawson at 616 387-2546, Dr. Michael at 616 387-2691, or Dr. Zabik at 616 387-2542.

Thank you!

Name	Phone	Name	Phone

Name	Phone	Email

Appendix C

Health Screening Form

Physical Activity Readiness Questionnaire

Name:_________________________ **Date:_____________**
WMU Phone:____________________ **Age:_______________**

This form has been designed to help identify whether or not you should consult your personal physician before beginning an exercise program.

Please read the following questions carefully and check (√) the appropriate answer. Answer the questions to the best of your ability.

Yes	No	
___	___	1. Have you ever had a stroke, heart attack, or heart surgery?
___	___	2. Do you frequently suffer from chest pain?
___	___	3. Have you ever been told that you have a bone, joint, or muscle problem that could be made worse by physical activity?
___	___	4. Do you have any major illnesses that could be made worse by physical activity?
___	___	5. Have you ever been told that you have a heart or blood vessel problem?
___	___	6. Are you over the age of 45 and just beginning an exercise program?
___	___	7. Do you have blood pressure greater than 140/90 or cholesterol higher than 240 mg/dl?

If you answered **yes to any** of the above questions, it is recommended that you receive medical clearance from your physician before participating in any physical activity.

Exercise Participation Agreement

I have voluntarily chosen to participate in the research conducted in the Exercise Physiology lab at the Student Recreation Center, Western Michigan University. I answered the medical questions above to the best of my ability and affirm that my physical condition is good and I have no conditions that prevent me from participating in fitness activities. I understand that the researchers in this study recommend improving physical fitness through an exercise plan consisting of gradual warm-up, aerobic exercise, strength development, and a cool-down. I also realize that participation is at my own pace and that I am free to discontinue my participation at any time. Further more, I agree to self-limit my exertion through good judgment and to terminate any activity immediately if it exceeds my personal limitations.

I understand that by signing this agreement, I hereby waive and release Western Michigan University, its president, Board of Trustees, staff and employees and any and all persons or organizations involved in any way from any and all claims, liabilities or demands of any kind as a result of an injury, loss or adverse health condition arising from my participation in this activity. I realize that I am not required to participate in this activity, but do so voluntarily.

I affirm that I have read and fully understand the above document and I wish to participate in fitness activities.

____________________________________ _________________
Signature of Participant Date

Appendix D

Consent Form

Western Michigan University
Department of Health, Physical Education, and Recreation
Principal Investigators: Drs. Mary Dawson, Tim Michael, and Roger Zabik
Student Investigators: Alicia Armour and George Hajiefremides

I have been invited to participate in a research project that will study the physiological and biomechanical effect of exercise when using an elliptical trainer. The research will describe the alignment of the lower extremities during a complete cycle of motion, the cardiopulmonary (heart and lungs) efficiency at various grades and elevations, and my perceived exertion. I will exercise on one Precor, elliptical trainer; the EFX 546 or the EFX 556. The research project in which I am involved is part of a project conducted by Drs. Dawson, Michael, Zabik, and students (Katherine Wehmeyer and Erica McManus) and will be conducted in the Exercise Physiology and Biomechanics Laboratory in the Department of Health, Physical Education and Recreation in the Student Recreation Building at Western Michigan University. The extent of my participation involves the paragraph(s) checked below. I will not be involved in those paragraphs that are not checked.

☐ My consent to participate in this project indicates that I will be asked to attend four, 45-minute sessions. I will meet the researchers in the Student Recreation Building, Rooms 1050-60, Western Michigan University. These sessions will begin with a 10-15 minute period in which I will be allowed to warm up using my personal pre-exercise workout. During each of the four sessions I will complete one of the following exercise conditions on the elliptical trainer EFX 556: (1) Arms on moveable handles, legs move forward; (2) Arms on moveable handles, legs move backward; (3) Arms on stationary handles, legs move forward; and (4) Arms on stationary handles, legs move backward. During each session, I will exercise in the manner described above for a 5-6 minute period at a prescribed resistance level. I will then stop and rest until my heart rate is below 100 bpm. After resting, I will repeat this procedure for two different resistance levels.

☑ My consent to participate in this project indicates that I will be asked to attend three, 45-minute sessions. I will meet the researchers in the Student Recreation Building, Rooms 1050-60, Western Michigan University. The sessions will begin with a 10-15 minute period in which I will be allowed to warm up using my personal pre-exercise workout. During each of the three sessions I will complete one of the following exercise conditions on the elliptical trainer EFX 546: (1) 5% elevation, (2) 10% elevation, and (3) 15% elevation. During each session, I will exercise in the manner described above for a 5-6 minute period at a prescribed resistance level. I will then stop and rest until my heart rate is below 100 bpm. After resting, I will repeat this procedure for two different resistance levels.

- ☑ My consent to participate in this project indicates that I will be asked to attend two, 45 minute sessions. I will meet the researchers in the Student Recreation Building, Rooms 1050-60, Western Michigan University. These sessions will begin with a 10-15 minute period in which I will be allowed to warm up using my personal pre-exercise workout. During each of the two sessions I will be administered a test that measures my cardiopulmonary (heart and lungs) limits. For this test, I will run on a treadmill with the speed and uphill grade increasing until I decide I can not continue or until the investigators decide that I should stop.

- ☑ During my participation on the elliptical trainer, I will breathe through a mouth piece like a swimming snorkel. To assure that I am breathing only through my month, I will wear nose clips. My heart rate will be monitored by wearing an adjustable elastic band with build in electrodes around my rib cage just below the breast bone. The elastic band will be under my exercise shirt. My heart rate will be recorded on a display that I will wear on my wrist like a watch.

- ☐ During my participation on the elliptical trainer my performance will be video taped so that the researchers can measure the joint angles in my lower legs during selected parts of the cyclic motion.

- ☐ At the end of my first session as a subject, I will be asked to run on a treadmill at the same rate (stepping rate) that I performed on the elliptical trainer. During the time I am running, I will be video taped.

- ☐ Prior to my participation EMG electrodes will be placed over the following muscles in my lower extremities: Front of thighs, back of thighs, back of calf, and front of calf . The site of the electrode placement will be scrubbed vigorously with a sterile alcohol pad and may be shaved to provide a better electrode contact surface. The placement of the electrodes will be on the midpoint of the longitudinal axis of the muscle.

The current testing may be of no benefit to me. Knowledge of how the body reacts to Precor elliptical trainers may help fitness specialists in who should and should not use the trainers and aid the company in design changes in future models of Precor trainers.

As in all research, there may be unforeseen risks to the participant. The risks to the research participant in this study include risks taken in any moderate fitness program for normal healthy individuals that utilizes the elliptical trainer. Since the elliptical trainer does not involve impact forces the likely risk is fatigue and sore muscles and possibly falling. A person trained in first aid and CPR will be present during the exercise sessions. If an emergency arises, appropriate immediate care will be provided and I will be referred to the Sindecuse Health Center. No

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H. S. I. R. B.
Approved for use for one year from this date:

SEP 1 8 2001

x Mary Lagerwey
HSIRB Chair

compensation or treatment will be made available to me except as otherwise specified in this consent form.

All information concerning my participation is confidential. This means that my name will not appear in any document related to this study. The forms will all be coded. Dr. Dawson will keep a separate master list with the names of all participants and their code numbers. Once the data are collected and analyzed, the master list will be destroyed. The consent and data forms, a disk copy of the electronic generated data, and the video tapes will be retained for a minimum of 3 years in a locked file in the principal investigator's laboratory. A second disk copy of the electronic data will be stored by Dr. Michael for a minimum of 3 years.

I may refuse to participate or stop at any time during the study without any effect on my grades or relationship with Western Michigan University, If I have any questions or concerns about this study, I may contact Dr. Mary Dawson at (616) 387-2546, Dr. Timothy Michael at (616) 387-2691, or Dr. Roger Zabik at (616) 387-2542. I may also contact the Chair of Human Subjects Review Board at (616) 387-8293 or the Vice President for Research at (616) 387-8928 with any concern that I have.

My signature below indicates that I am aware of the purpose and requirements of the study and that I agree to participate.

This consent document has been approved for 1 year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right hand corner of all pages of this consent form. Subjects should not sign this if the corners do not show a stamped date and signature.

Signature of Participant ________________ Date ________________

Signature of Investigator Obtaining Consent ________________ Date ________________

Appendix E

Bruce Protocol

The Bruce Treadmill Graded Exercise Protocol

	Time (min)					
% Grade	3	6	9	12	15	18
10	1.7 mph					
12		2.5 mph				
14			3.4 mph			
16				4.2 mph		
18					5.0 mph	
20						5.5 mph

Appendix F

Borg's RPE Scale

Borg's Category Scale

RPE Scale	Perceptual Responses
6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

Appendix G

Correlation Matrix

Table G_1

Variables Correlation Matrix

	Gender	VO_2 max	Weight	Height	BMI	Age	Termination Stage	Avg HR for termination	Avg watts for termination	Avg RPE for termination	Avg HR Stage 1	Avg HR Stage 2	Avg HR Stage 3	Avg watts Stage 1	Avg watts Stage 2	Avg watts Stage 3	Avg RPE Stage 1	Avg RPE Stage 2	Avg RPE Stage 3
Gender	1.00																		
VO_2 max	-0.61*	1.00																	
Weight	-0.76*	0.30*	1.00																
Height	-0.70*	0.38*	0.78*	1.00															
BMI	-0.48*	0.10	0.75*	0.21	1.00														
Age	-0.17	0.17	-0.04	0.01	-0.04	1.00													
Termination Stage	-0.44*	0.44*	0.55*	0.49*	0.33*	-0.02	1.00												
Avg HR for termination	0.49*	-0.41*	-0.42*	-0.35*	-0.29*	-0.41*	-0.31*	1.00											
Avg watts for termination	-0.62*	0.36*	0.80*	0.62*	0.59*	0.01	0.69*	-0.38*	1.00										
Avg RPE for termination	-0.10	0.01	0.19	0.15	0.13	-0.16	0.44*	-0.02	0.39*	1.00									
Avg HR Stage 1	0.14	-0.26	-0.07	-0.10	0.00	-0.32*	-0.55*	0.26	-0.45*	-0.37*	1.00								
Avg HR Stage 2	0.17	-0.30*	-0.11	-0.14	-0.02	-0.33*	-0.59*	0.33*	-0.47*	-0.36*	0.99*	1.00							
Avg HR Stage 3	0.33*	-0.39*	-0.29*	-0.28*	-0.16	-0.31*	-0.69*	0.41*	-0.61*	-0.41*	0.94*	0.97*	1.00						
Avg watts Stage 1	-0.68*	0.20	0.93*	0.69*	0.73*	-0.04	0.54*	-0.40*	0.83*	0.16	-0.12	-0.15	-0.31*	1.00					
Avg watts Stage 2	-0.61*	0.12	0.84*	0.64*	0.64*	-0.01	0.52*	-0.38*	0.75*	0.06	-0.16	-0.20	-0.37*	0.89*	1.00				
Avg watts Stage 3	-0.59*	0.13	0.83*	0.59*	0.70*	-0.02	0.45*	-0.35*	0.71*	0.04	-0.10	-0.12	-0.27	0.88*	0.78*	1.00			
Avg RPE Stage 1	-0.17	0.05	0.02	-0.06	0.10	0.02	-0.07	-0.12	-0.06	0.20	0.01	0.00	0.00	-0.06	-0.03	-0.14	1.00		
Avg RPE Stage 2	-0.06	-0.07	0.07	-0.02	0.12	-0.92	-0.14	-0.08	-0.04	0.45*	0.18	0.19	0.13	-0.02	-0.10	-0.11	0.66*	1.00	
Avg RPE Stage 3	0.87	-0.14	-0.06	-0.11	0.00	-0.18	-0.18	0.03	-0.14	0.52*	0.21	0.21	0.19	-0.12	-0.22	-0.23	0.48*	0.89*	1.00

Note. *Indicates a significance at the 0.05 level.

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