INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI®

Modifications of the

Rockport Fitness Walking Test

Freddie D. McConnell II

A dissertation presented to the Graduate Faculty of Middle
Tennessee State University in partial fulfillment of the
requirements for the Doctor of Arts degree in Physical
Education in the Department of Health, Physical Education,
Recreation, and Safety

August, 2001

UMI Number: 3016335

UMI®

Modifications of the

Rockport Fitness Walking Test

Freddie D. McConnell II

APPROVED:

Graduate Committee:

_____
Major Professor

_____
Committee Member

_____
Committee Member

_____
Head of the Department of Health, Physical
Education, Recreation, and Safety

_____
Dean of the Graduate College

ABSTRACT

The Rockport Walk Fitness Test (RWFT) is a one-mile maximally-paced walk used to estimate aerobic fitness. Since its development, this test has been subject to few modifications. Previous research (George et al., 1998) has indicated that participants experience leg pain when asked to walk a mile at a maximal pace. The aim of this investigation was to determine which modification of the RFWT (1-mile, ½-mile, or ¼-mile) using a self-selected brisk pace produced the most accurate estimate of maximal oxygen consumption ($\dot{V}O_{2max}$). In addition, the tests were evaluated to determine if participants maintained a steady walking pace. Aerobically untrained college-age females (N = 33) performed a graded maximal treadmill test to determine $\dot{V}O_{2max}$. On separate days, but within 10 days of the treadmill test, participants randomly performed one of three walk tests (1-mile, ½-mile, or ¼-mile). Estimated $\dot{V}O_{2max}$ values were calculated using the Kline, Porcari, Hintermeister, et al. (1987) age-generalized female equation. Heart rate values were recorded using Polar® heart rate monitors. Results indicated that the ¼-mile ($r = .67$) and the 1-mile walk ($r = .68$) $\dot{V}O_{2max}$ estimates were most strongly related to measured $\dot{V}O_{2max}$. Results also

revealed that participants did not maintain a steady walking pace in any of the three tests. These findings indicate that the ¼-mile and 1-mile versions of the RFWT using a self-selected brisk, walking pace do produce acceptable estimations of $\dot{V}O_{2max}$ in college-age females. Further, administrators of this field test must stress the importance of maintaining a steady pace throughout the entire test.

DEDICATION

This dissertation is dedicated to the love of my life, Nicole. Thanks for your ever-continuing support, love, and encouragement. Without you, my life is incomplete.

ACKNOWLEDGMENTS

It would be almost impossible to name every individual who has influenced me up to this point. However, I would like to express my deepest gratitude to the following people:

Dr. Doug Winborn, thank you for your guidance and support and helping me realize that it's just a matter of "jumping through the right hoops".

Dr. Jennifer Caputo, thank you for being there whenever I needed you. Your caringness and true concern for helping others is matched by no other. Thank you so much and long live Toby!

Dr. Jane Williams, thank you for all your help throughout this process. Your impeccable professionalism and dedication to pedagogy will always be remembered.

Dr. Molly Whaley, thank you for giving me the opportunity to pursue my dreams.

Dr. Jim Colligon, Dr. Joyce McIntosh, and Mr. Don McBrayer, thank you for your guidance early on in my college days. It is individuals like you who have molded me and shaped me into what I am today.

Mom and Dad, thanks for giving me the continued support that has enabled me to make it this far. I will never be able to repay all the love that you have provided me.

Todd Sherman and Dr. J. P. Barfield, thanks for your advice throughout this process and for being such great friends. Brothers forever!

TABLE OF CONTENTS

List of Tables

viii

List of Appendixes

ix

CHAPTER 1

Introduction

For the past 50 years, cardiovascular disease has been the number one cause of death in the United States and the Western world (McKenzie & Pinger, 1995; Robergs & Roberts, 1997). While numerous measures to prevent cardiovascular disease are available, research has consistently demonstrated that aerobic exercise is the most effective method of developing and maintaining cardiovascular health (Blair et al., 1995; Blair et al., 1996). Among many individuals who begin exercise programs, walking may be a more popular activity than running. Hence, tests used to estimate a person's fitness level have been developed to simulate this familiar activity.

There are many techniques to accurately measure or predict an individual's maximal oxygen consumption (i.e., ability to consume, transport, and utilize oxygen). Maximal oxygen consumption ($\dot{V}O_{2max}$) represents an individual's aerobic capacity or cardiovascular fitness level. Cardiovascular fitness level can be measured or estimated in either a laboratory setting or in a field setting. Although providing only an estimated aerobic capacity, field tests offer many advantages over actual

1

maximal measurements and have become popular among exercise professionals (Bowers & Fox, 1988).

While field tests are popular among practitioners, the direct measurement of $\dot{V}O_{2max}$ is considered the single best indicator of an individual's aerobic capacity (McArdle, Katch, & Katch, 1996). The measurement of $\dot{V}O_{2max}$ testing evolved from the concept of calorimetry. Calorimetry is the term used to describe "the measurement of body metabolism from heat released by the body" (Robergs & Roberts, 1997, p. 127). Any mechanical work performed by the body results in heat production. Because it is known how much oxygen is utilized in producing a given amount of heat, it is then possible to estimate oxygen consumption.

Two main methods of calorimetry have been developed: direct and indirect. Direct calorimetry involves participants being placed into a small, insulated chamber where they live, eat, sleep and exercise. Cold water is run through copper coils placed on the ceiling. The water absorbs the heat that the participant dissipates and the temperature change of the water is determined. This change in water temperature reflects the amount of heat produced by the participant and is directly related to the amount of oxygen consumed by the body. Oxygen consumption may also be measured by analyzing the air leaving the chamber.

Direct calorimetry was the first of the two methods to be developed and is typically only found in hospital settings due to the high cost associated with building and maintaining the structure. It is also difficult to perform direct calorimetry during exercise-related studies due to the heat produced from exercise equipment placed inside the chamber (Bowers & Fox, 1988; McArdle, Katch & Katch, 1996).

A better technique for measuring oxygen consumption during exercise is indirect calorimetry (McArdle, Katch, & Katch, 1996). Indirect calorimetry was derived from direct calorimetry and can be separated into closed-circuit and open-circuit subdivisions. Closed-circuit calorimetry is used predominantly in hospitals and laboratory settings where resting energy expenditure is assessed. Participants breathe from a container of 100% oxygen, commonly called a spirometer. This method is named, "closed-circuit spirometry", because participants do not breathe ambient air but are required to breathe only the air in the spirometer. Measurements are taken according to the change in volume in the canister. Due to the resistance of the system to large breathing volumes, the bulkiness of the spirometer, and the inefficiency of the speed of carbon dioxide removal, this method is rarely used to measure

oxygen consumption during moderate or heavy exercise (McArdle, Katch, & Katch 1996).

Exercise physiologists primarily use indirect, open-circuit calorimetry. Open-circuit calorimetry/spirometry involves similar techniques to those of closed-circuit; however, participants inspire ambient air rather than a known concentration of bottled air. The open-circuit method does not restrict breathing volume and more easily allows for higher intensity exercise to be performed. Several methods of indirect, open-circuit calorimetry include: (a) expired gas analysis; (b) carbon/nitrogen excretion analysis; (c) doubly-labeled water analysis; and (d) respiration chamber assessment. Because expired gas analysis is a direct measurement of $\dot{V}O_{2max}$ it is considered the most accurate method and has become the preferred choice among researchers (American College of Sports Medicine [ACSM], 1995; Robergs & Roberts, 1997).

Up until the early 1960's, $\dot{V}O_{2max}$ testing was primarily performed on treadmills and cycle ergometers at maximal or near-maximal efforts. Douglas bags were used to capture expired air and the contents were analyzed for oxygen and carbon dioxide content. This technique required great amounts of time, special equipment, highly trained personnel, and the lab equipment confined researchers and

participants to the laboratory setting. To surpass the confines of the lab, Balke (1963) introduced a 15-minute field performance walk-run test to assess aerobic fitness. Soon thereafter, Cooper (1968) popularized field-testing even further by shortening the 15-minute test and publishing the 12-minute performance test.

Field tests provide advantages over maximal effort tests performed in the laboratory. Field tests are inexpensive, do not require specialized equipment or extensively trained personnel, and are time-efficient (ACSM, 1995). Because of these advantages, additional field tests have been developed that can be performed on a wide range of individuals. The Balke (1963) and Cooper (1968) tests were designed for the participant to cover the greatest distance possible in a given time frame. However, these tests were primarily developed as near-maximal run tests while still allowing participants to walk whenever necessary to prevent exhaustion. Two decades following the introduction of maximal run field tests, Kline, Porcari, Hintermeister, et al. (1987) developed the first 1-mile maximally-paced walking test. This field test became known as the Rockport Fitness Walking Test (RFWT) and has since been subjected to few modifications.

Field tests are based on the assumption that a linear relationship exists between an individual's heart rate (HR) and oxygen consumption (McArdle, Katch, & Katch, 1996). Therefore, by using submaximal HR values, one can predict maximal oxygen consumption. The original RFWT regression equation utilizes specific predictor variables (i.e., HR, walk time, gender, weight, and age) to estimate $\dot{V}O_{2max}$. For example, in the following equation, as HR or exercise time increases, the estimation of $\dot{V}O_{2max}$ decreases:

$$\dot{V}O_{2max}\,(L\cdot min^{-1}) = 6.9652 + (0.0091\cdot Weight) - (0.0257\cdot Age) + (0.5955\cdot Gender) - (0.2240\cdot Exercise\ Time) - (0.0115\cdot HR).$$

For field tests that estimate oxygen consumption, the predictive accuracy of $\dot{V}O_{2max}$ is increased when exercise HR is above 110 beats per minute (bpm) (Golding, Meyers, & Sinning, 1989). Because HR and walk time are two of the predictor variables used in the original RFWT equation, it is important for participants to walk at a steady pace that will achieve and maintain a steady-state HR above the 110 bpm value.

Field tests are easy to administer, do not require any special equipment or training and can usually be performed by the general public (ACSM, 1995). The nature of this

research focused on modifications of a commonly used submaximal walk test (RFWT) used to predict cardiovascular fitness level. The original RFWT requires participants to perform a 1-mile maximally-paced walk. Most individuals are not accustomed to walking at a maximal intensity and participants often experience leg pain while performing the original RFWT (George, Fellingham, & Fisher, 1998).

George et al. (1998) conducted the only study to date that attempted to modify the original RFWT from a 1-mile distance to a ¼-mile distance. However, George et al. recorded ¼-mile walk time during the 1-mile walk rather than having the participants actually perform a ¼-mile walk test. Measuring ¼-mile walk time during a 1-mile walk may result in error and adversely affect the results of the study. For example, an individual may not be able to maintain a steady pace throughout a 1-mile walk, thus altering $\dot{V}O_{2max}$ estimation.

In order to accurately estimate $\dot{V}O_{2max}$ from submaximal HR values, a steady state or level HR must be attained. It has been noted in previous research that a steady-state HR can be achieved within three minutes of constant intensity activity (George, Vehrs, Allsen, Fellingham, & Fisher, 1993; Golding et al., 1989). Because it will take most participants more than three minutes to complete a ¼-mile

walk, it would stand to reason that participants would be able to obtain a steady-state HR within this distance. However, if participants were not capable of achieving a steady-state HR within a ¼-mile walk, an alternative would be to perform a ½-mile walk, which would allow participants more time to attain a steady-state HR. This alternative will also be examined in this investigation.

In addition, if participants are unable to maintain a steady pace throughout the test, HRs may fluctuate. If a participant's HR increases or decreases prior to the completion of the test, $\dot{V}O_{2max}$ estimations would be spuriously high or low. Because a steady pace is imperative in obtaining a steady-state HR, participants should strive to maintain a constant walking pace.

Significance of the Study

If modifications (i.e., distance, pace) of the RFWT can be established, researchers, as well as participants, would greatly benefit from a more time-efficient test and one that is easier to perform. Thus, the development of a safe and effective walk test that accurately estimates an individual's aerobic capacity would be beneficial. It has been noted in previous research that college-age females demonstrate a lower predictive accuracy when estimating $\dot{V}O_{2max}$ from the original RFWT (Coleman et al., 1987; Dolgener

et al., 1994; George et al., 1998). Thus, further investigation is warranted to evaluate the use of modified versions of the original RFWT on college-age females.

Statement of the Problem

It is unknown whether shorter and self-paced versions of the 1-mile walk test can be used in estimating maximal oxygen consumption. Research is warranted to determine which distance (i.e., ¼-mile, ½-mile, or 1-mile) of a modified RFWT more accurately estimates an individual's $\dot{V}O_{2max}$. Additionally, walking pace was examined to determine if participants maintain a steady pace over the course of each of three distances.

Purpose of the Study

The purpose of the study was to:

1) Determine which distance (i.e., ¼-mile, ½-mile, and 1-mile) of a modified RFWT using a self-selected brisk walking pace yields the highest correlation of $\dot{V}O_{2max}$ estimation when compared to measured $\dot{V}O_{2max}$ among college-age females;

2) Determine if college-age females maintain a steady pace during the administration of modified versions of the RFWT (¼-mile, ½-mile, and 1-mile).

Research Questions

1) Based on correlations between measured $\dot{V}O_{2max}$ and estimated $\dot{V}O_{2max}$ obtained from the ¼-mile, ½-mile, and 1-mile walk tests, which modified RFWT is most strongly related to an individual's true $\dot{V}O_{2max}$?

2) By comparing equidistant segments within each modified RFWT (¼-mile, ½-mile, and 1-mile), do individuals maintain a steady pace during each walk test?

Assumptions

1) The participant pool used in this study was representative of typical college-age women with respect to cardiovascular fitness level.

Delimitations

1) Only students enrolled in classes taught at Middle Tennessee State University participated in the study.

2) Only apparently healthy adults who were between the ages of 18 and 29 were allowed to participate. Individuals who had cardiac, respiratory, or orthopedic problems, as well as those who were pregnant, were also excluded.

3) The participant pool consisted only of women.

4) During each walk test, participants self-selected a steady, brisk pace. This pace may have varied among tests and participants.

Definition of Terms

Rockport Fitness Walking Test (RFWT). The original RFWT was operationally defined as a 1-mile maximally-paced walk test and will be referenced as the original RFWT (Kline, Porcari, Hintermeister, et al. 1987).

Modified Rockport Fitness Walking Test. Previous research has attempted to modify the original RFWT (George et al., 1998). These modifications include participants walking only a ¼-mile distance and walking at a self-selected, steady, brisk pace. The modified RFWT was operationally defined as a self-selected, steady, brisk-paced walk. Distance during the modified RFWT will vary (¼-mile, ½-mile, or 1-mile) and will be referenced accordingly.

Maximal oxygen consumption ($\dot{V}O_{2max}$). Also commonly referred to as an individual's aerobic capacity or cardiovascular fitness level, maximal oxygen consumption refers to the maximal amount of oxygen the body can consume, transport, and utilize. $\dot{V}O_{2max}$ was operationally defined as the maximal amount of oxygen consumed per minute by the body (expressed in $mL \cdot kg^{-1} \cdot min^{-1}$) (Robergs & Roberts, 1997).

CHAPTER II

Review of Literature

The method or procedure for measuring an individual's maximal oxygen uptake or consumption ($\dot{V}O_{2max}$) cannot be traced to a single individual but instead has developed over a period of time beginning with the work of Crawford and Lavoisier in the 1770's (Robergs & Roberts, 1997). With the development of new procedures, numerous protocols and methods for measuring and estimating $\dot{V}O_{2max}$ have been created. This literature review focuses on (a) early methods leading to $\dot{V}O_{2max}$ measurement, (b) development of field tests, (c) development of the Rockport Fitness Walking Test (RFWT), and (d) modifications of the RFWT.

Early Methods Leading to $\dot{V}O_{2max}$ Measurement

Over the past 200 years, many scientists have contributed both directly and indirectly to the development of $\dot{V}O_{2max}$ testing. As early as the 1770's, Crawford and Lavoisier conducted the first direct animal calorimetry research (Robergs & Roberts, 1997). Lavoisier is recognized as the scientist who theorized that life and combustion were supported by a component referred to as "oxygen". Due to Laviosier's premature death, research in the field of calorimetry experienced little advancement

12

until the mid 1800's (Robergs & Roberts, 1997). During this period, scientists began combining direct calorimeters with respirometers. Direct calorimeters were developed primarily to determine caloric expenditure, specifically the temperature change of water as it was passed through a chamber where a test participant was sitting. However, the main function of respirometers was to measure the amount of oxygen consumed via analysis of expired gases (Robergs & Roberts, 1997).

Researchers soon began to realize that oxygen consumption and carbon dioxide production varied with the type of food consumed. In 1860, Bischoff and Voit built a bomb calorimeter (Robergs & Roberts, 1997). This device determined the exact energy value of each food source (carbohydrate, fat, protein) by measuring the amount of oxygen consumed and carbon dioxide produced during the combustion of the food source. However, it was not until 1901 that Rubner published animal research that demonstrated the caloric equivalents for carbohydrate, fat, and protein that continue to be used today to determine body metabolism (Robergs & Roberts, 1997). In 1903, Atwater and Benedict confirmed Rubner's findings with the use of human participants (Robergs & Roberts, 1997). Although Rubner, a German scientist, was the first to

publish these caloric values, it was Atwater, an American, who received the recognition for this work (Robergs & Roberts, 1997).

Other advancements in the measurement of $\dot{V}O_{2max}$ have taken place over the years, such as the development of Douglas bags in the early 1900's. Douglas bags are used to capture expired air from a participant during the administration of an exercise test. This air is then analyzed to determine the individual's $\dot{V}O_{2max}$. This process is time consuming and labor intensive. Other innovations such as portable gas collection equipment, advanced gas analyzers, and enhanced computer capabilities have greatly improved $\dot{V}O_{2max}$ testing and allow for almost instantaneous analysis of oxygen consumption. These improvements have made the measurement of $\dot{V}O_{2max}$ a more time-efficient method of assessing aerobic capacity, as well as making it easier for the researcher to administer such tests.

Development of Field Tests

Until the 1960's, exercise testing was primarily conducted in a laboratory setting with the use of a treadmill. Conducting maximal and submaximal exercise tests in a laboratory setting has advantages, such as control over temperature and humidity. A laboratory setting also makes it easier to monitor participants with

equipment that is readily available. However, maximal exercise testing also has disadvantages: (a) tests can be time consuming to administer; (b) expensive equipment is generally required; and (c) only one participant can be tested at a time. It was most likely for these reasons that field tests were developed (ACSM, 1995; Ward, Ebbeling, & Ahlquist, 1995).

While conducting research in a controlled laboratory setting has benefits, field tests also have advantages. A large number of participants can perform a field test at the same time. Field tests generally do not require expensive equipment and are easily administered. Field tests also tend only to require a submaximal effort while performing a familiar exercise such as walking or running. A submaximal effort field test also greatly reduces the risk of injury to the participant. These advantages make submaximal field tests excellent tools for estimating aerobic capacity across a wide range of individuals. Submaximal field tests, therefore, are oftentimes the tests of choice among researchers who desire only an estimate of an individual's $\dot{V}O_{2max}$ (ACSM, 1995; McArdle, Katch, & Katch, 1996; Ward, Ebbeling, & Ahlquist, 1995).

One of the first field tests developed was the Harvard Step Test published by Brouha, Graybiel, and Heath in 1943

(McArdle, Katch, & Katch, 1996). Step tests require participants to step at a specific cadence up and down a step/platform of a given height. Many participants can perform this test at the same time as long as a step/bleacher/platform of a desired height is available. However, this step test does not estimate an individual's $\dot{V}O_{2max}$ but generates an index that places each participant's aerobic capacity into a specific classification, such as excellent or good. Since the development of the Harvard Step Test, other step tests such as the Queens College Step Test (McArdle, Katch, Pechar, Jacobson, & Ruck, 1972) and the Siconolfi Step Test (Siconolfi, Garber, Laster & Carleton, 1985) have been developed. These field tests produce $\dot{V}O_{2max}$ estimations that are related to actual $\dot{V}O_{2max}$ measurements in the moderate ($r = 0.75$) to strong range ($r = 0.92$) (McArdle, Katch, & Katch, 1996; Ward, Ebbeling, & Ahlquist, 1995).

One of the first walking/running field tests was developed by Balke (1963). Using military personnel, Balke used the maximal distance that could be covered during a 15-minute run to estimate $\dot{V}O_{2max}$. The length of this field test prompted Kenneth Cooper to modify Balke's 15-minute run. In 1968, Cooper shortened the 15-minute run to a 12-minute performance run. Both of these tests required

participants to run the greatest distance possible within a given time frame, but allowed walking to prevent exhaustion. Shortly thereafter, Cooper introduced the 1.5-mile run as an alternative to the 12-minute run/walk (Cooper, 1970). With these two field tests and the coining of the term "aerobics", Cooper became recognized as one of the great pioneers of fitness testing.

Development of the Rockport Fitness Walking Test (RFWT)

Many prediction equations have been developed to estimate maximal oxygen consumption through submaximal cycling, stepping, and jogging. However, until the development of the Rockport Fitness Walk Test (RFWT), there was not a field test to estimate aerobic capacity through walking. Lohman (1981) reported that in order to develop an accurate field test the estimated mean values and standard deviations should be similar to measured values. The field test should also yield a high correlation with the criterion measure.

Kline, Porcari, Hintermeister, et al. (1987) developed a submaximal field test to predict maximal oxygen consumption from a walk test. The investigators, supported in part by the Rockport Company (a corporation that specializes in walking shoes), had 390 volunteers (183 males, 207 females) participate in the study.

Participants' ages ranged from 30 to 69 years. Each participant performed a maximal treadmill test and expired gases were analyzed using a metabolic cart. In order for the test to be considered a maximal effort, two of the following three criteria had to be met: (1) respiratory exchange ratio (RER) values $\geq$ 1.1; (2) leveling off of oxygen consumption despite an increase in work; and (3) heart rate (HR) no less than 15 beats per minute (bpm) below age-predicted maximal HR (220 - age). A total of 343 participants (165 males, 178 females) met these criteria. Each participant performed a minimum of two 1-mile maximally-paced walks. If walk times were not within 30 seconds of each other, additional trials were performed. During the walk, heart rates were recorded and noted at the end of each quarter mile. Total exercise time was also recorded. From these data, the investigators developed both generalized and gender-specific regression equations. Predictor variables that yielded the best estimate of $\dot{V}O_{2max}$ were walk time, HR (at the end of the walk), age (years), weight (lbs), and gender (1 = male, 0 = female). The following equation was developed using multiple regression analysis:

$\dot{V}O_{2max}$ (L$\cdot$min^{-1}) = 6.9652 + (0.0091$\cdot$Weight) - (0.0257$\cdot$Age) + (0.5955$\cdot$Gender) - (0.2240$\cdot$Exercise Time) - (0.0115$\cdot$HR).

This generalized equation exhibited a strong relationship with $\dot{V}O_{2max}$ (r = 0.93, standard error of the estimate (SEE) = 0.325 L·min^{-1}). Cross-validation using 169 participants from the sample resulted in similar findings (r = 0.92 and SEE = 0.355 L·min^{-1}). Looking at gender-specific correlations, Kline, Porcari, Hintermeister, et al. reported a correlation of 0.86 for females when comparing $\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1}) estimations with actual $\dot{V}O_{2max}$ values. Males demonstrated an almost identical correlation (r = 0.85) to that of the female value. Because this research was funded in part by the Rockport Company, this "new" maximally-paced 1-mile walk test became known as the Rockport Fitness Walking Test (RFWT).

Since the development of the RFWT in 1987, researchers have attempted to validate the RFWT on other populations. O'Hanley et al. (1987) administered the original RFWT protocol to 70 - 79 year-old men and women (N = 29) and reported a correlation coefficient of 0.88 and a SEE = 4.43 mL·kg^{-1}·min^{-1} when comparing $\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1}) estimations with actual $\dot{V}O_{2max}$ values. Likewise, Fenstermaker, Plowman, and Looney (1992) attempted to validate these equations on the elderly. The researchers had 16 females (mean age = 69.4) perform three 1-mile maximally-paced walks. Using the gender-specific and generalized equations (L·min^{-1} and

$mL \cdot kg^{-1} \cdot min^{-1}$) developed by Kline, Porcari, Hintermeister, et al. (1987), correlation coefficients ranging from 0.66 to 0.72 when comparing $\dot{V}O_{2max}$ estimations with actual $\dot{V}O_{2max}$ values were reported along with SEEs falling within the specified range of 0.25 $L \cdot min^{-1}$ and 4.5 $mL \cdot kg^{-1} \cdot min^{-1}$. Therefore, the Kline, Porcari, Hintermeister, et al. (1987) equations used to predict $\dot{V}O_{2max}$ also appear to be valid for use with the senior population.

Looking at younger populations, Coleman et al. (1987) conducted a study to validate the 1-mile walk test on 20 - 29 year-olds. Using 90 participants (40 males, 50 females), the researchers used the Kline, Porcari, Hintermeister, et al. (1987) generalized equation (r = 0.88; SEE = 5.0 $mL \cdot kg^{-1} \cdot min^{-1}$) for estimating $\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$). Using this generalized equation, Coleman et al. calculated a correlation coefficient of 0.79 when comparing $\dot{V}O_{2max}$ estimations with actual $\dot{V}O_{2max}$ values while yielding a SEE = 5.68 $mL \cdot kg^{-1} \cdot min^{-1}$. However, when males and females were analyzed separately, females yielded a lower correlation (r = 0.62; SEE = 5.55 $mL \cdot kg^{-1} \cdot min^{-1}$) than did the males (r = 0.79; SEE = 5.73). However different, this did not dissuade the authors from reporting that the Kline, Porcari, Hintermeister, et al. equation was a valid means

of estimating $\dot{V}O_{2max}$ in both male and female 20 - 29 year-olds.

Zwiren, Freedson, Ward, Wilke, and Rippe (1991) also attempted to validate the original RFWT, but used females aged 30 - 39. While using the generalized $(mL \cdot kg^{-1} \cdot min^{-1})$ equation, the authors followed the same procedures as did Coleman et al. and reported a slightly higher correlation of 0.73 with a SEE of 4.57 $mL \cdot kg^{-1} \cdot min^{-1}$ when comparing estimations to true $\dot{V}O_{2max}$ values. George et al. (1998) also reported that the original gender-specific equations developed by Kline, Porcari, Hintermeister, et al. (1987) and the gender-specific equations developed by Dolgener et al. (1994) yielded lower correlations (0.69 - 0.71) for females than for males (0.78 - 0.79). Thus, research seems to indicate the equations for women tend to exhibit a lower predictive accuracy than do the equations for men when estimating $\dot{V}O_{2max}$. It is not yet clear why the accuracy of the equations would differ between men and women.

Contrary to previous research (Coleman et al., 1987; Zwiren et al., 1991), Dolgener, Hensley, Marsh, and Fjelstul (1994) reported overestimations of $\dot{V}O_{2max}$ using the original equations. Dolgener et al., using the same protocol described by Kline, Porcari, Hintermeister, et al. (1987), had 196 participants (100 females, 96 males) serve

as a validation group. Once new prediction equations were developed, 78 participants (33 males, 45 females) were used to cross-validate the equations. The investigators used the generalized and gender-specific equations developed by Kline, Porcari, Hintermeister, et al. to predict $\dot{V}O_{2max}$ on college-age students (mean age = 19.4). Dolgener et al. reported that for each of the Kline, Porcari, Hintermeister, et al. equations, the predicted $\dot{V}O_{2max}$ was consistently overestimated for college-age students. In fact, the Kline, Porcari, Hintermeister, et al. prediction equations yielded correlations ranging from 0.39 to 0.59, with only the combined (male, female) generalized $\dot{V}O_{2max}$ ($L \cdot min^{-1}$) equation and the combined generalized equation ($mL \cdot kg^{-1} \cdot min^{-1}$) yielding a correlation of 0.86 and 0.69, respectively. Dolgener et al. found that the Kline, Porcari, Hintermeister, et al. equations over predicted $\dot{V}O_{2max}$ in college men and women by 16 - 23%, as also reported by George, Fellingham, and Fisher (1998).

Based on these findings, Dolgener et al. developed new prediction equations to estimate $\dot{V}O_{2max}$. Only one equation yielded a correlation sufficient ($r = 0.84$, SEE = 0.397 $L \cdot min^{-1}$) to recommend its use. The predictor variable of

age was excluded from the equations due to the narrow age range of the sample. The following equation was developed:

$$\dot{V}O_{2max} \ (L \cdot min^{-1}) = 3.5959 + (0.6566 \cdot gender) +$$

$$(0.0096 \cdot weight) - (0.0996 \cdot walk \ time) - (0.0080 \cdot heart \ rate),$$

where male = 1, female = 0, weight is in pounds, walk time in minutes, and HR equals beats per minute (bpm) at the end of the walk. The gender-specific equations $(mL \cdot kg^{-1} \cdot min^{-1})$ developed by Dolgener et al. (1994) produced correlations ranging from 0.38 for females to 0.50 for males when comparing $\dot{V}O_{2max}$ estimations with actual $\dot{V}O_{2max}$ values while yielding similar SEEs of previous research. In addition, the new generalized equation $(mL \cdot kg^{-1} \cdot min^{-1})$ exhibited a correlation of 0.70.

Dolgener et al. (1994) posed a possible explanation for the overestimation of $\dot{V}O_{2max}$ using the Kline, Porcari, Hintermeister, et al. (1987) equation. Previous research (Kline, Porcari, Freedson, et al., 1987) has indicated that $\dot{V}O_{2max}$ values that fall in the low and middle fitness categories tend to be overestimated and those that fall into the high fitness group are likely to be underestimated. Thus, it may be speculated that participants' fitness levels may affect the prediction of

$\dot{V}O_{2max}$. Kline, Porcari, Freedson, et al. caution against interpretation of results when using fitness extremes of the population.

Modifications of the RFWT

Since the development of the original RFWT, this field test has seen few modifications. However, George et al. (1998) conducted a study to assess whether or not modifications of the original RFWT would yield acceptable predictions of $\dot{V}O_{2max}$ in college men and women. The authors sought to modify the existing protocol in two ways. First, the researchers had participants self-select a brisk walking pace instead of performing at the maximal pace the original RFWT requires. The researchers also shortened the test from 1-mile to a ¼-mile walk. The original RFWT takes approximately 10 to 15 minutes to administer, whereas the ¼-mile version can be completed in only three to four minutes.

Previous research has shown that participants can attain a steady-state HR during constant intensity exercise in approximately three minutes (George et al., 1993; Golding et al., 1989). Because few individuals (only those who are highly fit) are able to complete a ¼-mile in less than three minutes, this modification of the original RFWT would enable researchers to administer this walk test in a

more time-efficient manner. This modification also involved participants walking at a self-selected, brisk pace rather than the maximal pace required in the original RFWT. Most people are not experienced with maximal-paced walking, as George et al. (1998) reported, and participants usually experience lower leg pain therefore making the original RFWT somewhat uncomfortable for the participant to perform.

Using these modifications of the original RWFT, George et al. (1998) had 98 college students (males 39, females 59) walk the regular 1-mile distance at a self-selected brisk pace. At each ¼-mile mark, participants' heart rates and exercise times were noted. The investigators estimated $\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1}) using both the age-generalized equation (r = 0.88) developed by Kline, Porcari, Hintermeister, et al. (1987) and the age-specific equation (r = 0.70) developed by Dolgener et al. (1994). As with the Dolgener et al. findings, $\dot{V}O_{2max}$ was overestimated in this study by 8 - 20% using the age-generalized equation developed by Kline, Porcari, Hintermeister, et al. This equation yielded a correlation of 0.84 and SEE = 3.61 mL·kg^{-1}·min^{-1} for the 1-mile walk and r = 0.81 and SEE = 3.94 mL·kg^{-1}·min^{-1} for the ¼-mile distance derived from the 1-mile walk. The Dolgener et al. age-specific equation yielded similar

correlations and SEEs (1-mile, r = 0.85, SEE = 3.48 mL·kg⁻¹·min⁻¹; ¼-mile, r = 0.83, SEE = 3.67 mL·kg⁻¹·min⁻¹). Based on these findings, George et al. concluded that using the Dolgener et al. (1994) age-specific equation yielded acceptable estimations of $\dot{V}O_{2max}$ in college-age men and women and furthermore that the ¼-mile walk appeared to generate similar predictions. However, these results should be interpreted with caution because the researchers did not have the participants perform an actual ¼-mile walk, but instead analyzed ¼-mile data derived from a 1-mile test.

Measuring ¼-mile walk time during a 1-mile walk may result in error and adversely affect the results of the study. However, if new research shows that participants are not capable of maintaining a steady pace during a ¼-mile walk, an alternative is to perform a ½-mile walk. Performing a ½-mile walk would allow more time for participants to attain a steady-state HR and still require less time and energy than the 1-mile version of the walk test.

In an effort to account for potential error, research was warranted to determine whether participants maintain a steady pace over ¼-mile, ½-mile, and 1-mile distances. If a steady pace cannot be achieved with a ¼-mile walk, performing a ½-mile walk may allow enough time for

participants to reach a steady-state HR and thus decrease the distance required by the original RFWT. Additionally, if participants are not maintaining a steady pace throughout the test, HRs may fluctuate during the test resulting in inaccurate $\dot{V}O_{2max}$ estimations.

Significance of Study Population

The original RFWT investigation examined men and women whose ages ranged from 30 to 69 years. However, the original RFWT is a popular field test that is commonly used to estimate $\dot{V}O_{2max}$ among college-age students. Previous literature has shown that the $\dot{V}O_{2max}$ estimation of college-age individuals is overestimated using the original RFWT equation (Dolgener et al., 1994; George et al., 1998). As well, college-age women have exhibited a lower predictive accuracy than have college-age men (Coleman, et al., 1987; Dolgener et al., 1994; George et al., 1998). For the purpose of this study, only college-age women were participants in an effort to further investigate the effectiveness of the use of modified versions of the RFWT in this population.

Summary

Field tests have been a widely used means of estimating an individual's fitness level. Specifically, the original RFWT has been used extensively in the college

setting. However, a disadvantage of the original RFWT is that it requires participants to walk at a maximal pace for a distance of one mile. Modifying the original RFWT may allow participants to walk at a self-selected pace for a shorter distance (¼- or ½-mile) while yielding results similar to earlier findings. Decreasing the distance and the intensity of the original RFWT would greatly improve the existing protocol and make the RFWT an easier field test to perform and administer.

CHAPTER III

Method

The methodology that was employed during this
investigation is described in this chapter. Information
provided in this chapter includes: (a) the pilot study;
(b) participants; (c) measurements; (d) the maximal
treadmill test; (e) the field tests; (f) procedures; and
(e) analysis of data.

Pilot Study

A pilot study was performed in an effort to justify
the number of participants that were needed to conduct this
study. Participants performed three walk tests (¼-mile, ½-
mile, and 1-mile). Each test was divided into four
equidistant segments. As the participant crossed each
segment, exercise time was recorded in an effort to monitor
walk pace. For each walk test, a separate repeated
measures analysis of variance (ANOVA) was performed. It
was concluded that a total of 26 participants were required
to elicit a power of 0.81.

Participants

With the exception of five participants, data were
collected using participants recruited from walk/jog/run
classes taught by the principal investigator and also
walk/jog/run classes taught by a doctoral candidate at

29

Middle Tennessee State University (MTSU). In an effort to keep a homogeneous participant pool of college-age women, only healthy females who were between 18 and 29 years of age were included. A total of 33 students from the above-mentioned classes over the course of the Fall 2000 semester were examined. An oral script (Appendix A) initiated the recruitment of participants. The primary investigator was the chief data collector but was also aided in the collection process by the aforementioned doctoral candidate. Participation was strictly voluntary. No monetary compensation was given for participation. As well, students' grades were not affected in any way by participating or choosing not to participate. Each eligible participant signed a letter of informed consent (Appendix B).

Measurements

Physical Activity Readiness-Questionnaire (PAR-Q)

Due to the risks associated with a maximal graded exercise test, all participants were screened by completing a Physical Activity Readiness Questionnaire [PAR-Q] (Appendix C) developed by the Canadian Society for Exercise Physiology, Inc. (1994).

Height and Weight

Each participant's height, without shoes, (recorded to the nearest half-inch) and weight, without shoes, (recorded to the nearest half-pound) were collected using a physician's balance-beam scale.

Maximal Treadmill Test

Participants performed a maximal exertion graded exercise stress test on a laboratory treadmill (Model 55; Quinton, Inc., Seattle, WA). Using indirect, open-circuit gas analysis obtained from a MedGraphics CardioPulmonary Diagnostic System (Cart Model CPX-D; St. Paul, MN), each participant's measured $\dot{V}O_{2max}$ was obtained. Participants were instructed to follow the Bruce (1973) protocol during the treadmill test. To determine whether participants had reached a true $\dot{V}O_{2max}$, participants had to meet two of the three following criteria: (1) leveling of $\dot{V}O_{2max}$ despite an increase in work, (2) respiratory exchange ratio (RER) $\geq$ 1.1, and/or (3) heart rate no less than 15 beats below their age-predicted maximal heart rate (220 - age) (Kline, Porcari, Hintermeister, et al. 1987).

Field Tests

Participants randomly performed a modified 1-mile Rockport Fitness Walk Test (RFWT), as well as two other modifications of the RFWT ($\frac{1}{4}$-mile and $\frac{1}{2}$-mile walk).

Participants walked the required distance on a climate controlled indoor track. Appropriate track distances were measured using a Rolatape® (Model 300) distance wheel. During the walk, participants wore a Polar® Vantage XL heart rate monitor, which recorded and stored instantaneous heart rates. Participants performed all three walk tests at a self-selected, brisk walking pace. Participants were instructed to maintain this pace throughout the duration of each walk test (Appendix E). Variations of selected paces between the walk tests were not of importance as long as participants were performing at an intensity that elicited a HR of 110 bpm or above. $\dot{V}O_{2max}$ predictive accuracy is improved when participants perform at an intensity that generates a HR response of this magnitude (Golding et al., 1989). The time required to finish each walk test was recorded using a standard stopwatch. All three walk tests were divided into four equidistance segments and one of three data collectors recorded time at each segment as the participant passed.

Procedures

Participant recruitment was initiated using an oral script (Appendix A). From this initial response, potential participants completed a PAR-Q (Appendix C). Potential participants who answered yes to one or more of the PAR-Q

questions were excluded from the study (Canadian Society for Exercise Physiology, Inc., 1994). Participants who answered no to all of the questions were immediately scheduled to attend the first of four meetings.

During the first meeting, eligible participants signed an informed consent and were given time to ask questions related to the study. Each participant's height, weight, and age was measured and recorded. Also during this first session, participants performed a maximal treadmill exercise test.

Within ten days after the administration of the treadmill test, each participant performed three randomly ordered submaximal walk tests (¼-mile, ½-mile, 1-mile). Each walk test was conducted on a separate day with one day's rest in between tests. During each walk test, participants' HRs and exercise times were recorded. Walk times for the ¼-mile and ½-mile walk were transformed into 1-mile durations, as computed by George et al. (1998).

<u>Analysis of Data</u>

All analyses were performed using the SPSS (version 10.0) statistical package. Descriptive statistics were calculated for each of the following variables: age, height, weight, walk time and ending exercise HR for each of the three tests. Estimations for each individual's $\dot{V}O_{2max}$

were determined for each walk test using the original

Kline, Porcari, Hintermeister, et al. (1987) age-

generalized, female regression equation (r = 0.86)

(Appendix D).

Pearson product-moment correlation coefficients were

determined for the ¼-mile, ½-mile, and 1-mile walks

relating each participant's estimated $\dot{V}O_{2max}$ value with the

measured $\dot{V}O_{2max}$ value obtained from the treadmill test.

Correlations for each walk test were compared to determine

which walk test more accurately estimates an individual's

$\dot{V}O_{2max}$. Standard error of the estimates (SEEs) were also

calculated to determine the predictive accuracy of the

estimations.

Exercise walk times were recorded at each of the

following segments:

¼-mile Walk Test:

1/16-mile, 1/8-mile, 3/16-mile, and ¼-mile;

½-mile Walk Test:

1/8-mile, ¼-mile, 3/8-mile, and ½-mile;

1-mile Walk Test:

¼-mile, ½-mile, ¾-mile, and 1-mile.

Three separate repeated measures ANOVAs were employed for

each walk test to compare walk times for each equidistant

segment to determine if individuals maintained a constant

walking pace. Tukey post hoc comparisons indicated where disparities existed. Statistical significance level was set at 0.05 for all analyses.

CHAPTER IV

<u>Results</u>

Data were collected on 33 female college volunteers.
Due to incomplete data, one participant was dropped from
the study. The mean age of the remaining sample was 20.6
years. Participants' ages ranged from 19 to 26 years old.
Mean height and weight were 63.6 inches and 138.1 pounds,
respectively. Height ranged from 56.5 to 70 inches,
whereas weight ranged from 102.5 to 257.0 pounds.

Table 1

<u>Physical Characteristics of the Participants (n = 32)</u>

Variable	Range	Mean	Standard Deviation
Age (years)	19 - 26	20.6	2.6
Height (inches)	56.5 - 70.0	63.6	2.4
Weight (pounds)	102.5 - 257.0	138.1	27.8

Participants' measured and estimated $\dot{V}O_{2max}$ values are
presented in Table 2. Mean measured $\dot{V}O_{2max}$ for the sample
was 37.6 mL·kg^{-1}·min^{-1}. Mean estimated $\dot{V}O_{2max}$ for the 1-mile,
½-mile, and ¼-mile walks were 42.6 mL·kg^{-1}·min^{-1}, 43.7 mL·kg^{-1}·min^{-1}, and 45.0 mL·kg^{-1}·min^{-1}, respectively.

36

Table 2

Physiological Characteristics of the Participants (n = 32)

Variable	Range	Mean	Standard Deviation
Measured $\dot{V}O_{2max}$ *	24.5 - 45.0	37.6	4.8
Estimated $\dot{V}O_{2max}$ * 1-mile walk	26.2 - 47.4	42.6	3.5
Estimated $\dot{V}O_{2max}$ * ½-mile walk	30.6 - 47.7	43.7	3.2
Estimated $\dot{V}O_{2max}$ * ¼-mile walk	32.4 - 48.6	45.0	3.1

Note. * Expressed in $mL \cdot kg^{-1} \cdot min^{-1}$.

As noted in Chapter One, the first research question was to determine which modification of the RFWT (1-mile, ½-mile, and ¼-mile) more accurately estimated an individual's measured $\dot{V}O_{2max}$. Pearson product moment correlations were used to determine the relationship between participants' $\dot{V}O_{2max}$ values estimated from each of the three walk tests (1-mile, ½-mile, ¼-mile) and measured $\dot{V}O_{2max}$ from the maximal treadmill test. As presented in Table 3, oxygen consumption estimates from the 1-mile walk test and the ¼-mile walk test yielded the highest correlations with measured $\dot{V}O_{2max}$. The 1-mile and ¼-mile walks produced correlations of 0.68 and 0.67, respectively. The ½-mile

walk produced a lower correlation of 0.59. Standard errors of the estimates (SEE) (3.58 - 3.92 $mL \cdot kg^{-1} \cdot min^{-1}$) fell within the specified range of 4.5 $mL \cdot kg^{-1} \cdot min^{-1}$ reported by Kline, Porcari, Hintermeister, et al.(1987).

Table 3

Pearson Product Moment Correlation and Standard Error of the Estimate of Measured $\dot{V}O_{2max}$ to Estimated $\dot{V}O_{2max}$ from Three Walk Tests

	$\dot{V}O_{2max}$ Estimation		
	1-mile	½-mile	¼-mile
Measured $\dot{V}O_{2max}$	.68*	.59*	.67*
SEE $(mL \cdot kg^{-1} \cdot min^{-1})$**	3.58	3.92	3.59

Note. *p < .01. **SEE (standard error of the estimate)= $SD\sqrt{1 - (r^2)}$.

The purpose of the second research question was to determine if participants maintained a steady walking pace throughout each walk test. Mean walking times for each segment were analyzed using three repeated measures ANOVAs and Tukey post hoc tests. Each walk test was divided into four equidistant segments and the time for each of the participants was recorded at each segment during each of the three tests. Results for the 1-mile walk test

identified an overall statistically significant difference (F(3, 93) = 4.46, p < .05) in mean walking time across the four equidistant segments. Specifically, mean walking time for segment one (3.50 minutes) was significantly faster than segments two (3.54 minutes) and three (3.57 minutes). Walk times for segment two were significantly faster than segment three.

Table 4

Repeated Measures Analysis of Variance for Segments in the 1-mile Walk Test

	Segment Comparisons		
Segments	2	3	4
1 (3.50)	3.54*	3.57*	3.56
2 (3.54)		3.57*	3.56
3 (3.57)			3.56

Note. Means expressed in minutes. * F(3, 93) = 4.46, p < .05.

Statistical analyses also revealed an overall significant difference (F(3, 93) = 6.78, p < .05) in mean walking time across the segments in the ½-mile walk test. Post hoc analysis revealed that mean walking time for segment one (1.68 minutes) was significantly faster than all other segments.

Table 5

Repeated Measures Analysis of Variance for Segments

in the ¼-mile Walk Test

	Segment Comparisons		
Segments	2	3	4
1 (1.68)	1.72*	1.74*	1.73*
2 (1.72)		1.74	1.73
3 (1.74)			1.73

Note. Means expressed in minutes. * $F(3, 93) = 6.78$,

$p < .05$.

The repeated measures ANOVA for the ¼-mile walk test also indicated a statistically significant overall difference ($F(3, 93) = 15.01$, $p < .05$) in mean walking time across the four equidistant segments. As shown in Table 6, mean walking time for segment one (.83 minutes) was significantly faster than segments three (.85 minutes) and four (.85 minutes). Additionally, the mean walking time for segment two (.83 minutes) was faster than segments three and four.

Table 6

Repeated Measures Analysis of Variance for Segments

in the ¼-mile Walk Test

	Segment Comparisons		
Segments	2	3	4
1 (.83)	.83	.85*	.85*
2 (.83)		.85*	.85*
3 (.85)			.85

Note. Means expressed in minutes. * $F(3, 93) = 15.01$,

$p < .05$.

CHAPTER V

Discussion

The objective of this investigation was to evaluate
the effectiveness of three versions of a submaximal walk
test in college-age females. Specifically, the aim was to
determine which walk test (1-mile, ½-mile, or ¼-mile),
using a self-selected brisk pace, produced the most
accurate $\dot{V}O_{2max}$ estimation. In addition, the tests were
evaluated to determine if participants maintained a steady
walking pace throughout each walk. It was concluded that
the $\dot{V}O_{2max}$ estimates from the 1-mile and ¼-mile tests were
the most strongly related of the three walk tests to
measured $\dot{V}O_{2max}$. Further, it was determined that
participants were not able to maintain a steady pace.

The remainder of this chapter includes the following
sections: (a) participant characteristics, (b)
relationships between measured and estimated $\dot{V}O_{2max}$, (c)
pacing characteristics, (d) future research
recommendations, and (e) summary and conclusions.

Participant Characteristics

Descriptive data were compared to earlier studies to
determine the representativeness of the current sample to
other college-age females. Participants' age, height, and
weight were similar to those in previous studies (Dolgner

42

et al., 1994; George et al., 1998). Measured $\dot{V}O_{2max}$ values

($\bar{x}$ = 37.6 mL·kg^{-1}·min^{-1}) were comparable to the national

average $\dot{V}O_{2max}$ values (35 - 43 mL·kg^{-1}·min^{-1}) for untrained,

college-age females (Nieman, 1995). Therefore,

participants in this sample were deemed representative of

aerobically untrained, college-age females.

Relationships between Measured and Estimated $\dot{V}O_{2max}$

As previously discussed, $\dot{V}O_{2max}$ estimates from the 1-

mile RFWT have yielded correlations ranging from 0.38 to

0.71 to measured $\dot{V}O_{2max}$ (Coleman et al. 1987; Dolgener et

al., 1994; George et al., 1998). In the present study,

correlations between measured $\dot{V}O_{2max}$ and estimated $\dot{V}O_{2max}$ for

the 1-mile (r = 0.68) and ¼-mile (r = 0.67) walks were

similar to earlier findings (Coleman et al., 1987; Dolgener

et al., 1994; George et al., 1998). However, the findings

should be interpreted with caution. Previous studies have

estimated $\dot{V}O_{2max}$ using the original equation developed by

Kline, Porcari, Hintermeister, et al. (1987) on a sample of

participants ranging in age from 30 to 69, containing both

males and females. The age-generalized female equation

developed by Kline, Porcari, Hintermeister, et al. (1987)

was selected in the current study because the sample being

examined was composed only of females. This makes an

overall comparison among previous studies difficult. In the only study to examine college-age females specifically using the age-generalized, female equation a correlation of 0.41 was produced when comparing measured $\dot{V}O_{2max}$ with estimated $\dot{V}O_{2max}$ (Dolgener et al., 1994). This finding suggests that females have a tendency to exhibit a lower correlation when evaluated alone.

Additionally, in the only study to date to examine a ¼-mile walk (George et al., 1998), a correlation of 0.64 was reported for college-age females using the original Kline, Porcari, Hintermeister, et al. (1987) equation. This value is comparable to the correlations produced by the 1-mile and ¼-mile walks established in the present study. The correlation obtained for the ½-mile walk was lower (r = 0.59) than the correlations obtained for the 1-mile and ¼-mile walks. Because all three walk tests were counterbalanced to guard against order effects and conducted in the same manner, it is unclear why the ½-mile walk yielded a lower correlation than the 1-mile and ¼-mile walks.

As in previous findings (Dolgener et al., 1994; George et al., 1998), participants' estimated $\dot{V}O_{2max}$ values were overestimated for all three walk tests. The mean $\dot{V}O_{2max}$ overestimation for the 1-mile, ½-mile, and ¼-mile walk

tests were 14%, 18%, and 21%, respectively. This overestimation is likely due to the inadequacy of the original RFWT equation in regard to the sample being tested. As stated previously, the original RFWT equation was developed on a sample of males and females ranging in age from 30 years to 69 years. However, the sample used in this study consisted of college-age females. Because the Kline, Porcari, Hintermeister, et al. (1987) equations are the most widely referenced and accepted equations, this equation was chosen instead of the equation developed by Dolgener et al. (1994). When selecting a regression equation that will be used to estimate an individual's $\dot{V}O_{2max}$, administrators of the RFWT should consider the age of the participant and take this into account when interpreting results. Another factor which may have contributed to the overestimation in $\dot{V}O_{2max}$ was the inability of the participants to maintain a steady walking pace during each of the walk tests.

Pacing Characteristics

It is important for participants to maintain a steady walking pace during the Rockport Fitness Walking Test. If participants do not maintain a steady pace, then HR, a predictor variable for $\dot{V}O_{2max}$, fluctuates throughout the test. In the present study, participants did not maintain

a steady pace throughout each walk test. For the 1-mile walk, pace slowed significantly from the first segment to the second and third segments, respectively. During the ½-mile walk, participants covered the first segment significantly faster than the remaining three segments. In addition, in the ¼-mile walk, pace progressively slowed from the first segment to the fourth segment. If heart rate values are lower at the end of each test, this would in turn overestimate participants' $\dot{V}O_{2max}$. This may also, in part, explain the $\dot{V}O_{2max}$ overestimation documented in this study and in previous studies because lower HR values are indicative of higher $\dot{V}O_{2max}$ values.

This variation may have had more of an impact on the estimation of $\dot{V}O_{2max}$ in the ¼-mile walk than in the other two walks. During the ¼-mile walk test, participants did not maintain a steady pace through the first half of the walk. In the present study, the mean total walk time for the ¼-mile walk was 3.34 minutes. It takes approximately three minutes to achieve a steady-state HR (George, Vehrs, Allsen, Fellingham, & Fisher, 1993; Golding et al., 1989) and, therefore, it is unlikely that a steady-state HR could be achieved in only the last half of a ¼-mile walk.

Two potential factors may have contributed to the lack of pacing documented in the current sample. First, during

the 1-mile walk, many participants verbally complained of
lower leg pain (predominantly in the shins), as has been
previously documented (George et al., 1998). This leg pain
could be a possible explanation as to why participants'
pace slowed midway through each walk. Secondly,
participants had difficulty maintaining a steady pace
during the initial segment of each walk. This may be
justified partly due to participants' initial excitement or
anxiety about the test. Participants also verbally
expressed boredom because the 1-mile walk test was too
long. This boredom may also have contributed to the
slowing pace during the 1-mile walk. To prevent these
factors from impacting participants' performance,
administrators of this test should stress the importance of
maintaining a steady pace throughout the entire test.
Additionally, because participants' comfort level appears
to play a role when performing the RFWT, selecting a ¼-mile
version of the RFWT could be an acceptable alternative.

Future Research Recommendations

This study suggests that the ¼-mile walk and 1-mile
walk using a self-selected brisk pace may be an acceptable
alternative to the original 1-mile RFWT. As in the George
et al. (1998) study, this investigation used the equation
that was developed from a 1-mile distance to estimate $\dot{V}O_{2max}$.

Therefore, walk times for the ¼-mile and ½-mile tests had to be converted into 1-mile times by multiplying by four and two, respectively. Future research should focus on developing a regression equation to predict $\dot{V}O_{2max}$ specifically for the distances examined in this study (i.e., ½-mile and ¼-mile). Because the 1-mile walk was covered in a self-selected pace rather than at a maximal pace as in the original RFWT, a new regression equation appropriate for a self-selected 1-mile test must also be developed. The RFWT is used predominantly in the college setting so it is important to have supporting data on both men and women. Researchers should include both men and women to validate any new regression equations that may be derived for these shorter distances. As well, researchers should examine a sample with a wide age range to determine if new regression equations are appropriate for alternate age groups. This would make shorter versions of the RFWT more generalizeable to the larger population.

Researchers should also attempt to determine the practical significance of slight variations in regard to pacing and total exercise time. Even though participants were unable to maintain a steady pace throughout each walk test, it is unknown how pace impacts HR response as it relates to the administration of the RFWT. Research should

focus on how changes in pace affect HR values and, in turn

affect $\dot{V}O_{2max}$ estimation.

Summary and Conclusions

The most accurate method of assessing an individual's

$\dot{V}O_{2max}$ is through indirect calorimetry (ACSM, 1995; Robergs

& Roberts, 1997). However, this technique is not feasible

for the general population because it requires expensive

equipment, a maximal effort, a large time commitment, and

trained personnel to conduct the test. One alternative is

to perform a field test which estimates an individual's

$\dot{V}O_{2max}$. Field tests offer many advantages over maximal

effort tests performed in the laboratory in that they are

inexpensive, do not require specialized equipment or

extensively trained personnel, and are time-efficient

(ACSM, 1995). However, field tests do not provide a

precise or actual measurement of $\dot{V}O_{2max}$, only an estimate.

As demonstrated in the present study, pacing should be

closely monitored when administering a walk test such as

the RFWT. If participants do not maintain a steady pace,

then $\dot{V}O_{2max}$ estimations may be inaccurate due to fluctuation

of the participants' heart rate. This should be an

important consideration for test administrators.

The RFWT was originally developed to address some of the disadvantages associated with administering a maximal effort treadmill test. Even then, the original RFWT had its drawbacks, such as time efficiency and participant comfort level. Modifications of the original RFWT have since attempted to improve the existing walk test.

Results from this study suggest that researchers may administer a shorter self-paced version of the RFWT (¼-mile) or a self-paced 1-mile version and yield correlations similar to those found in previous studies (Coleman et al., 1987; George et al., 1998). In addition, the original RFWT calls for participants to walk at a maximal pace. The present study, along with previous work (George et al. 1998), suggests that participants can self-select a steady, brisk walking pace and yield similar results, as long as the pace is within the linear portion of the $HR/\dot{V}O_{2max}$ relationship. A self-selected pace and a shorter distance make the Rockport Fitness Walking Test a more comfortable test for the participant and more time efficient for the test administrator.

Appendix A

Oral Script for Recruitment of Participants

Appendix A

Oral Script for Recruitment of Participants

The purpose of this research project is to validate modifications of a commonly used field test known as the Rockport Fitness Walking Test. The Rockport Fitness Walking Test is a one-mile walk test used to estimate cardiovascular fitness level. As a part of this study, you will be asked to perform a maximal treadmill test and three separate walk tests (¼-mile, ½-mile, and 1-mile). By participating in this study, you will benefit by receiving an assessment of your cardiovascular or aerobic fitness level (retail value of over $150). This assessment can be used to classify your fitness level and better recommend an exercise program specifically for you. In order to participate, you must be female and between the ages of 18 and 29. This study is strictly voluntary and your grade will not be affected in any way if you choose to participate or choose not to participate. If you wish to take part in this study, please indicate so by signing the accompanying page.

Appendix B

Informed Consent

Appendix B

Informed Consent

1. Explanation of the Tests

Treadmill Test: To assess your aerobic fitness level, you will perform a maximal effort treadmill test. The exercise intensity will begin at a low level and will be advanced in stages until you can no longer continue. The test may be stopped at any time. However, keep in mind that a maximal effort is necessary in order to complete a valid test. You can expect the test to last anywhere from 12 to 18 minutes, depending on your fitness level.

Walk Tests: Within ten days of completion of the treadmill test you will be asked to perform three separate walk tests. Each test will be performed on a different day. You will be able to self-select a brisk pace or intensity during each walk test (¼-mile, ½-mile, & 1-mile). You will not be allowed to jog or run.

2. Attendant Risks and Discomforts

There exists the possibility of certain changes occurring during the test. The risks associated with the procedures being used in this study are extremely minimal for healthy, young adults. Feelings of discomfort sometimes associated with exercise include local muscular fatigue, shortness of breath, nausea, dizziness, and

muscular soreness. Research has indicated that 0.5 deaths may occur per 10,000 maximal exercise tests. However, risks associated with this testing procedure are no more or less than would be expected with regular participation in athletic practices and competitions. Every effort will be made to minimize these risks by evaluation of preliminary information relating to your health and fitness and by observations during testing. Personnel trained in first aid and CPR will be available to deal with unusual situations that may arise.

3. Responsibilities of the Participant

Information you possess about your health status or previous experiences of unusual feelings with physical effort may affect the safety and value of your exercise test and should be revealed prior to participation. Your prompt reporting of feelings of discomfort during the exercise test is also of great importance. You are responsible for fully disclosing such information when requested by the investigator.

4. Benefits to be Expected

By participating in this study, you will benefit by receiving an assessment of your cardiovascular or aerobic fitness level. This assessment can be used to classify

your fitness level and better recommend an exercise program
specifically for you.

5. Inquiries

Any questions about the procedures used in the exercise
test or the results of your test are encouraged. If you
have any concerns or questions, please ask for further
explanations. If for some reason (questions, concerns,
etc.) you need to contact someone regarding this study, you
can call Freddie McConnell (898-5545 or 867-2790) or Dr.
Doug Winborn (898-5110).

6. Freedom of Consent

Your permission to perform these exercise tests is
voluntary. You are free to stop the test at any point, if
you so desire without any consequences. You can feel
confident that your test results will not be made public at
any time. Keep in mind this study takes a considerable
time commitment from you and your cooperation is greatly
appreciated.

I have read this form and I understand the test procedures
that I will perform and the attendant risks and
discomforts. Knowing these risks and discomforts, and
having had an opportunity to ask questions that have been

answered to my satisfaction, I consent to participate in this test.

_____   _____
Date   Signature of Participant

_____   _____
Date   Signature of Witness

Form adapted from:

American College of Sports Medicine. (1995). ACSM's guidelines for exercise testing and prescription (5th ed.). Baltimore: Williams & Wilkins.

American College of Sports Medicine. (2000). ACSM's guidelines for exercise testing and prescription (6th ed.). Philadelphia: Lippincott, Williams, & Wilkins.

Appendix C

Physical Activity Readiness Questionnaire

(PAR-Q) and You

Appendix C

Physical Activity Readiness Questionnaire (PAR-Q) and You

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly.

Check YES or NO

YES	NO	
☐	☐	1. Has your doctor ever said that you have a heart condition _and_ that you should only do physical activity? recommended by a doctor?
☐	☐	2. Do you feel pain in your chest when you do physical activity?
☐	☐	3. In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart? condition?
☐	☐	7. Do you know of any other reason why you should not do physical activity?

If

you

answered

YES to one or more questions

Talk to your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want—as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to _all_ PAR-Q questions, you can be reasonably sure that you can:

- Start becoming much more physically active—slowly and build up gradually. This is the safest and easiest way to go.

- Take part in a fitness appraisal—this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively.

Delay becoming much more active:

- If you are not feeling well because of a temporary illness such as a cold or a fever—wait until you feel better; or
- If you are or may be pregnant—talk to your doctor before you start becoming more active.

Please note: If your health changes so that you can then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

Name_____   Date_____

Signature_____   Witness_____

Appendix D

RFWT Prediction Equation

Appendix D

RFWT Prediction Equation

Kline, Porcari, Hintermeister, et al. (1987) Age-

Generalized Female Equation:

$$\dot{V}O_{2max}\,(mL\cdot kg\cdot min^{-1}) = 116.579 - (0.3855\cdot age) - (0.0585\cdot weight)$$
$$- (2.7961\cdot time) - (0.1109\cdot HR),$$

where time (minutes and seconds), HR (at the end of the

walk), age (years), and weight (pounds).

Appendix E

Oral Script Explaining the Walk Tests

Appendix E

Oral Script Explaining the Walk Tests

For each walk test, you will need to select a brisk pace and maintain that pace throughout each walk. It is extremely important that you select a pace that will significantly increase your heart rate. Your test will be considered invalid and can not be used for analysis purposes if this criterion is not met. Remember, a brisk pace is required and should remain constant until the completion of the walk.

Appendix F

Institutional Review Board Approval

Elementary and Special Education Department   ◢◣◥◤TSU

P.O. Box 69
Middle Tennessee State University
Murfreesboro, Tennessee 37132
(615) 898-2680

To: Freddie McConnell

From: Nancy Bertrand, Chair *Nancy Bertrand*
            MTSU Institutional Review Board

Re: "Validation of Modifications to the Rockport Fitness Walking
            Test"
            Protocol # 01-062

Date: November 1, 2000

The above named human subjects research proposal has been reviewed and approved. This approval is for one year only. Should the project extend beyond one year or should you desire to change the research protocol in any way, you must submit a memo describing the proposed changes or reasons for extensions to your college's IRB representative for review.

Best of luck in the successful completion of your research.

cc: Dr. Doug Winborn

References

American College of Sports Medicine. (1995). ACSM's guidelines for exercise testing and prescription (5th ed.). Baltimore: Williams & Wilkins.

American College of Sports Medicine. (2000). ACSM's guidelines for exercise testing and prescription (6th ed.). Philadelphia: Lippincott, Williams & Wilkins.

Balke, B. (1963). A simple field test for the assessment of physical fitness. Civil Aeromedical Research Institute Report, 63(6), 1-8.

Blair, S. N., Kohl, III, H. W., Barlow, C. E., Paffenbarger, R. S., Gibbons, L. W., & Macera, C. A. (1995). Changes in physical fitness and all-cause mortality: A prospective study of healthy and unhealthy men. The Journal of the American Medical Association, 273(14), 1093-1098.

Blair, S. N., Kampert, J. B., Kohl, III, H. W., Barlow, C. E., Macera, C. A., Paffenbarger, Jr., R. S., & Gibbons, L. W. (1996). Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. The Journal of the American Medical Association, 276(3), 205-210.

Bowers, R. W. & Fox, E. L. (1988). Sports physiology (3rd ed.). Dubuque, IA: William C. Brown.

Bruce, R. A., Kusumi, F., & Hosmer, D. (1973). Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. American Heart Journal, 85(4), 545-562.

Canadian Society for Exercise Physiology, Inc. (1994). Physical activity readiness questionnaire.

Coleman, R. J., Wilkie, S., Viscio, L., O'Hanley, S., Porcari, J., Kline, G., Keller, B., Hsieh, S., Freedson, P. S., & Rippe, J. (1987). Validation of 1-mile walk test for estimating $\dot{V}O_{2max}$ in 20-29 year olds. Medicine and Science in Sports and Exercise, 19, S29. (Abstract No. 171).

Cooper, K. H. (1968). A means of assessing maximal oxygen uptake. Journal of the American Medical Association, 203(3), 135-138.

Cooper, K. H. (1970). The new aerobics. New York: Bantam.

Dolgener, F. A., Hensley, L. D., Marsh, J. J., & Fjelstul, J. K. (1994). Validation of the Rockport Fitness Walking Test in college males and females. Research Quarterly for Exercise and Sport, 65(2), 152-188.

Fenstermaker, K. L., Plowman, S. A., & Looney, M. A. (1992). Validation of the Rockport Fitness Walking Test in females 65 years and older. Research Quarterly for Exercise and Sport, 63(3), 322-327.

George, J. D., Vehrs, P. R., Allsen, P. E., Fellingham, G. W., & Fisher, A. G. (1993). Development of a submaximal treadmill jogging test for fit college-aged individuals. Medicine and Science in Sports and Exercise, 25(5), 643-647.

George, J. D., Fellingham, G. W., & Fisher, A. G. (1998). A modified version of the Rockport Fitness Walking Test for college men and women. Research Quarterly for Exercise and Sport, 69(2), 205-209.

Golding, L. A., Meyers, C. R., & Sinning, W. E. (1989). The Y's way to physical fitness. Rosemont, IL: YMCA of America.

Kline, G., Porcari, J., Freedson, P., Ward, A., Ross, J., Wilkie, S., & Rippe, J. (1987). Does aerobic capacity affect the validity of the 1-mile walk $\dot{V}O_{2max}$ prediction? Medicine and Science in Sports and Exercise, 19, (Suppl. 29). (Abstract No. 172).

Kline, G. M., Porcari, J. P., Hintermeister, R., Freedson, P. S., Ward, A., McCarron, R. F., Ross, J., & Rippe, J. M. (1987). Estimation of $\dot{V}O_{2max}$ from a 1-mile track walk, gender, age, and body weight. Medicine and Science in Sports and Exercise, 19(3), 253-259.

Lohman, T. G. (1981). Skinfold and body density and their relationship to body fat: A review. Human Biology, 53, 181-225.

McArdle, W. D., Katch, F. I., & Katch, V. L. (1996). Exercise physiology: Energy, nutrition, and human performance (4th ed.). Baltimore: Williams & Wilkins.

McArdle, W. D., Katch, F. I., Pechar, G. S., Jacobson, L., & Ruck, S. (1972). Reliability and interrelationship between maximal oxygen uptake, physical work capacity and step-test scores in college women. Medicine and Science in Sports, 4, 182-186.

McKenzie, J. F. & Pinger, R. R. (1995). An introduction to community health. New York: HarperCollins College Publishers.

Nieman, D. C. (1995). Fitness and sports medicine: A health-related approach (3rd ed.). Palo Alto, CA: Bull Publishing Co.

O'Hanley, S., Ward, A., Zwiren, L., McCarron, R., Ross, J., & Rippe, J. M. (1987). Validation of a 1-mile walk test in 70-79 year olds. Medicine and Science in Sports and Exercise, 19, S28. (Abstract No. 167).

Robergs, R. A., & Roberts, S. O. (1997). Exercise physiology: Exercise, performance, and clinical applications. St. Louis: Mosby.

Siconolfi, S. F., Garber, C. E., Laster, T. M., & Carleton, R. A. (1985). A simple, valid step test for estimating maximal oxygen uptake in epidemiologic studies. American Journal of Epidemiology, 121, 382-390.

Ward, A., Ebbeling, C. B., & Ahlquist, L. E. Indirect methods for estimation of aerobic power. In P. J. Maud & C. Foster (Eds.), Physiological assessment of human fitness (pp. 37-56). Champaign, IL: Human Kinetics.

Zwiren, L. D., Freedson, P. S., Ward, A., Wilke, S., & Rippe, J. M. (1991). Estimation of $\dot{V}O_{2max}$: A comparative analysis of five exercise tests. Research Quarterly for Exercise and Sport, 62(1), 73-78.