Development of Walk Tests to Estimate

Aerobic Fitness in 10 to 13 Year-Old Children

by

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Aerobic fitness is an important indicator of health for children. Estimation of aerobic fitness (VO_{2max}) from field-based tests is an essential aspect of youth fitness tests. Field tests can also provide researchers with more practical ways to examine status or track changes in aerobic fitness than laboratory-based tests. Most fitness tests require a maximal effort from participants. Submaximal walk tests may provide accurate estimates of aerobic fitness and be appropriate for overweight, unfit, or unmotivated children. The accuracy of walk tests to estimate VO_{2max} in young children is not known. **Purpose:** The purpose of this study was to develop and examine the reliability and validity of quarter-mile, half-mile, and one-mile walk tests for 10-13 year old children. A secondary purpose was to cross-validate previously published walk test equations. **Methods:** Participants (N = 61) walked one-mile twice on different days with at least 7 days between sessions. Walk times and heart rates were recorded at one-quarter mile, one-half mile, and one-mile distances. Physical activity questionnaires, height, body mass, skinfolds, BODPOD, and maximal treadmill tests were administered. VO_{2max} was directly measured during the treadmill test. Multiple regression was used to develop models to estimate aerobic fitness with and without body mass and self-reported physical activity as predictors. The PRESS-related statistic was used to cross-validate the models. **Results:** Quarter-mile walk models were slightly more accurate than half-mile or one-mile walk tests. Eight quarter-mile regression models, which can be used for a variety of purposes, were developed. Results showed that heart rate did not add significantly to the prediction of VO_{2max} when body mass was in the model. Removal of heart rate from the model makes test administration substantially more practical because the test user would not have to assess heart rate. Self-reported physical activity added significantly to the prediction of VO_{2max}. The recommended model was: VO_{2max} = 64.481 – (0.143 * body mass [lb]) + (3.930 * Gender [F=0, M=1]) – (3.835 * Quarter-mile Walk Time [min]) + (1.363 * 30-Day Physical Activity Recall), R = .92, standard error of estimate (*SEE)* = 4.22 $ml \cdot kg^{-1} \cdot min^{-1}$. The accuracy of the equation was confirmed when cross-validated. Walk times (R_{xx} ~ .90), heart rates (R_{xx} ~ .82), and estimated VO_{2max} values (R_{xx} ~ .98) were highly reliable over the two test sessions. Cross-validation of previously published walk test equations demonstrated lower correlations with measured VO_{2max} and higher *SEEs* than the walk tests developed in the present study. **Conclusion:** The quarter-mile walk tests developed in the present study provide valid estimates of VO_{2max} in young children. The quarter-mile walk tests should be useful for educators and researchers who would like to estimate aerobic fitness from a submaximal field test, particularly in overweight, unfit, or unmotivated young children.

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Introduction

Aerobic fitness is an important component of children's health. As an accurate indicator of aerobic fitness, VO_{2max} is defined as the maximal amount of oxygen consumed during maximal exercise. The direct measurement of VO_{2max} is considered the most accurate method of assessing an individual's aerobic fitness, and this measurement is used in clinical and research settings for diagnostic purposes and for examining the effectiveness of endurance training programs for healthy individuals and individuals involved in clinical exercise programs (Kline, Porcari, Hintermeister et al., 1987; Pober, Freedson, Kline, McInnis, & Rippe, 2002). The direct measurement of VO_{2max}, however, has several limitations in its practical application. It requires expensive laboratory equipment, dedicated laboratory space, trained technicians, and much time, which makes it less useful for testing large numbers of people or school children (Kline, Porcari, Hintermeister et al., 1987; McSwegin, Plowman, Wolff, & Guttenberg, 1998; Pober et al., 2002). In addition, participants must provide maximal exertion during direct assessment for accurate and meaningful results (McSwegin et al., 1998). To avoid these limitations, several field-based submaximal tests have been developed to estimate aerobic fitness.

The FITNESSGRAM® has been selected as the youth fitness test for the Presidential Youth Fitness Program. The FITNESSGRAM® aerobic fitness assessments include the Progressive Aerobic Cardiovascular Endurance Run (PACER), one-mile run/walk, and walk test (Meredith & Welk, 2010). During the PACER or any of the maximal effort distance run tests, it may be difficult to elicit maximal exertion from unmotivated young children or from obese, overweight, and unfit children. Therefore, a walk test that does not require a maximal effort may be a practical and appropriate aerobic fitness test for unmotivated or overweight youth.

However, few studies have examined the walk test for young children, especially for children under 14 years of age. Kline, Porcari, Hintermeister et al. (1987) developed regression equations for the one-mile walk test, referred to as Rockport Fitness Walking Test (RFWT), for male and female participants aged 30-69 years. The Kline, Porcari, Hintermeister et al. equations were shown to overestimate measured VO_{2max} in college-age participants (Dolgener, Hensley, Marsh, & Fjelstul, 1994). Several studies (Greenhalgh, George, & Hager, 2001; McSwegin et al., 1998; Weiglein, 2011) supported the accuracy of the Kline, Porcari, Hintermeister et al. equations with high school students and highly fit adult participants. The equations developed by Dolgener et al. (1994) were demonstrated to be more accurate for young and lower fit participants than the Kline, Porcari, Hintermeister et al. equations (George, Fellingham, & Garth, 1998). Walk test regression equations to estimate aerobic fitness developed to date have been validated or cross-validated on participants aged 14 years and older. A review of the literature found no published studies focusing on either validation or development of walking equations for children 13 years and younger. In addition, few studies have examined walk tests for either validity or reliability of distances shorter than one-mile (Greenhalgh et al., 2001), and none in children younger than 14 years of age.

Purpose Statement

The primary purpose of this study was to develop and examine the validity and reliability of one-mile, half-mile, and quarter-mile walk test regression equations to predict aerobic fitness in children aged 10-13 years. A secondary purpose was to cross-validate previously published one-mile walk equations.

Research Hypothesis

For the primary purpose, one-mile, half-mile, and quarter-mile walk test regression equations are hypothesized to show evidence of acceptable validity and reliability. For the secondary purpose, the equations developed in this study are hypothesized to be more accurate in predicting VO_{2max} of the 10-13 year old children than previously published equations. The equations developed in this study will offer valuable and useful walk tests to predict aerobic fitness in young children.

Definition of Terms

For the purposes of this study, the following terms were defined as follows:

Aerobic Fitness – Aerobic fitness is defined as the maximal capacity to take in, transport, and utilize oxygen. It indicates the functional capacity of the respiratory system, the circulatory system, and the muscles (Sharkey, 1997).

Rockport Fitness Walking Test – The Rockport Fitness Walking Test is a field-based submaximal aerobic fitness test to estimate VO_{2max} using a one-mile walk protocol (Dolgener et al., 1994).

VO_{2max} – VO_{2max} is the maximum amount of oxygen the body can use during a specified period of intense exercise, which depends on body mass and the strength of the lungs. VO_{2max} will be measured using the COSMED $K4b^2$ portable metabolic system. VO_{2max} is the product of the maximal cardiac output and arterial-venous oxygen difference (American College of Sports Medicine, 2013).

Delimitations

The study was delimited by the following factors:

1. Participants aged 10-13 years children were evaluated.

2. VO_{2max} was measured with the COSMED $K4b^2$ portable metabolic system during specific maximal treadmill protocols.

3. The distances of walk tests examined included one-mile, half-mile, and quarter-mile.

4. The one-mile walk was conducted indoors on a track in which 7 laps and 170 feet was equivalent to one-mile.

5. Percent body fat was estimated from skinfolds with Slaughter et al. (1988) equations and from BODPOD air-displacement plethysmography body density measurement with the Lohman (1986) equation.

6. Physical activity was estimated from the 30-Day Physical Activity Recall (30-Day PAR), Youth Risk Behavior Survey (YRBS), Physical Activity Readiness Questionnaire (PAR-Q), and Physical Activity Questionnaire for Older Children (PAQ-C).

Limitations

The study includes the following limitations:

1. Results are generalizable only to similarly aged and similar aerobic fitness status participants.

2. Representativeness of participants cannot be guaranteed.

3. Maximal effort of the participants on the treadmill test is important for a valid criterion measure of VO_{2max}.

4. Participant's honesty to answer the questions of physical activity questionnaire is important for accurate estimates of physical activity.

Significance of the Study

No data are available for walk tests on participants younger than 14 years of age. The present study, which attempted to develop and validate shorter distance walk tests, is especially important because some unfit, obese, and overweight children may not be able to run a mile due to health concerns, cannot run or walk a mile due to their low fitness, or would not want to run or walk a mile due to low motivation. During the current obesity epidemic, the prevalence of obesity has increased in children and adolescents. Among children aged 6-11 years, the obesity rate increased from 6.5% to 19.6% between 1976-1980 and 2007-2008, and among children aged 12-19 years, the obesity rate increased from 5.0% to 18.1% during the same period (Ogden & Carroll, 2010). Thus, the equations developed in this study may be appropriate to estimate aerobic fitness in a large number of children.

Review of Literature

Aerobic fitness is an important component of children’s health. Direct measurement of aerobic fitness has many limitations in its application; thus, accurate and reliable field-based aerobic fitness tests are necessary to estimate aerobic fitness in children. One of the recommended tests to estimate aerobic fitness in youth is the one-mile walk test. The purpose of this chapter is to review literature on the validity and reliability of laboratory-based submaximal and field-based aerobic fitness tests. This chapter is divided into six sections: (a) aerobic fitness; (b) laboratory-based submaximal aerobic fitness tests; (c) field-based aerobic fitness tests; (d) one-mile walk test; (e) short distance walk test; and (f) summary.

Aerobic Fitness

Aerobic fitness is the ability of the heart, lungs, and blood vessels to supply oxygen to the working muscles and the ability of the muscles to use the available oxygen to continue work or exercise (Baumgartner et al., 2006). In addition, the American College of Sports Medicine (ACSM) stated that “aerobic fitness is related to the ability to perform large muscle, dynamic, moderate-to-vigorous intensity exercise for prolonged periods of time” (American College of Sports Medicine, 2013, p. 72). Aerobic fitness reflects the maximal oxygen consumption, known as VO_{2max}, during maximal exercise, and VO_{2max} is generally expressed as milliliters of oxygen per kilogram of body mass per minute ($ml \cdot kg^{-1} \cdot min^{-1}$) (McArdle, Katch, & Katch, 2010). VO_{2max} can be determined by measuring expired gas during maximal exercise using open-circuit spirometry (Baumgartner et al., 2006; McArdle et al., 2010). Gas and expired air volume are measured for analysis of oxygen and carbon dioxide content through valves attached to a mask, and those analyzed values go into computerized systems to determine oxygen consumption (McArdle et al., 2010).

Several studies examined the relationship between aerobic fitness and health. Low aerobic fitness is a significant precursor of mortality for both males and females (Blair, Clark, Cureton, & Powell, 1989; Blair et al., 1996). Aerobic fitness is an important fitness factor for children as well. Aerobic fitness in children is negatively associated with abdominal adiposity (Castro-Pinero, Mora, Gonzalez-Montesinos, Sjostrom, & Ruiz, 2009; Gutin, Yin, Humphries, & Barbeau, 2005; Ortega et al., 2007; Ortega, Ruiz, Castillo, & Sjostrom, 2008; Ruiz et al., 2006), insulin resistance (Castro-Pinero et al., 2009; Gutin et al., 2004; Ruiz, Rizzo et al., 2007), body fatness (Ruiz, Rizzo et al., 2007), blood pressure (Castro-Pinero et al., 2009; Ruiz, Ortega, Loit, Veidebaum, & Sjostrom, 2007), and clustering of metabolic risk factors (Castro-Pinero et al., 2009; Rizzo, Ruiz, Hurtig-Wennlof, Ortega, & Sjostrom, 2007; Ruiz, Ortega, Rizzo et al., 2007). Low aerobic fitness in children is also related to cardiovascular disease risk factors (Carnethon et al., 2003; Eisenmann, Wickel, Welk, & Blair, 2005) later in life. Thus, aerobic fitness should be considered as a critical fitness factor not only for children's present, but also for their future health (Blair et al., 1989; Dennison, Straus, Mellits, & Charney, 1988; Rikli, Petray, & Baumgartner, 1992). Accordingly, accurate aerobic fitness assessment is important for children to diagnose their health status accurately, so that appropriate and accurate exercise intensity and volume can be prescribed. Once an estimate of aerobic fitness is known, the result can be evaluated by standards such as the Healthy Fitness Zone used in FITNESSGRAM® youth fitness test, which provide criterion-referenced standards which were developed relative to a clustering of cardiovascular risk factors (Adegboye et al., 2011; The Cooper Institute, 2010).

Age and gender specific percentiles of aerobic fitness for U.S. children aged 12-18 years were analyzed from NHANES data (1999-2002) (Eisenmann, Laurson, & Welk, 2011). In boys, there is a slight increase and then a leveling off in estimated VO_{2max} ($ml\cdot kg^{-1}\cdot min^{-1}$) across 12 to 15 years (42 to 46 $ml\cdot kg^{-1}\cdot min^{-1}$ for 50^{th} percentile) (Eisenmann et al., 2011). In girls, on the other hand, there is a slight decrease in estimated VO_{2max} ($ml\cdot kg^{-1}\cdot min^{-1}$) from 12 to 18 years old (39 to 37 $ml\cdot kg^{-1}\cdot min^{-1}$ for 50^{th} percentile) (Eisenmann et al., 2011). At every age, boys have higher aerobic fitness values than girls (Eisenmann et al., 2011).

Laboratory-based Submaximal Aerobic Fitness Tests

Maximal exercise tests are usually administered on treadmills or cycle ergometers with diverse protocols. However, a maximal test is time-consuming and requires the participant to exercise to exhaustion, which requires a high level of motivation from the participant (Baumgartner et al., 2006). An alternative to measuring VO_{2max} is to estimate VO_{2max} with laboratory-based submaximal tests on treadmills or cycle ergometers. These tests are based on the principle of a linear relationship between heart rate and oxygen consumption from aerobic exercise. In addition, it is assumed that VO_{2max} is reached at maximal heart rate. A less fit person will have a higher heart rate at any submaximal exercise intensity than someone who is more aerobically fit (Baumgartner et al., 2006). VO_{2max} is usually estimated from regression equations that include variables such as heart rate, age, gender, and body mass.

McArdle, Katch, Pechar, Jacobson, and Ruck (1972) developed the Queens College 3-min step test regression equation to estimate VO_{2max} in college women aged 18-22 years. The participants stepped up and down on bleacher steps for 3-min following the cadence of 88 beats per min. The predictor variable was the recovery heart rate between 5 sec and 15 sec after the test. The reliability of the recovery heart rate from step tests was $R = .92$. The multiple R and standard error of estimate (*SEE)* of the equation were $R = .75$ and $SEE = 2.90$ $ml \cdot kg^{-1} \cdot min^{-1}$. Jette, Campbell, Mongeon, and Routhier (1976) developed the Canadian Home Fitness Step Test to estimate VO_{2max} on participants aged 15-74 years. The participants stepped up and down on double 20 cm steps following a six count step rhythm so that one count was made at each step, then the tempo of the rhythm increased. This test consisted of seven and six stages for males and females, respectively. Two stages were administered depending on the participants' age. The predictor variables were submaximal VO_2 ($L \cdot min^{-1}$)

which is average oxygen cost of the second step test stage, body mass, post-exercise heart rate, and age. The standard error of measurement (SE_M) and the multiple R of the equation were SE_M = 4.08 ml·kg^{-1}·min^{-1} and R = .91. Jacks, Topp, and Moore (2011) developed a step test regression equation to estimate VO_{2max} in children aged 8-12 years using the YMCA submaximal bench stepping protocol. The participants stepped up and down on a 12 inch bench following a cadence of 24 rises per minute. The predictor variables were height, resting heart rate, and heart rate response during the submaximal bench stepping test. VO_2 was expressed in absolute terms (L·min^{-1}). The coefficient of determination (R^2) was R^2 = .71, indicating that 71% of the variability in actual VO_{2max} can be explained by the predictors in the regression equation.

Cycle ergometers are one of the laboratory-based submaximal test protocols. Siconolfi, Cullinane, Carleton, and Thompson (1982) developed a cycle ergometer test to estimate VO_{2max} (L·min^{-1}) of participants aged 20-70 years using a modified Astrand-Ryhming protocol. The predictor variables were VO_2 estimated by the Astrand-Ryhming nomogram (Astrand & Ryhming, 1954) using the average of the last two steady-state heart rates, the final exercise rate, and age. The multiple R and SEE of developed equations were R = .86 and SEE = 0.36 L·min^{-1} for males, and R = .97 and SEE = 0.20 L·min^{-1} for females of validation group (n = 50). The equations were cross-validated on the cross-validation group (n = 63). The correlation (r) and SEE between measured and estimated VO_{2max} from two equations were r = .94 and SEE = 0.25 L·min^{-1}. Greiwe, Kaminsky, Whaley, and Dwyer (1995) examined the reliability and validity of VO_{2max} estimated from the ACSM submaximal cycle ergometer equation on participants aged 21-54 years. The correlation coefficient of estimated VO_{2max} from two test trials and SE_M were r = .86 and SE_M = 0.40 L·min^{-1}. The multiple R and SEE from the first test were R = .79 and SEE = 0.49 L·min^{-1}. The authors concluded that the ACSM protocol failed to provide reliable estimates of VO_{2max} and tended to overestimate actual VO_{2max} on the participants.

Since cycling and stepping are not an activity as common as walking or running, submaximal treadmill walking or running tests may be more appropriate for many participants, especially for children, who are not accustomed to cycling or stepping. According to a survey of 1,400 U.S. exercise testing facilities conducted about 30 years ago, 71% used treadmill protocols, whereas only 17% used cycle ergometers for estimating aerobic fitness (Stuart & Ellestad, 1980; Swank et al., 2001). Treadmill test protocols are slightly different from each other in terms of grade or rate of increase in speed. Kline, Porcari, Hintermeister et al. (1987) discussed several studies (Bonen, Heyward, Cureton, Boileau, & Massey, 1979; Hermiston & Faulkner, 1971; Metz & Alexander, 1971) of submaximal treadmill tests on people aged 7-45 years, but tests required measures of expired gas samples to estimate VO_{2max} and were claimed to have limitations to be used in non-laboratory settings (Swank et al., 2001).

Baumgartner et al. (2006) presented two studies (DiNallo, Jackson, & Mahar, 2000; Ebbeling, Ward, Puleo, Widrick, & Rippe, 1991) that developed treadmill tests to estimate aerobic fitness. Ebbeling et al. (1991) developed single stage 4-minute treadmill walking test regression equations on participants aged 20-59 years. The predictor variables were speed, submaximal heart rate, age, and gender. The range of R^2 and *SEE* of VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) equations were from R^2 = .83 to .87 and from *SEE* = 4.72 to 5.25 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. DiNallo et al. (2000) developed single-stage treadmill walking test regression equations on men aged 17-70 years and women aged 21-66 years. The predictor variables were age, percent body fat or body mass index (BMI), self-reported physical activity, and submaximal VO_2 estimated from ACSM models. The range of multiple R and *SEE* of VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) equations were from R = .84 to .87 and from *SEE* = 4.0 to 4.4 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. Swank et al. (2001) developed regression equations using a treadmill protocol which was modified from the Town and Golding (1977) version on men (aged 30.0 ± 1.8 years) and women (aged 31.3 ± 1.6 years), and examined the validity of the test. The predictor variables were percentage of age-predicted maximum heart rate achieved at stage three, age-predicted maximum heart rate, speed, and grade. The R^2 and *SEE* of the equation from all participants were $R^2 = .89$ and $SEE = 4.56$ ml·kg^{-1}·min^{-1}. Nemeth et al. (2009) developed regression equation to estimate aerobic fitness using a submaximal treadmill protocol on 113 overweight children aged 11-14 years. The predictor variables were gender, body mass, height, heart rate after 4 minutes walking on the treadmill (4 min HR), heart rate difference between 4 min HR and resting heart rate, and speed. The R^2 of the equation was $R^2 = .75$.

Though the laboratory-based submaximal aerobic fitness tests reviewed above do not require maximal exertion, they still have several limitations with respect to practical application such as expensive equipment. In the step test, a participant who has balance problems should be carefully monitored, and the validity of step test might be low when participants have excessive fatigue in the limbs (American College of Sports Medicine, 2013). In the cycle test, underestimation of VO_{2max} might be possible when a participant has limiting localized muscle fatigue (American College of Sports Medicine, 2013), and children might feel leg fatigue earlier than adults due to less experience with those activities. Additionally, both treadmill and cycle tests require expensive laboratory equipment, dedicated laboratory space, trained technicians and much time, and therefore are not useful for testing large numbers of people (Kline, Porcari, Hintermeister et al., 1987; McSwegin et al., 1998; Pober et al., 2002). A limited number of studies have examined and validated cycle, step, and submaximal treadmill tests to estimate aerobic fitness for children.

Field-based Aerobic Fitness Tests

Running, jogging, or walking in some field-based aerobic fitness tests are familiar modes of activity to many people. The one-mile run/walk is a common test included in several youth fitness test batteries, such as the FITNESSGRAM®, the Australian Fitness Education Award, and the President's Challenge (Castro-Pinero et al., 2009; Meredith & Welk, 2010; The President's Challenge, n.d.).

Cureton, Sloniger, O'Bannon, Black, and McCormack (1995) developed one-mile run/walk regression equation to estimate VO_{2max} using participants aged 8-25 years in their validation group (n = 495). The predictor variables were run/walk time, run/walk time squared, age × gender interaction, and BMI. The equation had the multiple $R = .74$ and SEE = 4.99 $ml \cdot kg^{-1} \cdot min^{-1}$ on 258 participants in the cross-validation group.

The norm-referenced and criterion-referenced reliability of the one-mile run/walk test was assessed by Rikli et al. (1992) on 1,229 K-4 grade children. Intra-class reliability estimates R of time for one-mile run/walk for test and re-test during the fall season on children in grades 3 and 4 were $R > .84$, but reliability was lower for the younger ages (grades 1 and 2) ($.39 < R < .71$). The younger children were, the lower the reliability tended to be. Rikli et al. reported a proportion of classification agreement (P_a) for criterion-referenced reliability estimates during both the fall and spring seasons in children aged 8-9 years ($.83 < P_a < .94$) and 5-7 years ($.45 < P_a < .85$) using FITNESSGRAM® standards (Cooper Institute for Aerobics Research, 1987).

The criterion-referenced validity of the FITNESSGRAM® standards (Cooper Institute for Aerobics Research, 1987) was examined by Cureton and Warren (1990) on 581 children aged 7-14 years, and 85% of the children were shown to be correctly classified.

The validity of Cureton et al. (1995) equation to estimate VO_{2max} was examined by Castro-Pinero et al. (2009) on 68 healthy and physically active children aged 8-17 years. The correlation between measured and estimated VO_{2max} from the equation was $r = .70$ and SEE = 3.0 $ml \cdot kg^{-1} \cdot min^{-1}$. The validity of Cureton et al. equation in VO_{2max} estimation was also examined by Plowman and Liu (1999) on 94 participants aged 18-30 years. The equation had the multiple *R* = .82 and *SEE* = 4.53 ml·kg^{-1}·min^{-1}. They also reported the criterion-referenced validity coefficient (*C*) of the FITNESSGRAM® standards (Cooper Institute for Aerobics Research, 1992) on the participants. The criterion-referenced validity coefficient was *C* = .97, which means that 97% of the participants were correctly classified, and the Phi coefficient (*Phi*) was *Phi* = .65.

Damitz, Ebbeling, Ward, Freedson, and Rippe (1994) developed a one-mile run/walk equation to estimate aerobic fitness of 131 children aged 6-13 years. The predictor variables were gender, body composition, body mass, and run time. The correlation between run time and measured VO_{2max} was *r* = -.68. The validity of the regression equation was examined as well, adjusted R^2 = .67, and *SEE* = 3.96 ml·kg^{-1}·min^{-1}.

The PACER 20-m multistage shuttle run is the recommended test of aerobic fitness in children for test batteries such as the FITNESSGRAM® (Mahar, Guerieri, Hanna, & Kemble, 2011; Meredith & Welk, 2010), EUROFIT (Council of Europe, 1988; Ruiz et al., 2009), the President's Challenge, and the Australian Fitness Education Award (Ruiz et al., 2009; Russell, Isaac, & Wilson, 1989). This test has several advantages as a field-based maximal aerobic fitness test. First, the test can be administered both indoors and outdoors in a relatively small area with a variety of surfaces, such as grass, wood, and rubber floors (Ruiz et al., 2009). Second, the test excludes pacing problems that most other field tests have, because it resembles a maximal exercise test. The work load increases progressively and running speed is dictated by a prerecorded cadence (Aandstad, Holme, Berntsen, & Anderssen, 2011; Liu, Plowman, & Looney, 1992; Mahar, Welk, Rowe, Crotts, & McIver, 2006).

Several studies developed regression equations to estimate VO_{2max} from the PACER test, and others examined the validity or reliability of the developed equations on diverse participants. Leger, Mercier, Gadoury, and Lambert (1988) developed regression equation to estimate VO_{2max} on 188 participants aged 8-19 years. The predictor variables were age and speed. They reported a correlation between measured and estimated VO_{2max} of $r = .71$ and $SEE = 5.90$ ml·kg^{-1}·min^{-1}. The reliability of VO_{2max} estimated from the PACER for children was ($R = .89$).

Mahar et al. (2006) developed PACER regression equations to estimate VO_{2max} of 135 children aged 12-14 years. Predictor variables were PACER laps, gender, and body mass or BMI. The BMI model had the multiple $R = .65$ and $SEE = 6.35$ ml·kg^{-1}·min^{-1}. The body mass model had the multiple $R = .65$ and $SEE = 6.38$ ml·kg^{-1}·min^{-1}. Additionally, Mahar et al. (2006) cross-validated the Leger et al. (1988) equation. They reported a correlation of $r = .54$ between measured and estimated VO_{2max}, and $SEE = 6.67$ ml·kg^{-1}·min^{-1}.

Ruiz et al. (2008) developed PACER regression equations to estimate VO_{2max} on 193 adolescents aged 13-19 years. The predictor variables were gender, age, body mass, height, and last stage number completed. They reported a correlation between measured and estimated VO_{2max} of $r = .96$ and a SEE of 2.84 ml·kg^{-1}·min^{-1} on the total sample.

Mahar et al. (2011) developed regression equations to estimate VO_{2max} of 244 children aged 10-16 years. The predictor variables were PACER laps, PACER laps squared, gender, BMI, age, and the gender by age interaction. These equations had values for multiple R that ranged from .66 to .73, and *SEEs* that ranged from 6.39 to 6.99 ml·kg^{-1}·min^{-1} on the total sample.

Liu et al. (1992) cross-validated the Leger et al. (1988) equation on 62 students aged 12-15 years. They reported a correlation of $r = .72$ between measured and estimated VO_{2max}, and $SEE = 5.27$ ml·kg^{-1}·min^{-1}. They also reported an intra-class reliability coefficient (*ICC*) of $R = .93$ for number of laps completed.

Ruiz et al. (2009) cross-validated several PACER equations developed by Leger et al. (1988), Barnett, Chan, and Bruce (1993), Matsuzaka et al. (2004), and Ruiz et al. (2008) on

48 children aged 13-19 years. They reported correlation coefficients of $r = .59$ (Leger et al.), $r = .76$ (Barnett et al.), $r = .74$ (Matsuzaka et al.), and $r = .76$ (Ruiz et al.) between estimated and measured VO_{2max}. They also reported *SEEs* of 6.50 (Leger et al.), 5.30 (Barnett et al.), 5.50 (Matsuzaka et al.), and 5.30 $ml \cdot kg^{-1} \cdot min^{-1}$ (Ruiz et al.).

Mahar et al. (1997) examined criterion-referenced test-retest reliability of the PACER using FITNESSGRAM® standards (Cooper Institute for Aerobics Research, 1992) on 241 students aged 10-11 years. They reported $Pa = .89$ and a modified kappa (Kq) of $Kq = .78$ on the total sample.

Though one-mile run/walk and PACER tests generally have evidence of validity and reliability, many unfit or overweight children may not be able to run or jog to estimate VO_{2max} due to health concerns. Particularly for young children, motivating them to run or jog over a one-mile distance may be difficult for researchers, physical education teachers, or physical activity leaders. Not only for less motivated children, but also for unhealthy children, walk tests may be more appropriate than running test, because walking presents a low risk of injury, is less challenging than running, and is the most familiar and usual type of activity.

One-mile Walk Test

Kline, Porcari, Hintermeister et al. (1987) developed a one-mile walk test referred to as the Rockport Fitness Walking Test (RFWT) as an alternative aerobic fitness field test to estimate VO_{2max}. All participants walked one-mile at least two times. If the first two one-mile walk times of any participant were not within 30 sec of each other, another one-mile walk was required until he or she could meet the requirement. Participants were instructed to walk as fast as they can. Testers recorded heart rate every minute. The average of the last two one-minute heart rates at the end of the first one-mile walk test was used to produce regression equations. Equations were developed using variables such as body mass (lb), age, gender (0 = female, 1 = male), time for the first walk test session (min), and heart rate ($b \cdot min^{-1}$) from 82 males and 92 females aged 30 to 69 years. The Kline, Porcari, Hintermeister et al. equation is (R = .88, SEE = 5.0 $ml \cdot kg^{-1} \cdot min^{-1}$):

$VO_{2max}\ (ml \cdot kg^{-1} \cdot min^{-1}) = 132.853 - (0.0769 * \text{body mass in pounds}) - (0.3877 * \text{age}) + (6.3150 * \text{gender [female = 0, male = 1]}) - (3.2649 * \text{time in min}) - (0.1565 * \text{heart rate})$

(1)

Kline, Porcari, Hintermeister et al. (1987) cross-validated this equation on the cross-validation group (n = 169). The correlation between measured and estimated VO_{2max} from *Equation 1* was r = .88 and SEE = 4.40 $ml \cdot kg^{-1} \cdot min^{-1}$.

Dolgener et al. (1994) studied 274 college students (19.4 ± 2.7 years) to validate the RFWT and to develop new equations for college students. They cross-validated the Kline, Porcari, Hintermeister et al. (1987) equations on 196 participants and developed new equations with the same participants. The remaining 78 participants were grouped as a cross-validation group for new equations. The participants were administered the one mile walk test one time. Participants were instructed to walk as rapidly as they could while maintaining a constant pace for a mile. As the participant crossed the one-mile finish line, their heart rate was recorded immediately within 5 seconds. The correlation between measured and estimated VO_{2max} from *Equation 1* was r = .69, SEE = 5.50 $ml \cdot kg^{-1} \cdot min^{-1}$ and Total Error (*TE)* = 13.26 $ml \cdot kg^{-1} \cdot min^{-1}$. Average measured VO_{2max} was 41.2 ± 8.09 $ml \cdot kg^{-1} \cdot min^{-1}$ and average estimated VO_{2max} from *Equation 1* was 49.6 ± 5.84 $ml \cdot kg^{-1} \cdot min^{-1}$. Dolgener et al. suggested that the equation developed by Kline, Porcari, Hintermeister et al. did not provide accurate estimates of measured VO_{2max} in the college-age population. Dolgener et al. then developed a new equation as follows to estimate VO_{2max} in 18-29 year old participants from body mass (lb), age, gender, time to walk one-mile, and heart rate.

Dolgener et al. equation without age (R = .70, SEE = 5.39 $ml \cdot kg^{-1} \cdot min^{-1}$):

$VO_{2max}\ (ml \cdot kg^{-1} \cdot min^{-1}) = 88.7688 - (0.0957 * \text{body mass in pounds}) + (8.8924 * \text{gender}$

*[female = 0, male = 1]) – (1.4537 * time in min) – (0.1194 * heart rate)*

(2)

Equation 2 produced a higher correlation (r = .70, *SEE* = 5.39 ml·kg^{-1}·min^{-1}) than did *Equation 1* (r = .69, *SEE* = 5.50 ml·kg^{-1}·min^{-1}) and was slightly more accurate at estimating VO_{2max} in the college-aged population. The correlation between measured and estimated VO_{2max} from *Equation 2* in the cross-validation group was r = .58, *SEE* = 2.44 ml·kg^{-1}·min^{-1} and *TE* = 4.38 ml·kg^{-1}·min^{-1}.

Supporting the findings of Dolgener et al. (1994), George et al. (1998) demonstrated that the Kline, Porcari, Hintermeister et al. (1987) *Equation 1* overestimated measured VO_{2max} on 85 participants aged 18-29 years. The average measured VO_{2max} was 42.8 ± 6.6 ml·kg^{-1}·min^{-1} and the average estimated VO_{2max} from *Equation 1* was 47.8 ± 5.4 ml·kg^{-1}·min^{-1}. The correlation between measured and estimated VO_{2max} was r = .84 and *SEE* = 3.61 ml·kg^{-1}·min^{-1}. *TE* of *Equation 1* (*TE* = 6.16 ml·kg^{-1}·min^{-1}) on the participants was higher than *SEE* of 3.61 ml·kg^{-1}·min^{-1}, indicating a systematic difference between measured and estimated VO_{2max} from Kline, Porcari, Hintermeister et al. *Equation* 1. On the other hand, Dolgener et al. *Equation 2* slightly underestimated measured VO_{2max}. The average estimated VO_{2max} from *Equation 2* was 41.6 ± 5.2 ml·kg^{-1}·min^{-1}. The correlation between the measured and estimated VO_{2max} was r = .85 and *SEE* = 3.48 ml·kg^{-1}·min^{-1}. *TE* (*TE* = 3.74 ml·kg^{-1}·min^{-1}) was similar to the *SEE* of 3.48 ml·kg^{-1}·min^{-1}, indicating no systematic bias of Dolgener et al. *Equation 2*. In conclusion, Dolgener et al. *Equation 2* was more accurate than Kline, Porcari, Hintermeister et al. *Equation 1* on 18-29 years old participants in the study by George et al. In the study by George et al., participants were instructed to walk at a steady and self-selected brisk pace rather than the fastest walk possible pace used in the RFWT from the previous two studies. Because, participants are generally unaccustomed to the maximal walk pace, they may experience leg muscle soreness during the walk test at that a maximal pace (George et al., 1998).

Two studies (Greenhalgh et al., 2001; McSwegin et al., 1998) supported the appropriateness of the Kline, Porcari, Hintermeister et al. (1987) equation for estimating VO_{2max} in young adults. McSwegin et al. (1998) examined the validity of the walk test equation of Kline, Porcari, Hintermeister et al. and Dolgener et al. (1994) in 44 high school students aged 14-18 years and found a high correlation between measured and estimated VO_{2max} from both Kline, Porcari, Hintermeister et al. *Equation 1* (r = .80) and Dolgener et al. *Equation 2* (r = .84). Dolgener et al. *Equation 2* had a slightly higher correlation and better accuracy for VO_{2max} estimation (*SEE* = 4.50 $ml \cdot kg^{-1} \cdot min^{-1}$) than the estimation from Kline, Porcari, Hintermeister et al. *Equation 1* (*SEE* = 4.99 $ml \cdot kg^{-1} \cdot min^{-1}$), but Dolgener et al. *Equation 2* had a higher *TE* (*TE* = 7.16 $ml \cdot kg^{-1} \cdot min^{-1}$) than Kline, Porcari, Hintermeister et al. *Equation 1* (*TE* = 5.17 $ml \cdot kg^{-1} \cdot min^{-1}$), indicating a systematic difference between measured and estimated VO_{2max} from Dolgener et al. *Equation 2*. The average measured VO_{2max} (45.39 ± 8.26 $ml \cdot kg^{-1} \cdot min^{-1}$) was underestimated by the Dolgener et al. *Equation 2* (39.88 ± 5.87 $ml \cdot kg^{-1} \cdot min^{-1}$), and slightly overestimated by the Kline, Porcari, Hintermeister et al. *Equation 1* (46.91 ± 6.38 $ml \cdot kg^{-1} \cdot min^{-1}$). Thus, although those two equations showed similar correlations between measured and estimated VO_{2max} and similar *SEEs*, the Dolgener et al. *Equation 2* was not recommended because of the higher *TE* and the underestimation compared to Kline, Porcari, Hintermeister et al. *Equation 1*. The reliabilities of VO_{2max} estimation from both Kline, Porcari, Hintermeister et al. and Dolgener et al. equations were also examined using 21 participants who completed the one-mile walk twice. Both *ICCs* of VO_{2max} estimation from Kline, Porcari, Hintermeister et al. *Equation 1* (R = .91) and Dolgener et al. *Equation 2* (R = .97) were high. The average heart rate from the first and second sessions were 152 ± 25.56 $b \cdot min^{-1}$ and 146 ± 22.15 $b \cdot min^{-1}$, respectively. The *ICC* was R = .60. The average walk time from the first and second sessions were 15.03 ± 1.72 minutes and 15.17 ± 2.24 minutes, respectively. The *ICC* was $R = .67$. The criterion-referenced reliability for both equations was 100%, indicating that all participants were consistently classified using FITNESSGRAM® standards (Cooper Institute for Aerobics Research, 1992). The criterion-referenced validity was examined for the Kline, Porcari, Hintermeister et al. *Equation 1*. The percentage of participants correctly classified was 91% and the phi coefficient was *phi* = .76. McSwegin et al. concluded that one-mile walk test with Kline, Porcari, Hintermeister et al. *Equation 1* is recommended as an aerobic fitness field test in 14-18 year old participants.

Greenhalgh et al. (2001) validated the Kline, Porcari, Hintermeister et al. *Equation 1* and Dolgener et al. *Equation 2* in 37 college students aged 18-29 years. They stated two limitations of the one-mile walk test. First, the test requires approximately 12 minutes to complete. Others have noted that it takes only 3 minutes of constant intensity exercise to achieve steady state heart rate (Golding, Meyers, & Sinning, 1989; Greenhalgh et al., 2001), so that shorter tests may be appropriate. Second, the one-mile walk test protocol of Kline, Porcari, Hintermeister et al. (1987) requires people to walk at their maximal walking speed, which may be uncomfortable and difficult to sustain for a mile for obese or unfit people (Greenhalgh et al., 2001). Thus, participants in the Greenhalgh et al. study were instructed to walk using a self-selected fast steady pace walk. They reported a relatively accurate estimation of measured VO_{2max} values from Kline, Porcari, Hintermeister et al. *Equation 1*, with an average residual of -0.36 $ml \cdot kg^{-1} \cdot min^{-1}$ and a correlation of $r = .84$. The average measured VO_{2max} was 48.51 ± 7.35 $ml \cdot kg^{-1} \cdot min^{-1}$ and the average estimated VO_{2max} from the Kline, Porcari, Hintermeister et al. *Equation 1* was 48.15 ± 5.12 $ml \cdot kg^{-1} \cdot min^{-1}$. *TE* for this equation was similar to *SEE* values (*TE* = 4.12 $ml \cdot kg^{-1} \cdot min^{-1}$, *SEE* = 4.03 $ml \cdot kg^{-1} \cdot min^{-1}$), indicating no systematic difference between measured and estimated VO_{2max}. Estimates using the Dolgener et al. *Equation 2,* however, underestimated measured VO_{2max} with a mean residual of -6.83 ml·kg^{-1}·min^{-1} and a correlation of r = .85. The average estimated VO_{2max} from the Dolgener et al. *Equation 2* was 41.68 ± 5.08 ml·kg^{-1}·min^{-1}. *TE* was higher than the *SEE* values (*TE* = 7.93 ml·kg^{-1}·min^{-1}, *SEE* = 3.93 ml·kg^{-1}·min^{-1}), indicating a systematic difference between measured and estimated VO_{2max}. Thus, the Kline, Porcari, Hintermeister et al. *Equation 1* provided a more accurate estimate of aerobic fitness of the participants aged 18-29 years in this study than Dolgener et al. *Equation 2*.

Ward et al. (1987) compared measured VO_{2max} to estimated VO_{2max} from five tests: Astrand-Ryhming cycle ergometer test, YMCA cycle ergometer test, 1.5 mile run, one-mile walk, and Queen's College step test on 17 overweight females (aged 30 ± 5 years). The average measured and estimated VO_{2max} from Kline, Porcari, Hintermeister et al. *Equation 1* were 32.2 ± 4.9 ml·kg^{-1}·min^{-1} and 36.1 ± 4.9 ml·kg^{-1}·min^{-1}, respectively. The correlation between measured and estimated VO_{2max} was r = .78 and *SEE* = 3.2 ml·kg^{-1}·min^{-1}. Ward et al. concluded that the Kline, Porcari, Hintermeister et al. *Equation 1* overestimated measured VO_{2max} by 12%, but the one-mile walk test would be an appropriate test for overweight people compared to other tests.

Coleman et al. (1987) examined the validity of the Kline, Porcari, Hintermeister et al. *Equation 1* to estimate VO_{2max} on 90 young adults aged 20-29 years. The average measured and estimated VO_{2max} from the Kline, Porcari, Hintermeister et al. *Equation 1* were 49.4 ± 5.3 ml·kg^{-1}·min^{-1} and 49.5 ± 5.3 ml·kg^{-1}·min^{-1}, respectively. The correlation between measured and estimated VO_{2max} was r = .79 and *SEE* = 5.68 ml·kg^{-1}·min^{-1}. Coleman et al. concluded that there was no significant difference between measured and estimated VO_{2max} from the Kline, Porcari, Hintermeister et al. *Equation 1*.

Kline, Porcari, Freedson et al. (1987) categorized the participants from the Kline, Porcari, Hintermeister et al. (1987) study into low, mid, high, and the highest VO_{2max} groups. Then they studied whether the aerobic fitness affected the validity of the one-mile walk test equation or not. The correlations between measured and estimated VO_{2max} from Kline, Porcari, Hintermeister et al. *Equation 1* among groups were r = .77, .81, .88, and .71 in order from the low to the highest VO_{2max} group. The *SEEs* were 5.06, 3.78, 2.97, and 3.24 $ml \cdot kg^{-1} \cdot min^{-1}$ in order from the low to the highest VO_{2max} group. Thus, Kline, Porcari, Freedson et al. concluded that the Kline, Porcari, Hintermeister et al. *Equation 1* overestimated VO_{2max} of the low and mid groups by 6.0% and 3.4%, respectively, and underestimated that of the high and the highest groups by 8.0% and 6.5%, respectively.

Zwiren, Freedson, Ward, Wilke, and Rippe (1991) examined the validity of the Kline, Porcari, Hintermeister et al. *Equation 1* on 38 females aged 30-39 years. The average measured and estimated VO_{2max} from the Kline, Porcari, Hintermeister et al. *Equation 1* were 41.3 ± 6.6 $ml \cdot kg^{-1} \cdot min^{-1}$ and 42.8 ± 3.9 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. The correlation between measured and estimated VO_{2max} was $r = .73$ and $SEE = 4.57$ $ml \cdot kg^{-1} \cdot min^{-1}$. Zwiren et al. concluded that the estimated VO_{2max} from the Kline, Porcari, Hintermeister et al. *Equation 1* was not significantly different from the measured VO_{2max}.

Fenstermaker, Plowman, and Looney (1992) examined reliability and validity of Kline, Porcari, Hintermeister et al. *Equation 1* on 16 female older adults aged over 65 years. Three walk tests were administered and reliability was examined. The test-retest *ICC* for all three VO_{2max} estimations from the Kline, Porcari, Hintermeister et al. *Equation 1* was $R = .71$, but $R = .97$ when only the last two trial estimations were analyzed. First walk and last walk trials were used for analyzing validity coefficients, the correlation between measured and estimated VO_{2max} from the first walk using Kline, Porcari, Hintermeister et al. *Equation 1* was $r = .59$, and *TE* was higher than *SEE* ($TE = 12.06$ $ml \cdot kg^{-1} \cdot min^{-1}$, $SEE = 2.65$ $ml \cdot kg^{-1} \cdot min^{-1}$). The correlation between measured and estimated VO_{2max} from the last walk using the Kline, Porcari, Hintermeister et al. *Equation 1* was $r = .79$, and *TE* was slightly higher than *SEE* ($TE = 4.74$ $ml \cdot kg^{-1} \cdot min^{-1}$, $SEE = 2.02$ $ml \cdot kg^{-1} \cdot min^{-1}$). The authors stated that a learning effect between first and last walk test occurred.

Dotson, Nieman, and Warren (1992) examined the learning effect on the one-mile walk using one of the Kline, Porcari, Hintermeister et al. (1987) equations with 28 sedentary older adult women (73.5 ± 0.8 years). Participants were divided into two groups to examine the effect of 5 weeks of brisk walking practice: a walking practice group and a control group without walking practice. In the walking practice group, the difference between measured and estimated VO_{2max} from the initial one-mile walk test was much higher (estimated VO_{2max} = 15.4 ± 1.7 $ml·kg^{-1}·min^{-1}$, measured VO_{2max} = 19.0 ± 1.1 $ml·kg^{-1}·min^{-1}$) than the difference from the second one-mile walk test after 5 weeks of brisk walking practice (estimated VO_{2max} = 19.4 ± 1.6 $ml·kg^{-1}·min^{-1}$, measured VO_{2max} = 20.5 ± 1.2 $ml·kg^{-1}·min^{-1}$). However, the control group had almost no change between the first one-mile walk test (estimated VO_{2max} = 15.1 ± 1.5 $ml·kg^{-1}·min^{-1}$, measured VO_{2max} = 18.9 ± 0.7 $ml·kg^{-1}·min^{-1}$) and second one-mile walk test (estimated VO_{2max} = 16.6 ± 1.3 $ml·kg^{-1}·min^{-1}$, measured VO_{2max} = 19.3 ± 0.6 $ml·kg^{-1}·min^{-1}$).

Hageman, Walker, Pullen, and Pellerito (2001) examined test-retest reliability of VO_{2max} estimation using the Kline, Porcari, Hintermeister et al. *Equation 1* on 31 women aged 50-69 years. Estimated VO_{2max} from the equation had a reliability of R = .96. Reliability for one-mile walk time and 15-sec recovery heart rate were R = .97 and R = .69, respectively.

The one-mile walk test was also included as an alternative aerobic fitness test in the Air Force fitness program from 2010 and its validity for Air Force personnel was examined in several studies (Department of the Air Force, 2010). Fontenot (2001) studied the validity of the Dolgener et al. equations on 31 female United States Air Force Academy cadets and officers aged 18-30 years. The average measured VO_{2max} was 41.83 ± 5.65 $ml·kg^{-1}·min^{-1}$ which was similar to that of the participants from the study by Dolgener et al. (1994) (41.2 ± 8.09 $ml·kg^{-1}·min^{-1}$). However, the Dolgener et al. *Equation 2* overestimated the measured

VO_{2max} of the Air Force personnel in the study by 37.8% (estimated VO_{2max} = 57.66 ± 4.95 $ml \cdot kg^{-1} \cdot min^{-1}$). Weiglein (2011) examined validity of one-mile walk test on 24 active duty Air Force males aged 18-44 years. The average measured VO_{2max} was 50.3 ± 1.4 $ml \cdot kg^{-1} \cdot min^{-1}$. Estimated VO_{2max} using the Kline, Porcari, Hintermeister et al. *Equation 1* was 49.2 ± 1.1 $ml \cdot kg^{-1} \cdot min^{-1}$. The correlation between measured and estimated VO_{2max} was high (r = .82). The authors concluded that the one-mile walk test for VO_{2max} estimation using the Kline, Porcari, Hintermeister et al. *Equation 1* provided valid estimates of VO_{2max} in active duty Air Force males.

The maximum-paced walk protocol of the one-mile walk test of Kline, Porcari, Hintermeister et al. (1987) can be replaced by a steady-paced walk protocol to estimate VO_{2max} from either quarter-mile or one-mile results, such as heart rate and time (Byars, Greenwood, Greenwood, & Simpson, 2003; George et al., 1998). In addition, Byars et al. (2003) introduced the theoretical assumption that "regardless of the walking pace, as long as it is consistent, the resulting prediction of VO_{2max} would not be affected as long as the pace is within the linear proportion of the heart rate and VO_2 relationship" (p. 22), which was also stated by Dolgener et al. (1994) and Fontenot (2001). A heart rate of at least 110 $b \cdot min^{-1}$ is recommended before assuming that heart rate and VO_2 are linearly related (Fontenot, 2001; Golding et al., 1989).

Byars et al. (2003) examined the difference in estimated VO_{2max} between a steady-state normal walking technique for "everyday walking style with elbows extended" (p. 22) and a steady-state aerobic walking technique "with the elbows bent at ninety degrees" (p. 22) on 61 college students aged 18-39 years. The order of those two walk tests with different techniques was counterbalanced. All participants were instructed to walk at a self-selected brisk constant pace. Steady-state walking was monitored by heart rate and accepted if two heart rates for the last two laps were within five beats. Estimated VO_{2max} was calculated from the Dolgener et al.

equation with age as a predictor for participants under 30 years and from the Kline, Porcari, Hintermeister et al. equations for those aged ≥ 30 years. The average pre- and post-walk times were 16.16 ± 1.02 minutes and 15.69 ± 1.75 minutes, respectively. The average pre- and post-walk heart rates were 140.79 ± 21.05 and 146.49 ± 22.39 $b \cdot min^{-1}$, respectively. Additionally, the average pre- and post-walk VO_{2max} estimations were 36.89 ± 5.56 and 37.16 ± 5.72 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively, which were not significantly different. The intra-class test-retest reliability of VO_{2max} estimation was $R = .96$. In conclusion, there were no practical VO_{2max} estimation differences between the two different walking techniques (Byars et al., 2003).

Short Distance Walk Test

Although RFWT is a convenient and less physically stressful test in comparison with other field-based aerobic fitness tests such as the one-mile run/walk, the test still has several limitations. Limitations of the RFWT include the requirement of a long time to walk for one-mile and of maximal paced-walking (Greenhalgh et al., 2001). Additionally, it can be difficult to complete a one-mile walk at a maximal pace with obese or overweight children who cannot or should not walk a long distance or for children with low motivation (Greenhalgh et al., 2001).

George et al. (1998) examined the accuracy of VO_{2max} estimation from split quarter-mile walk data using a modified RFWT. In the modified RFWT in their study, a fast steady walking pace was required instead of a maximal walking pace. Additionally, walk time for the quarter-mile was multiplied by four, and then the value was entered into Dolgener et al. *Equation 2* for VO_{2max} estimation. Average walk time for the split quarter-mile was 3.53 ± 0.27 minutes (14.12 ± 1.07 after it was multiplied by 4) and walk time for one-mile was 14.34 ± 1.05 minutes. Average heart rate for the split quarter-mile was 127.4 ± 16.2 $b \cdot min^{-1}$ and for one-mile was 131.5 ± 17.6 $b \cdot min^{-1}$. Average VO_{2max} estimation from the Kline, Porcari, Hintermeister et al. *Equation 1* using split quarter-mile data was 49.2 ± 5.3 ml·kg^{-1}·min^{-1} and using data for one-mile was 47.8 ± 5.4 ml·kg^{-1}·min^{-1}. Lastly, average VO_{2max} estimation from the Dolgener et al. *Equation 2* using split quarter-mile data was 42.4 ± 5.1 ml·kg^{-1}·min^{-1}and that for one-mile was 41.6 ± 5.2 ml·kg^{-1}·min^{-1}. Walk times, heart rates, and VO_{2max} estimations from those two regression equations differed significantly between the split quarter and one-mile data. The correlation between measured and estimated VO_{2max} from the Kline, Porcari, Hintermeister et al. *Equation 1* using split quarter-mile data was r = .81 (r = .84 using one-mile data), *SEE* = 3.94 ml·kg^{-1}·min^{-1} (3.61 ml·kg^{-1}·min^{-1} using one-mile data) and *TE* = 7.5 ml·kg^{-1}·min^{-1} (6.16 ml·kg^{-1}·min^{-1} using one-mile data). The correlation between measured and estimated VO_{2max} from the Dolgener et al. *Equation 2* using split quarter-mile data was r =.83 (r = .85 using one-mile data), *SEE* = 3.67 ml·kg^{-1}·min^{-1} (3.48 ml·kg^{-1}·min^{-1} using one-mile data) and *TE* = 3.73 ml·kg^{-1}·min^{-1} (3.74 ml·kg^{-1}·min^{-1} using one-mile data). From the results above, George et al. stated that the quarter-mile walk test was acceptable if the data from the quarter-mile walk test was entered into the Dolgener et al. *Equation 2*. George et al. pointed out the importance of keeping a steady pace during the walk test and of achieving a steady-state heart rate at least at 110 b·min^{-1} (Golding et al., 1989). George et al. also examined average lap times at each quarter-mile lap, and found the first quarter-mile lap was faster than the rest of three quarter-mile laps though heart rates increased by about 5 b·min^{-1} from the first quarter-mile lap to the last quarter-mile lap. However, VO_{2max} estimations from the Dolgener et al. *Equation 2* using split quarter-mile and one-mile data were not practically different from each other (George et al., 1998).

Greenhalgh et al. (2001) examined the accuracy of VO_{2max} estimations from both the Kline, Porcari, Hintermeister et al. *Equation 1* and the Dolgener et al. *Equation 2*, to which actual quarter-mile walk data were entered instead of split quarter-mile walk data as George et al. (1998) did. Time to actual quarter-mile walk was multiplied by 4 to be entered into the both equations. Average time for the quarter-mile was 3.57 ± 0.25 minutes (14.3 ± 1.1 minutes after it was multiplied by 4) and average time for one-mile was 14.6 ± 1.3 minutes. There was no significant difference between time for actual quarter-mile walk time (3.57 ± 0.25 minutes) and split quarter-mile walk time from the one-mile walk test (3.6 ± 0.31 minutes). Average heart rate for the quarter-mile was 122.3 ± 15.8 $b \cdot min^{-1}$ and average heart rate for the one-mile was 128.5 ± 18.1 $b \cdot min^{-1}$. There was no significant difference between actual quarter-mile walk heart rate (122.3 ± 15.8 $b \cdot min^{-1}$) and quarter-mile heart rate during one-mile walk test (122.3 ± 14.6 $b \cdot min^{-1}$). Average estimated VO_{2max} between quarter-mile data (50.1 ± 4.4 $ml \cdot kg^{-1} \cdot min^{-1}$) and one-mile data (48.2 ± 5.1 $ml \cdot kg^{-1} \cdot min^{-1}$) using the Kline, Porcari, Hintermeister et al. *Equation 1* were significantly different from each other. In addition, average estimated VO_{2max} between quarter-mile data (42.8 ± 4.7 $ml \cdot kg^{-1} \cdot min^{-1}$) and one-mile data (41.7 ± 5.1 $ml \cdot kg^{-1} \cdot min^{-1}$) using the Dolgener et al. *Equation 2* were significantly different from each other as well.

McConnell (2001) examined validity of quarter, half, and one-mile walk tests to estimate measured VO_{2max} using a self-selected brisk steady state walking pace on 32 college females aged 19-26 years. Participants performed the quarter, half, and one-mile walk tests randomly on separate days. Walk times for the quarter and half-mile were multiplied by 4 and 2, respectively, to be entered in the Kline, Porcari, Hintermeister et al. gender-specific equation to estimate VO_{2max}. Average measured VO_{2max} was 37.6 ± 4.8 $ml \cdot kg^{-1} \cdot min^{-1}$. Average estimated VO_{2max} from quarter, half, and one-mile walk tests using the Kline, Porcari, Hintermeister et al. gender-specific equation were 45.0 ± 3.1, 43.7 ± 3.2, and 42.6 ± 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. VO_{2max} estimation from the one-mile walk test (r = .68, *SEE* = 3.58 $ml \cdot kg^{-1} \cdot min^{-1}$), and quarter-mile walk tests (r = .67, *SEE* = 3.59 $ml \cdot kg^{-1} \cdot min^{-1}$) produced the most accurate estimates. The half-mile walk test produced the least accurate estimate (r = .59, *SEE* = 3.92 $ml \cdot kg^{-1} \cdot min^{-1}$). In addition, McConell studied whether the participants maintained a steady pace or not during each test. In the one-mile walk test, the average first quarter-mile walk time (3.5 minutes) was significantly faster than the next two quarter-mile walk times (3.54 and 3.57 minutes, respectively). In the half-mile walk test, average walk times across four segments of a half-mile were significantly different from each other, and the first segment average time (1.68 minutes) was significantly faster than the others. In the quarter-mile walk test, average walk times across four segments of a quarter-mile were significantly different from each other and the first segment average time (0.83 minutes) was significantly faster than the others.

Summary

Greenhalgh et al. (2001) suggested that accuracy in VO_{2max} estimation varied depending on the sample tested. Kline, Porcari, Hintermeister et al. equations were developed across a broad age range (30–69 years) of relatively fit adults. Dolgener et al. (1994) used a younger, less fit sample of young adults with an average age of 19.1 ± 2.8 years. Three groups of researchers (Greenhalgh et al., 2001; McSwegin et al., 1998; Weiglein et al., 2011) supported the accuracy of the Kline, Porcari, Hintermeister et al. equations on younger adolescents and highly fit populations in their studies (average values of measured VO_{2max} were 48.1 ± 7.4 $ml \cdot kg^{-1} \cdot min^{-1}$, 45.4 ± 8.3 $ml \cdot kg^{-1} \cdot min^{-1}$, and 50.3 ± 1.4 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively), while George et al. (1998), whose findings supported the accuracy of the Dolgener et al. equations, used a younger but less fit sample (average measured VO_{2max} = 42.8 ± 6.6 $ml \cdot kg^{-1} \cdot min^{-1}$). The differences in estimated values might lie in the tendency of the Kline, Porcari, Hintermeister et al. equations to estimate VO_{2max} more accurately in young, highly fit populations, and of the Dolgener et al. equations to be more accurate in in young, less fit populations (Greenhalgh et al., 2001). For this reason, Greenhalgh et al. suggested that developed equations should be applied on the populations for which they were developed, as the validity may decrease when a prediction equation is used with a new sample, a tendency called shrinkage (Thomas, Nelson, & Silverman, 2011). Although the Kline, Porcari, Hintermeister et al. equations yielded the most desirable results in some studies, the Dolgener et al. equations provided more accurate estimates of VO_{2max} in a less fit samples. Additionally, different types of distance walk tests should be examined. Moreover, no walk test studies have been conducted on children younger than 14 years of age, so validity and reliability of walk tests for younger children should be examined.

Methods

Participants

Thirty boys and 31 girls (N = 61) aged 10 to 13 years were recruited from the East Carolina University listserve, by flyers sent to after-school programs, the home school organization, pediatricians at East Carolina University, and Pitt County schools, and also by an advertisement in the local newspaper. As monetary incentive, participants received $20 cash or gift card, and a parent of participants received $5 to compensate them for transporting their child to the research site.

The study was approved by the Institutional Review Board of East Carolina University (see Appendix A). Written informed consent was obtained from the participant's parent or guardian and assent was obtained from the participant. Every participant was screened for cardiovascular and orthopedic contraindications to the one-mile walk and maximal treadmill test with the Physical Activity Readiness Questionnaire (see Appendix B) (American College of Sports Medicine, 2013). No participants had contraindications, and none were taking medication which could influence the heart rate response during exercise.

Procedures & Measurements

Summary of Procedures. Testing took place in two sessions. During the first session, informed consent and assent were obtained. In addition, physical activity from self-report questionnaires, resting heart rate, height, body mass, and percent body fat from both skinfolds and BODPOD were assessed. After body composition assessment, participants completed a one-mile walk test. The second one-mile walk test was administered during the second session. At least, one week was required between the first and second sessions. A maximal treadmill test was completed either during the first or second session following adequate rest after the one-mile walk. Self-report questionnaires were administered at both sessions to allow an estimate of test-retest reliability. Participants were asked to drink plenty of fluids over the 24-hour period preceding the test to ensure normal hydration prior to the testing, to avoid food and caffeine for at least 2 hours before testing, and to avoid significant exertion or exercise on the day of the test (American College of Sports Medicine, 2013).

Physical Activity Questionnaires. Questionnaires used were the 30-Day Physical Activity Recall (30-Day PAR), Youth Risk Behavior Survey (YRBS), Physical Activity Readiness Questionnaire (PAR-Q) (Centers for Disease Control and Prevention, 2005), and Physical Activity Questionnaire for Older Children (PAQ-C) (see Appendices C, D, E, and F).

Resting Heart Rate. Resting heart rate was measured with a Polar heart rate monitor (Polar Electro Incorporation, Woodbury, NY) at the first session. Resting heart rate was recorded after 5 minutes of sitting quietly. A second resting heart rate was recorded after one additional minute in the same position. An average of the two heart rates was used as resting heart rate.

Height. Height was measured with a stand-alone stadiometer to the nearest 0.1 cm (SECA Incorporation, Hanover, MD). Participants were standing straight up with heels together without shoes, took a deep breath and held it (American College of Sports Medicine, 2013).

Body Mass. Body mass was measured on an electronic-scale (COSMED, Concord, CA) to the nearest 0.1 kg during the BODPOD procedure.

Skinfolds. Skinfolds were measured three times at the triceps of the right arm and calf site of the right leg with Lange calipers (Cambridge, MD) following FITNESSGRAM® guidelines (Meredith & Welk, 2010), and percent body fat was estimated from skinfolds with the equations of Slaughter et al. (1988) as shown below.

Boys: *Percent Body Fat = 0.735 (triceps + calf) + 1.0*

Girls: *Percent Body Fat = 0.610 (triceps + calf) + 5.1*

The triceps skinfold was measured on the back of the right arm over the triceps muscle, midway between the elbow and the acromion process of the scapula (Meredith & Welk, 2010). The calf skinfold was measured on the inside of the right leg at the level of maximal calf girth. The right foot was placed flat on a box with the knee flexed at a 90° angle. The median values of three measurements were used for estimating percent body fat.

BODPOD Test. Before starting the BODPOD test process, participants changed their clothing to a swim suit or compression shorts with girls wearing a sports bra. Participants also wore a bathing cap and took off jewelry, eyeglasses, shoes, and socks to minimize extracorporeal air volumes. Then participants were instructed about the BODPOD test procedures.

Before the BODPOD test, the system was warmed-up and calibrated. Then the participant’s information, such as date of birth, gender, height, and ethnicity, were entered into the computer software. The Lohman (1986) density model equation is recommended for the participants of this study in the BODPOD software, and it was used for all participants to estimate their percent body fat. Thoracic gas volume (TGV) was measured for all participants, and if one failed three times on the TGV measurement procedure, his or her TGV was estimated by the BODPOD software. During the measurement process, volume calibration was administered after the filter and breathing tube were installed. Body mass was measured on the BODPOD weighing scale (COSMED, Concord, CA) and then the participants were seated in the BODPOD chamber to measure their body volume. The volume measurement was administered twice. If the first two measures were inconsistent, a third volume measurement was performed, and the average volume of the two best estimates was used. Then the participants followed the TGV measurement procedure on the screen to measure their TGV.

One-mile Walk Test. The one-mile walk was performed indoors on a measured course. Since one lap of the course is 730 feet, participants walked for seven laps and 170 feet. The one-mile walk test was administered twice on separate days at least one week apart. The participants wore a heart rate monitor (Polar Electro Incorporation, Woodbury, NY), and the tester wore the receiver watch of the heart rate monitor on his right wrist. The tester used a stopwatch to time the walk. Participants were tested individually to eliminate heart rate receiver interruption from multiple participants. Before the test, participants were asked to walk with a slow, medium, and fast pace, and the tester asked ‘which pace do you think you can keep constant for the one-mile, which is about seven and a half laps?’ Additionally, participants were asked to consider the test as competition with other children and do their best while walking one-mile. Then participants were instructed to walk at the chosen pace for the entire distance. The tester walked behind and to the left side of the participant until the one-mile distance was completed. Verbal encouragement to complete the one-mile distance was provided. The tester pushed the start and stop button of the stop watch when a participant started and completed the walk. During the one-mile walk, the times and heart rates at a quarter-mile, a half-mile, and one-mile walk distances were recorded by the tester.

***Maximal Treadmill Test*.** Procedures for the maximal treadmill test were similar to those used by Mahar et al. (2011). Participants were administered a graded exercise test to volitional exhaustion on a Trackmaster (model TMX425C) treadmill to measure VO_{2max}. Participants who had not used treadmill before practiced until they were comfortable with the treadmill. Then the maximal treadmill test was administered.

Treadmill speed was set at 2.5 mph for the fırst minute and increased by 0.5 mph each minute until 5.0 mph was reached. Treadmill grade was maintained at 0% until 5.0 mph was reached. If a participant did not achieve a maximal effort before 5.0 mph, speed was maintained, and grade was increased by 3% each minute until the participant was no longer able to continue.

A modified treadmill protocol was developed and used for six unfit children. If a participant's BMI was over 30 $kg·m^{-2}$ or if the participant took more than 20 minutes to complete the one-mile walk test, then the following procedure was followed. The participant was asked to run on the treadmill at 5 mph for about 20 seconds before the maximal treadmill test. Then the participant was asked "Can you run at this speed for few minutes more until you cannot go any further?" If the participant responded that he or she might not be able to run at that speed, the modified treadmill protocol was administered. For the modified protocol, treadmill speed was set at 2.0 mph for the first minute and increased by 0.5 mph each minute until 4.0 mph was reached. Treadmill grade was maintained at 0% until 4.0 mph was reached. If a participant did not achieve a maximal effort before 4.0 mph was reached, speed was maintained, and grade was increased by 2% each minute until the participant was no longer able to continue.

During the maximal treadmill test, VO_2 of participants was measured using a COSMED $K4b^2$ portable metabolic system. The children's OMNI scale of perceived exertion (Utter, Robertson, Nieman, & Kang, 2002) was assessed each minute (see Appendix G). Prior to testing, the system was calibrated using known concentration sample gases. VO_{2max} was accepted as a maximal index if two of the following three conditions were satisfied. First, the participant showed signs of intense effort such as hyperpnea, facial flushing and grimacing, unsteady gait, and sweating (Mahar et al., 2011; Rowland, 1993). Second, maximal heart rate reached a value of at least 90% of age-predicted maximal heart rate (220-age) (Mahar et al., 2011; Rowland, 1993). Third, respiratory exchange ratio (RER) was greater than or equal to 1.0 (Armstrong & Welsman, 1994; Mahar et al., 2011; Rowland, 1993). Heart rate was monitored during the maximal treadmill test with a Polar heart rate monitor (Polar Electro Incorporation, Woodbury, NY). The average of the last 30 seconds of the test was used to analyze VO_{2max}. Verbal encouragement was provided to participants during the test. Most participants did not grip the hand rail, but some of them who had unbalanced gait on the treadmill were allowed to grip just one hand rail for a few minutes, and after they got used to the speed and grade, they were encouraged to not hold the hand rail.

Statistical Analysis

Descriptive Analysis. Descriptive statistics for age, height, body mass, BMI, BMI percentile, BMI z-score, percent body fat from both BODPOD and skinfolds, and physical activity level by 30-Day PAR were calculated. In addition, times to finish a quarter mile, a half mile, and one mile and associated heart rates and speed of walking were described. Lastly, both measured and estimated VO_{2max}, maximal heart rate, maximal respiratory exchange ratio, and resting heart rate were described.

Norm-referenced Test-retest Reliability. Reliabilities for the following variables were estimated with an intraclass correlation using a one-way model (Baumgartner, Jackson, Mahar, & Rowe, 2007): 30-Day PAR, quarter-mile walk time, half-mile walk time, one-mile walk time, heart rates associated with these walk times, and estimated VO_{2max}. Paired samples t-tests were calculated to compare differences between the first and second sessions for these variables. Effect size (*ES*) was calculated using Cohen's delta as shown below.

ES = (Mean of 1st session – Mean of 2nd session) / (Mean of standard deviations of 1st and 2nd sessions)

Bivariate Correlations. Bivariate correlation was used to examine correlations between measured VO_{2max} and predictor variables such as body mass, gender, walk time, heart rate, and 30-Day PAR.

Multiple Regression. Data from the first walk test were used to develop new equations. The initial predictor variables that were examined to develop new regression equations were body mass, gender, BMI, percent body fat from BODPOD or skinfolds, self-reported physical activity from four questionnaires, time to walk a quarter mile, time to walk a half mile, time to walk one mile, and associated heart rates. Body mass, gender, quarter-mile walk time, quarter-mile walk heart rate, and 30-Day PAR were used as final predictors because they were stronger predictors of measured VO_{2max} than the other variables. The 30-Day PAR was selected over the other self-report instruments because it had acceptable test-retest reliability (R_{xx} = .85 for two trials; R_{xx} = .74 for one trial), a higher correlation with measured VO_{2max} (r = .53) than the other self-report instruments, and was easy to administer and complete. The equations developed from the quarter-mile walk data provided slightly more accurate estimates of VO_{2max} than data from the other distances walked. In addition, the quarter-mile walk distance is more practical to administer and easier to complete than the longer distances. Thus, the current results focus more on the quarter-mile walk data than on data from the other distances.

Multiple regression was used to estimate measured VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) from body mass, gender, time to complete a quarter-mile, a half-mile, and a one-mile walk and associated heart rates, and the 30-Day PAR. The variables of body mass, heart rate, and 30-Day PAR were excluded from or added to other variables to examine whether that variable contributed significantly to the prediction of measured VO_{2max}.

Separate equations were developed for each distance tested at each session. The equations developed from all participants were cross-validated with the PRESS-related statistic (Holiday, Ballard, & Mckeown, 1995). Data of all participants can be used by using the PRESS-related statistic which avoids the data-splitting problem from the conventional cross-validation process (Holiday et al., 1995). Holiday et al. (1995) stated that the PRESS-related statistic could provide similar unbiased estimates of the future prediction accuracy of the equation developed in the current study. In that statistical technique, the PRESS residual is the difference between the actual response of a particular case and the predicted response for that case which was estimated by a model developed from other cases without that particular case (Holiday et al., 1995). Thus, prediction accuracy of newly developed equations could be examined by producing PRESS R^2 (R_p^2) and PRESS *SEE* (SEE_p) from cross-validation on all of the data. R_p^2 was calculated as: $R_p^2 = 1 –$ [Sum of Squares of PRESS residual / Sum of Squares (total)]. SEE_p was calculated as: $SEE_p = \sqrt{}$Sum of Squares of PRESS residual / *n.*

Prediction error was assessed with two equations to cross-validate the previously published regression equations of Kline, Porcari, Hintermeister et al. (Kline, Porcari, Hintermeister et al., 1987), and Dolgener et al. (Dolgener et al., 1994). The standard error of estimate (*SEE*) was calculated as: $SEE = S_Y\sqrt{1 - R^2_{YY'}}$. The cross-validation *SEE* (referred to as total error [*TE*]) was calculated as: $TE = \sqrt{\sum(Y - Y')^2/N}$. Y is measured VO_{2max} and Y´ is VO_{2max} estimated from the equations. Comparison of these two error estimates can be used to quantify the overestimation or underestimation of measured VO_{2max}.

Criterion-referenced Validity. Values of measured and estimated VO_{2max} from the previously published equations and from the equation developed in the current study were categorized into two categories (Healthy Fitness Zone [HFZ] and Needs Improvement Zone [NIZ]) using FITNESSGRAM® standards (Meredith & Welk, 2010). From these analyses, the validity coefficient *C* (proportion of correct classification decisions), and the *phi* coefficient statistics were calculated.

Results

Sixty-five participants were originally recruited. Four participants were excluded from the data pool due to an inability to complete the testing protocol. Two of the excluded participants had attention deficit hyperactivity disorder (one participant ceased participation before the walk test at the first session and one participant's pacing during the walk test fluctuated randomly such that heart rate was unstable), one participant had narcolepsy, and one participant reported discomfort from heart rate monitor.

Among 61 participants, time between the two test sessions was $\leq$ 10 days for half of the participants, $\leq$ 20 days for 40% of participants, and more than 20 days for the remainder of participants. Two participants did not reach the criteria for maximal exertion during the maximal treadmill test, and one participant did not reach at least 110 $b \cdot min^{-1}$, which was the minimum criteria for heart rate during the walk test at the first session (Fontenot, 2001; Golding et al., 1989). Thus, the remainder of participants (n = 58) were used for developing the quarter-mile walk regression equations. Moreover, one participant could finish only a quarter-mile distance walk. That participant's data were included when developing models for the quarter-mile distance, but were excluded for developing models for the longer distances.

Participant Characteristics

Participant characteristics are described in Table 1. Among participants, about 70% were white, 20% were black, and the rest were Asian, Hispanic, or categorized as other. Measured and estimated VO_{2max} of boys were significantly higher than that of girls ($p < .05$), and maximal heart rate of boys was significantly lower than that of girls ($p = .03$). Based on BMI percentile, 16% of participants were obese (BMI $\geq 95^{th}$ percentile), 8% were overweight (85^{th} percentile $\leq$ BMI $\leq 94^{th}$ percentile), 5% were underweight (BMI $\leq 4^{th}$ percentile), and the rest (71%) were healthy weight (5^{th} percentile $\leq$ BMI $\leq 84^{th}$ percentile). Based on measured VO_{2max}, 69% of participants were categorized as fit using Healthy Fitness Zone cut points of the FITNESSGRAM®.

Table 1

Participant Characteristics (M ± SD)

Variable	Boys (n = 30)	Girls (n = 31)	Combined (N = 61)
Age (years)	11.4 ± 1.2	11.8 ± 1.1	11.6 ± 1.1
Height (cm)	151.4 ± 9.1	151.4 ± 8.8	151.4 ± 8.8
Body Mass (kg)	44.1 ± 13.1	51.5 ± 21.8	47.9 ± 18.3
BMI (kg/m^2)	18.9 ± 3.8	22.3 ± 9.4	20.6 ± 7.4
BMI percentile	51.5 ± 33.4	59.4 ± 29.6	55.5 ± 31.5
BMI z-score	0.1 ± 1.2	0.5 ± 1.2	0.3 ± 1.2
Body Fat (%)			
BODPOD	21.2 ± 9.5	25.2 ± 11.4	23.2 ± 10.6
Skinfolds	26.6 ± 13.2	32.6 ± 14.1	29.7 ± 13.9
30-Day PAR			
1st session	4.3 ± 2.0	4.6 ± 2.3	4.5 ± 21.1
2nd session	4.6 ± 1.9	4.6 ± 2.2	4.6 ± 2.0
Measured VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	46.1 ± 7.7	39.4 ± 10.9*	42.7 ± 10.0
Estimated VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	45.9 ± 5.7	39.2 ± 10.6*	42.6 ± 9.1
Maximal heart rate ($b \cdot min^{-1}$)	196.8 ± 6.5	201.3 ± 9.3*	199.1 ± 8.3
Maximal RER	1.15 ± 0.10	1.15 ± 0.13	1.15 ± 0.12
Resting heart rate ($b \cdot min^{-1}$)	85.4 ± 9.1	84.9 ± 12.9	85.2 ± 11.1

Note. Percent body fat was estimated from triceps and calf skinfolds using equations of Slaughter et al. (1988); 30-Day PAR, 30-Day Physical Activity Recall; Estimated VO_{2max} was estimated by quarter-mile Model 1 using 1st session data; RER, respiratory exchange ratio; * $p < .05$, mean for girls is significantly different from mean for boys

Results of walk tests for both sessions are described in Table 2. Values for boys and girls did not differ significantly ($p > .05$). However, time to walk a quarter mile, a half mile, and one mile was slightly faster for boys than for girls. For the first session for the quarter-mile walk, the mean difference was 9 seconds. In addition, the associated heart rates of boys were slightly lower than that of girls for both sessions. Average walking speed ranged from 3.72 to 3.95 mph for the first session and from 3.85 to 4.09 mph for the second session.

Table 2

Mean (± SD) Heart Rates, Time, and Speed for Walk Tests

Variable	Boys (n = 30)	Girls (n = 29)	Combined (N = 59)
1st session			
Walk Time ¼-mile (min)	3.78 ± 0.35	3.93 ± 0.60	3.86 ± 0.49
Walk Time ½-mile (min)	7.77 ± 0.73	7.97 ± 1.06	7.87 ± 0.90
Walk Time 1-mile (min)	15.87 ± 1.69	16.23 ± 2.31	16.05 ± 2.01
HR ¼-mile ($b \cdot min^{-1}$)	140 ± 20	148 ± 18	144 ± 19
HR ½-mile ($b \cdot min^{-1}$)	141 ± 21	147 ± 17	144 ± 19
HR 1-mile ($b \cdot min^{-1}$)	144 ± 24	149 ± 19	146 ± 22
Speed first ¼-mile (mph)	4.00 ± 0.36	3.91 ± 0.48	3.95 ± 0.42
Speed ¼ to ½ mile (mph)	3.80 ± 0.37	3.70 ± 0.51	3.75 ± 0.44
Speed ½ to 1 mile (mph)	3.76 ± 0.45	3.68 ± 0.54	3.72 ± 0.50
2nd session			
Walk Time ¼-mile (min)	3.68 ± 0.49	3.85 ± 0.66	3.77 ± 0.59
Walk Time ½-mile (min)	7.54 ± 0.96	7.74 ± 1.11	7.64 ± 1.03
Walk Time 1-mile (min)	15.29 ± 1.79	15.83 ± 2.22	15.56 ± 2.02
HR ¼-mile ($b \cdot min^{-1}$)	143 ± 20	148 ± 18	145 ± 19
HR ½-mile ($b \cdot min^{-1}$)	144 ± 19	148 ± 19	146 ± 19
HR 1-mile ($b \cdot min^{-1}$)	144 ± 20	148 ± 20	146 ± 20
Speed first ¼-mile (mph)	4.14 ± 0.49	4.04 ± 0.53	4.09 ± 0.51
Speed ¼ to ½ mile (mph)	3.94 ± 0.45	3.86 ± 0.52	3.90 ± 0.48
Speed ½ to 1 mile (mph)	3.92 ± 0.42	3.78 ± 0.50	3.85 ± 0.46

Note. HR, heart rate; Speed first ¼-mile, speed between start and quarter-mile; Speed ¼ to ½ mile, speed between quarter-mile and half-mile; Speed ½ to 1 mile, speed between half-mile and one-mile

Walk Time and Heart Rate Comparison

The difference between first and second sessions for the 30-Day PAR, walk time, and heart rates were compared and reliability was estimated as shown in Table 3. *ICCs* ranged from .88 to .90 for the walk time and from .82 to .84 for the heart rates. Average time for all distances at the 1st session were significantly higher than that of the 2nd session ($p < .05$), whereas effect size was small ($ES \leq 0.25$).

Table 3
Comparison of Time and Heart Rate between 1st and 2nd Sessions

Variable	1st session	2nd session	*ICC*	*p*	*ES*
30-Day PAR	4.46 ± 21.11	4.59 ± 2.04	.85	.49	0.06
Walk Time ¼-mile (min)	3.86 ± 0.49	3.77 ± 0.59	.90	.03	0.17
Walk Time ½-mile (min)	7.87 ± 0.90	7.64 ± 1.03	.88	.01	0.24
Walk Time 1-mile (min)	16.05 ± 2.01	15.56 ± 2.02	.90	.00	0.25
HR ¼-mile (b·min^{-1})	144 ± 19	145 ± 19	.82	.13	0.10
HR ½-mile (b·min^{-1})	144 ± 19	146 ± 19	.84	.17	0.14
HR 1-mile (b·min^{-1})	146 ± 22	146 ± 20	.84	.78	0.03

Note. *M* ± *SD*; *ICC,* intra-class correlation coefficient (one way model); *ES,* effect size; HR, heart rate

Heart rates at different distances for both the first and second sessions were compared to each other, as shown in Figures 1 and 2. There were no statistically significant differences among any of comparisons for either session. Heart rate was similar at the quarter-mile, half-mile, and one-mile distance, indicating that participants were able to maintain a steady walking pace.

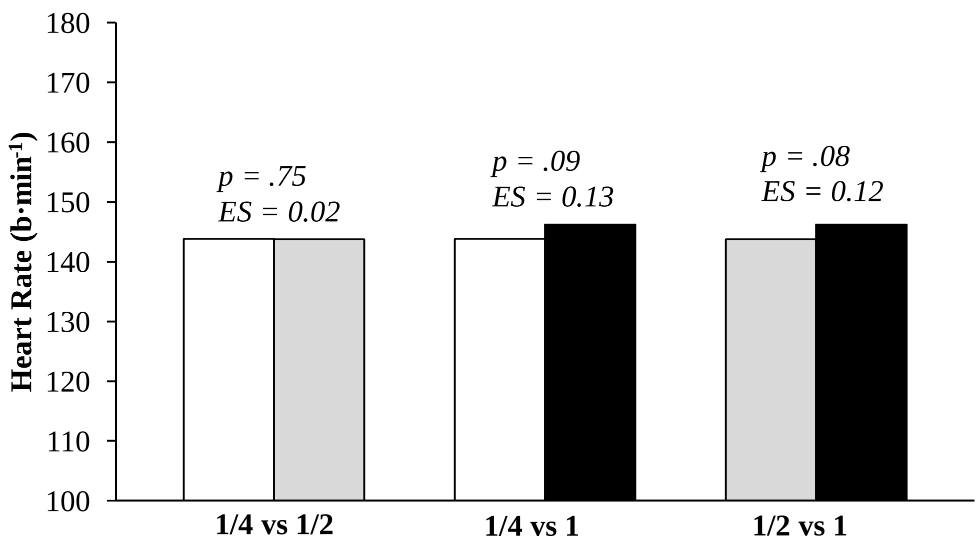

Figure 1. Comparison of heart rates at different distances for 1st session

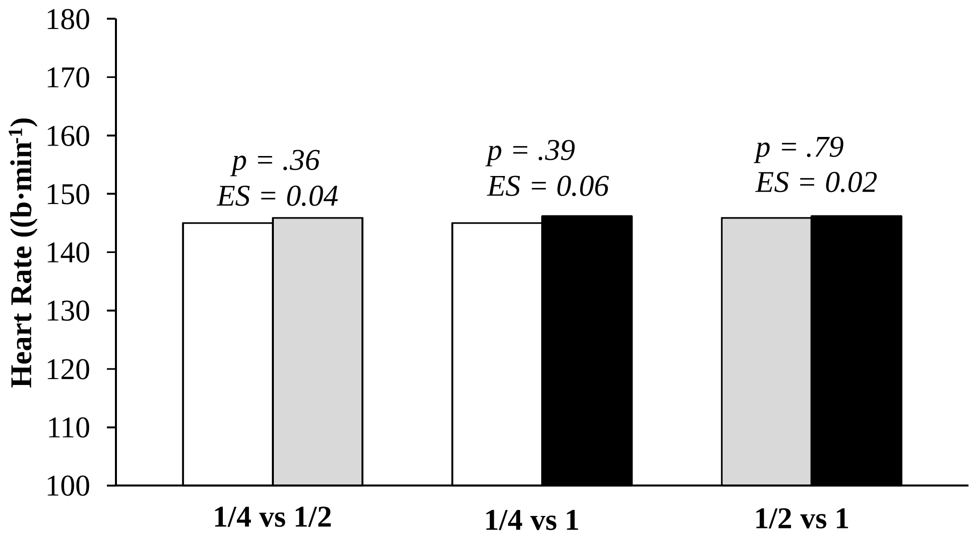

Figure 2. Comparison of heart rates at different distances for 2nd session

Inter-correlations of Predictor Variables

Correlations between measured VO_{2max} and predictor variables are presented in Table 4. Body mass had the highest correlation with measured VO_{2max} (r = -.84). Quarter-mile walk time (r = -.67) and 30-Day PAR (r = .54) were also relatively highly correlated with measured VO_{2max}. All predictor variables were significantly correlated with measured VO_{2max} (p < .05).

Table 4

Zero-Order Correlations between Measured VO_{2max} and Predictor Variables

Variable	Total sample (n = 58)
Body Mass (lb)	-.84*
Gender (0 = girl, 1 = boy)	.34*
¼-mile Walk Time (min)	-.67*
Heart Rate ($b \cdot min^{-1}$)	-.27*
30-Day PAR	.54*

Note. 30-Day PAR, 30-Day Physical Activity Recall; ¼-mile Walk Time and Heart Rate for quarter-mile walk at 1st session were used; *p < .05

New Regression Equations

Regression coefficients to estimate measured VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) for the quarter-mile walk test at the first session are described in Tables 5 and 6. Eight models were developed based on variables such as body mass, gender, walk time, heart rate, and 30-Day PAR.

Regression equations from Models 1 to 4 were developed using body mass, gender, walk time, heart rate, and 30-Day PAR as predictors. All predictor variables were entered in Model 1. In Model 1, all variables except for heart rate were significant predictors of measured VO_{2max}. The multiple *R* and *SEE* for Model 1 were .92 and 4.06 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. The R_p^2 and SEE_p for Model 1 were .79 and 4.52 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. Model 2 excluded heart rate as a predictor. For Model 2, the *SEE* was similar to the *SEE* for Model 1, and all variables in Model 2 were significant predictors of measured VO_{2max}. In Model 2, the R_p^2 of .81 and the SEE_p of 4.39 $ml \cdot kg^{-1} \cdot min^{-1}$ indicated that Model 2 was slightly more accurate than Model 1. Model 3 excluded 30-Day PAR as a predictor. For Model 3, all variables except for heart rate were significant predictors of measured VO_{2max}. Model 4 excluded both heart rate and 30-Day PAR. For Model 4, all variables were significant predictors of measured VO_{2max}. Model 3 and 4 showed similar accuracy, but were less accurate than Models 1 and 2.

Table 5

Regression Coefficients to Estimate VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) for Quarter-mile Data (n = 58)

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	65.226	64.481	83.035	78.865
Body Mass (lb)	-0.142*	-0.143*	-0.154*	-0.162*
Gender	3.908*	3.930*	2.937*	3.095*
Time (min)	-3.895*	-3.835*	-5.382*	-4.879*
HR ($b \cdot min^{-1}$)	-0.004	-	-0.035	-
30-Day PAR	1.356*	1.363*	-	-
R	.92	.92	.88	.88
R^2	.84	.84	.77	.77
SEE ($ml \cdot kg^{-1} \cdot min^{-1}$)	4.06	4.06	4.82	4.85
R_p^2	.79	.81	.71	.72
SEE_p ($ml \cdot kg^{-1} \cdot min^{-1}$)	4.52	4.39	5.41	5.28

Note. Gender: 0 = girl, 1 = boy; HR, heart rate; *SEE*, standard error of estimate; R_p^2 and SEE_p are PRESS R^2 *and* PRESS *SEE* respectively; *$p < .05$, statistically significant variable for prediction

Models 5 through 8 excluded body mass as a predictor so that prediction of VO_{2max} in heavy participants was not unduly influenced by body mass. Inclusion of body mass in the prediction model may cause heavier individuals to have lower estimated VO_{2max} values relative to lighter individuals who walk at the same speed and heart rate. In Model 5, all variables were significant predictors of measured VO_{2max}. The multiple *R* and *SEE* for Model 5 were .82 and 5.75 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. The R_p^2 and SEE_p for Model 5 were .61 and 6.21 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. For Model 5, without body mass as a predictor, heart rate contributed significantly to the prediction of measured VO_{2max}. However, Model 5 was less accurate compared to Model 1 with body mass as a predictor.

Table 6

Regression Coefficients to Estimate VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) for Quarter-mile Data (n = 58)

Variable	Model 5	Model 6	Model 7	Model 8
Intercept	88.056	71.544	112.317	90.700
Body Mass (lb)	-	-	-	-
Gender	5.091*	5.847*	4.018*	5.018*
Time (min)	-10.974*	-10.406*	-13.532*	-13.173*
HR ($b \cdot min^{-1}$)	-0.090*	-	-0.137*	-
30-Day PAR	1.638*	1.862*	-	-
R	.82	.81	.76	.72
R^2	.67	.65	.58	.51
SEE ($ml \cdot kg^{-1} \cdot min^{-1}$)	5.75	5.96	6.55	7.03
R_p^2	.61	.60	.51	.46
SEE_p ($ml \cdot kg^{-1} \cdot min^{-1}$)	6.21	6.35	6.99	7.32

Note. Gender: 0 = girl, 1 = boy; HR, heart rate; *SEE*, standard error of estimate; R_p^2 and SEE_p are PRESS R^2 *and* PRESS *SEE* respectively; *$p < .05$, statistically significant variable for prediction

Model 6, which excluded body mass and heart rate, had a prediction accuracy similar to that of Model 5. All variables in Model 6 were significant predictors of measured VO_{2max}. In Model 7, which excluded body mass and 30-Day PAR, all variables were significant predictors of measured VO_{2max}. In Model 7, the multiple *R* was lower than for Model 5 (.82 vs .76) and the *SEE* was higher than for Model 5 (5.75 vs. 6.55 $ml \cdot kg^{-1} \cdot min^{-1}$), indicating that excluding self-reported physical activity from the model substantially decreased prediction accuracy. Model 8 should theoretically be the least accurate of the models developed because the predictor variables of body mass, heart rate, and 30-Day PAR were not included in the model. For Model 8, all variables were significant predictors of measured VO_{2max}. Model 8 had the lowest multiple *R* (.72) and the highest *SEE* (7.03 $ml \cdot kg^{-1} \cdot min^{-1}$) of all models examined. Scatter plots of measured and estimated VO_{2max} for Models 1 to 8 are presented in Appendix H.

All other regression coefficients for half-mile and one-mile distances from first session data and for all distances from second session data are presented in Appendix I and J.

Reliability of VO_{2max} Estimation

VO_{2max} was estimated from the models developed from data collected during the first session using data from the first and second sessions to allow an estimate of reliability. Estimated VO_{2max} and *ICC* reliability estimates are presented in Table 7. All models developed in the current study produced highly reliable (*ICC* ≥ .98) estimates of VO_{2max}. Estimates of reliability of VO_{2max} from the Kline, Porcari, Hintermeister et al. (1987) and Dolgener et al. (1994) equations for the first and second sessions were also high. Estimates of mean VO_{2max} for the first and second session were generally within 1 $ml \cdot kg^{-1} \cdot min^{-1}$, with the exception of the Kline, Porcari, Hintermeister et al. which had a mean difference of 1.56 $ml \cdot kg^{-1} \cdot min^{-1}$.

Table 7
Reliability of VO_{2max} Estimation from Regression Models

Regression Model	Estimated VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) 1st session	2nd session	*ICC*	*p*	*ES*
Quarter-mile Model 1	42.57 ± 9.07	43.07 ± 9.45	.98	.12	0.05
Half-mile Model 1	43.00 ± 8.42	43.70 ± 8.50	.98	.03	0.08
One-mile Model 1	43.01 ± 8.42	43.80 ± 8.38	.98	.01	0.09
Kline et al.	48.34 ± 9.27	49.90 ± 9.83	.97	.00	0.16
Dolgener et al.	42.62 ± 7.95	43.28 ± 8.18	.99	.00	0.08

Note. *M* ± *SD*; *ICC*, intra-class correlation coefficient (one way model); *ES*, effect size; One-mile data was used for estimated VO_{2max} from Kline, Porcari, Hintermeister et al. and Dolgener et al. equations

Cross-validation of Previously Published Equations

Previously published equations were cross-validated on all participants using data from the first session. Cross-validation results, including the correlations between measured and estimated VO_{2max} and standard errors, are presented in Table 8. The correlations between measured and estimated VO_{2max} from the Kline, Porcari, Hintermeister et al. (1987) equation were slightly higher than those from Dolgener et al. (1994) equation. *SEE*s from the Kline, Porcari, Hintermeister et al. equation were slightly lower than the *SEEs* from the Dolgener et al. equation. However, the Kline, Porcari, Hintermeister et al. equation showed a tendency to overestimate measured $VO_{2max.}$ Estimated VO_{2max} from the Kline, Porcari, Hintermeister et al. equation was significantly different ($p < .05$) from measured VO_{2max} for all distances. *TE* of Kline, Porcari, Hintermeister et al. equation was much higher than the *SEE* indicating a systematic difference between measured and estimated VO_{2max} from Kline, Porcari, Hintermeister et al. equation. Scatter plots between measured and estimated VO_{2max} from the Kline, Porcari, Hintermeister et al. and Dolgener et al. equations using one-mile data are shown in Figure 3 and 4.

Table 8
Cross-validation of Previously Published Regression Equations

Data	Model	VO_{2max} (ml·kg^{-1}·min^{-1})	*r*	*SEE*	*TE*
Quarter-mile	Measured	42.65 ± 10.07	-	-	-
(*n* = 58)	Kline et al.	50.72 ± 10.75*	.83	5.55	10.04
	Dolgener et al.	43.63 ± 9.10	.81	5.94	6.04
Half-mile	Measured	43.15 ± 9.42	-	-	-
(*n* = 57)	Kline et al.	50.02 ± 9.16*	.82	5.38	8.67
	Dolgener et al.	43.51 ± 8.06	.78	5.90	5.81
One-mile	Measured	43.15 ± 9.42	-	-	-
(*n* = 57)	Kline et al.	48.68 ± 9.10*	.81	5.56	7.81
	Dolgener et al.	42.81 ± 7.93	.76	6.09	5.98

Note. *M* ± *SD*; *r*, correlation between measured and estimated VO_{2max}; *SEE*, standard error of estimate; *TE*, total error; *$p < .05$, significantly different between measured and estimated VO_{2max}; time for quarter and half-mile was multiplied by 4 and 2 respectively for the analysis; Kline et al., Kline, Porcari, Hintermeister et al.

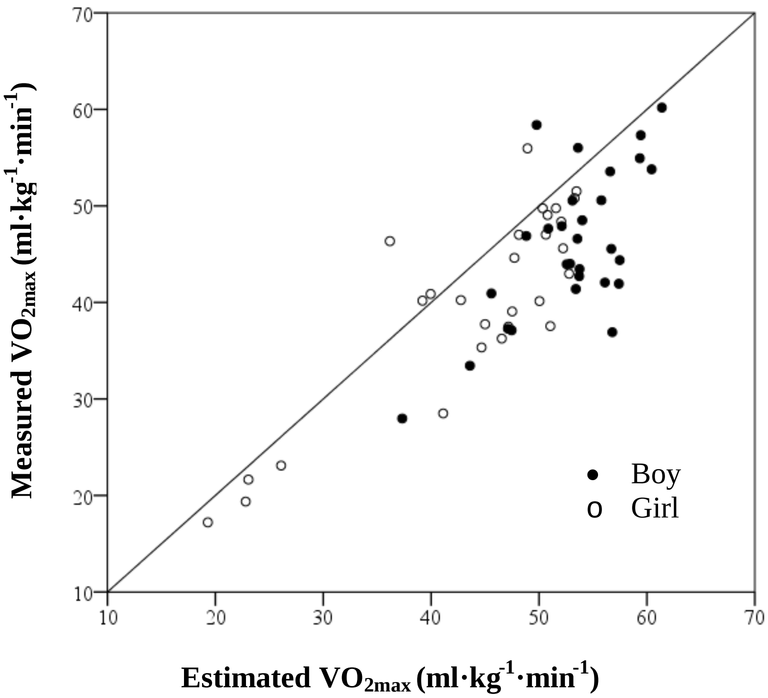

Figure 3. Scatter plot between measured and estimated VO_{2max} from the Kline, Porcari, Hintermeister et al.

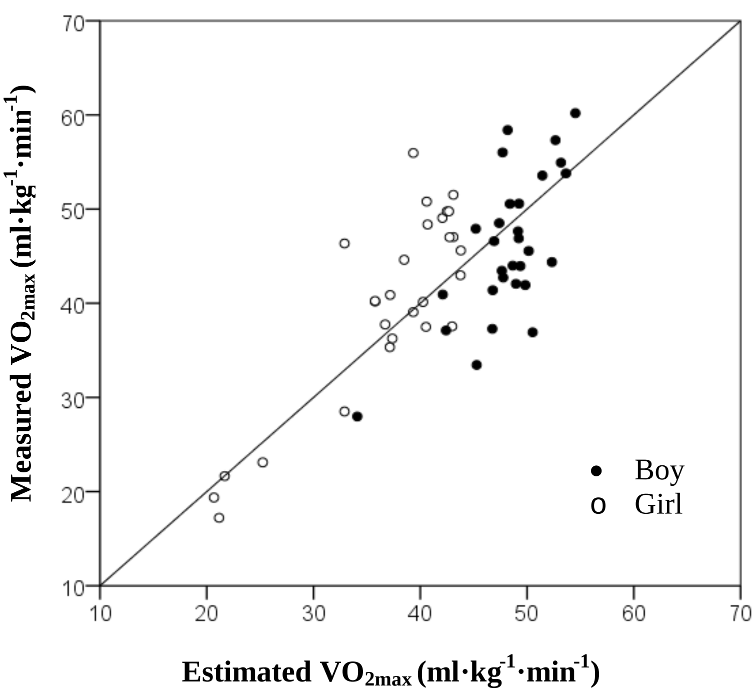

Figure 4. Scatter plot between measured and estimated VO_{2max} from Dolgener et al.

Criterion-referenced Validity

Criterion-referenced validity of previously published equations and equations developed in the current study was examined using FITNESSGRAM® standards (Meredith & Welk, 2010). Criterion-referenced validity results are presented in Table 9. The Model 1 equation developed in the current study categorized participants into either the HFZ or NIZ more accurately than the other models examined. Model 1 categorized 50 out of 58 participants accurately into either the HFZ or NIZ. The Kline, Porcari, Hintermeister et al. equation was the least accurate model examined, and accurately classified only 43 out of 57 participants.

Table 9
Comparison of Criterion-referenced Validity between Models

		Measured VO_{2max}			
Estimated VO_{2max}		HFZ	NIZ	*C*	*Phi*
Kline, Porcari,	HFZ	38	11		
Hintermeister et	%	66.7	19.3		
al.	NIZ	3	5		
(*n* = 57)	%	5.3	8.8	.75	.31
Dolgener et al.	HFZ	35	6		
(*n* = 57)	%	61.4	10.5		
	NIZ	6	10		
	%	10.5	17.5	.79	.48
Current study	HFZ	37	4		
Model 1	%	63.8	6.9		
(*n* = 58)	NIZ	4	13		
	%	6.9	22.4	.86	.67
Current study	HFZ	34	4		
Model 5	%	58.6	6.9		
(*n* = 58)	NIZ	7	13		
	%	12.1	22.4	.81	.57

Note. HFZ, healthy fitness zone; NIZ, need improvement zone; *C*, criterion validity coefficient; *phi*, phi coefficient; quarter-mile data at 1st session was used for the current study models and one-mile data at 1st session was used for the previous models

Discussion

Aerobic fitness is an important health-related fitness component. However, direct measurement of aerobic fitness is not practical for in some settings due to the need for expensive equipment, laboratory space, and trained technicians. Thus, in some situations a field test to estimate aerobic fitness that is practical and easier to administer than direct measurement of aerobic fitness is desirable. Maximal effort field tests, such as the one-mile run/walk and PACER, require high levels of participant motivation and may be too difficult to complete for some unmotivated, overweight, and unfit children.

The original one-mile walk test developed by Kline, Porcari, Hintermeister et al. (1987) was developed on adults and has been cross-validated in college-aged participants (Dolgener et al., 1994) and adolescents (McSwegin et al., 1998). No studies have previously examined the validity of walk tests for children younger than age 14 years. Thus, the purpose of the current study was to develop regression equations to estimate VO_{2max} for quarter-mile, half-mile, and one-mile walk tests for 10-13 year old children.

Participants walked one mile twice on different days and completed a maximal treadmill test with directly measured VO_{2max}. At least one week elapsed between the two sessions. One obese participant could not complete a one-mile walk, but she was able to complete a quarter-mile walk. Another participant did not reach a heart rate of 110 $b \cdot min^{-1}$ during the first walking trial. In addition, two children did not exert maximal effort during the maximal treadmill test, so their data were excluded. All other participants completed two trials of the one-mile walk and provided maximal efforts during the treadmill test.

Models to estimate VO_{2max} from quarter-mile, half-mile, and one-mile data were developed in this study. Heart rate responses were similar among the quarter-mile, half-mile, and one-mile distances, with average heart rates for the entire sample ranging from 144 $b \cdot min^{-1}$ for the quarter-mile and half-mile distance to 146 $b \cdot min^{-1}$ for the one-mile distance.

This indicates that participants maintained a relatively steady walking pace throughout the entire distance. Walk times ranged from an average of slightly less than 4 minutes for the quarter-mile walk to approximately 16 minutes for the one-mile distance for the first walking trial. An average one-mile walk time of about 16 minutes for children is much longer than other aerobic fitness field tests and it may be difficult for some children to walk such a long time. The quarter-mile distance might be more appropriate for children who are overweight or unmotivated to walk a mile at a constant fast pace.

Results demonstrated that the quarter-mile walk test provided a slightly more accurate estimate of VO_{2max} than the longer distances. Because the quarter-mile distance is also more practical than longer distances for a field test, the quarter-mile results were focused on in the current study. Every participant except for one had a heart rate over 110 $b \cdot min^{-1}$ after the quarter-mile walk. This value has been suggested as the minimum heart rate necessary to estimate VO_{2max} in submaximal heart rate prediction models (Fontenot, 2001; Golding et al., 1989). Average heart rate did not significantly change from the quarter-mile to the half-mile, which supports the idea that steady state heart rate can be reached after only three minutes of constant intensity exercise (Golding et al., 1999; Greenhalgh et al., 2001).

Based on previous studies (Dolgener et al., 1994; Kline, Porcari, Hintermeister et al., 1987) the variables of body mass, gender, walk time, and heart rate were examined. In addition, the value of self-reported physical activity as a predictor of VO_{2max} was also examined. Age was excluded as a predictor because of the restricted age range in the current sample. Eight models were developed to examine the impact of various predictor variables on prediction accuracy.

Because practitioners in some situations (e.g., schools) may prefer models that do not require body mass, four models without body mass as a predictor were evaluated. In general, models without body mass (Models 5-8) were less accurate than models with body mass

(Model 1-4) as a predictor. Measured VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) and body mass were significantly correlated (r = - .84). Models without the 30-Day PAR measure of self-reported physical activity were less accurate than models with the 30-Day PAR as a predictor. Measured VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) and 30-Day PAR were significantly correlated (r = .53). Children's perception of their physical activity levels was relatively highly related to their aerobic fitness level, and self-reported physical activity was a significant predictor for all regression equations. Inclusion of the 30-Day PAR as a predictor led to more accurate prediction models. The 30-Day PAR is easy to administer and appears to be a simple way for children to estimate their physical activity levels.

Surprisingly, heart rate measured during the walk test did not add significantly to the prediction of VO_{2max}. Measured VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) and heart rate were significantly correlated, but the correlation was weak (r = - .27). In the study by Kline, Porcari, Hintermeister et al. (1987), the correlation between measured VO_2 ($L \cdot min^{-1}$) and heart rate was also weak (r = -.14). These authors did not state whether heart rate was a significant predictor of VO_{2max} in their regression equation. Dolgener et al. (1994) used the same predictors as Kline, Porcari, Hintermeister et al. to allow comparison between their equations. Dolgener et al. did not state whether heart rate was a significant predictor of VO_{2max} or whether heart rate was significantly correlated with VO_{2max}. Heart rate was a significant predictor of VO_{2max} in the models without body mass as a predictor (Models 5-8), suggesting that the variance accounted for by body mass overlapped with the variance accounted for by heart rate. Overall, excluding heart rate from the walking equations does not reduce the accuracy of prediction and would reduce the burden on the tester who would not have to assess heart rate during or after the walk.

Reliability of VO_{2max} estimation was examined and compared for new and previously developed regression equations. Results showed all equations were highly reliable (*ICC*

$\geq .97$). *ICCs* in the present study were higher than that reported by Leger et al. (1988) from the PACER test (*ICC* = .89). In addition, heart rates (*ICC* $\geq .82$) and time for the quarter-mile, half-mile, and one-mile between first and second session were highly reliable (*ICC* $\geq .88$). The *ICC* for walk time in the current study was similar to the *ICC* for one-mile run/walk time (ICC $\geq .85$) from grade 4 children reported by Rikli et al. (1992). Therefore, the newly developed quarter-mile walk test can be assumed to provide a reliable estimate of VO_{2max} in children.

Accuracy of the newly developed regression equations was compared to that of previously published regression equations. The equations published by Kline, Porcari, Hintermeister et al. (1987) and Dolgener et al. (1994) were cross-validated on participants in the current study. Results from the cross-validation demonstrated that the newly developed regression equations were more accurate than the previously published equations for the 10-13 year old children in this sample. Correlations between measured and estimated VO_{2max} from the Kline, Porcari, Hintermeister et al. equation and the Dolgener et al. equation were $r = .81$ and $r = .76$, respectively. R_p from quarter-mile Model 1 was $R_p = .89$, which was a much stronger correlation coefficient than that of Kline, Porcari, Hintermeister et al. and Dolgener et al. equations. In addition, *SEEs* from Kline, Porcari, Hintermeister et al. equation and Dolgener et al. equation were 5.61 and 6.14 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively, which were slightly higher than the SEE_p (4.52 $ml \cdot kg^{-1} \cdot min^{-1}$) of quarter-mile Model 1. Models 1 and 2 for the half-mile and one-mile walk tests had accuracy similar to the quarter-mile Model 1 ($SEE_p < 5.00$ $ml \cdot kg^{-1} \cdot min^{-1}$). Therefore, it appears that the newly developed regression equations provide more accurate estimates of VO_{2max} than previously published equations.

In comparison between two previously published equations, mean estimated VO_{2max} from the Dolgener et al. equation similar to the mean measured VO_{2max}. However, the Kline, Porcari, Hintermeister et al. equation tended to overestimate measured VO_{2max} of participants in the current study. Figure 3 shows that cases were scattered under the reference line, which indicates overestimation of VO_{2max} from the Kline, Porcari, Hintermeister et al. On the other hand, for the Dolgener et al. equation, as seen in Figure 4, cases were scattered around the reference. The cross-validation results in the current study show the same trend as shown by other researchers. The Kline, Porcari, Hintermeister et al. equations tend to provide accurate estimates VO_{2max} in fitter populations, whereas the Dolgener et al. equations tend to provide accurate estimates of VO_{2max} in less fit populations. George et al. (1998) provided results that supported the accuracy of the Dolgener et al. equations on participants of the same fitness level (average measured VO_{2max} = 42.8 $ml \cdot kg^{-1} \cdot min^{-1}$) as children in current study (average measured VO_{2max} = 42.7 $ml \cdot kg^{-1} \cdot min^{-1}$). In contrast, three studies (Greenhalgh et al., 2001; McSwegin et al., 1998; Weiglein, 2011) that supported the accuracy of the Kline, Porcari, Hintermeister et al. equations had relatively highly fit participants (average measured VO_{2max} = 48.1, 45.4, and 50.3 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively). The Kline, Porcari, Hintermeister et al. and Dolgener et al. equations were not as accurate for children in current study as the walk tests developed in this study specifically for children.

The accuracy of the quarter-mile walk test developed in this study compares favorably to other field tests of aerobic fitness, such as the one-mile run/walk and PACER tests. The one-mile run/walk equation developed by Cureton et al. (1995) has been used to estimate VO_{2max} for children in the FITNESSGRAM®. Cureton et al. reported a multiple R = .71 and SEE = 4.78 $ml \cdot kg^{-1} \cdot min^{-1}$ for the one-mile run/walk regression equation in a large sample aged 8 to 25 years. Mahar et al. (2011) reported a multiple R = .75 and SEE = 6.17 for a PACER quadratic model in a 10-16 year old sample. The newly developed quarter-mile walk test (Model 1) had a multiple R = .92 and SEE = 4.26 $ml \cdot kg^{-1} \cdot min^{-1}$ for 10-13 year old children in current study. *SEEs* from different studies are not directly comparable because the standard deviation of the predicted variable, which differs from study to study, is used in calculation of the *SEE*.

The criterion-referenced validity of the quarter-mile walk test (Model 1) using FITNESSGRAM® Standards (Meredith & Welk, 2010) was C = .86. This represents the accuracy with which participants are categorized into either the HFZ or NIZ. The Kline, Porcari, Hintermeister et al. (1987) (C = .75) and Dolgener et al. (1994) (C = .79) equations had lower classification accuracy than the quarter-mile walk test. Accordingly, the quarter-mile walk test (Model 1) appears to be a better equation to differentiate children in the current study as healthy or unhealthy than other walk test equations using FITNESSGRAM ® Standards.

This study appears to be the first to develop a quarter-mile walk test for 10-13 year-old children. A major strength of the study is that a quarter-mile walk test for children that is practical and accurate was developed. The quarter-mile walk test is simple to take and can be administered in a short amount of time, making it practical for use in schools and other settings. Another strength of this study is that eight different models were developed, so school teachers or researchers can choose one of the models depending on their circumstances. Evidence of reliability and validity were provided for the new walk test equations. The new walk test equations appear to be as or more accurate than previously published walk tests, the one-mile run/walk, and the PACER test equations. Additionally, evidence of some degree of representativeness of the sample used in the current study can be provided by comparison with large-scale studies. Estimated VO_{2max} from the National Health and Nutrition Examination Survey (NHANES) (Welk, Laurson, Eisenmann, & Cureton, 2011) on a large, nationally representative sample aged 12-18 years was similar to measured VO_{2max} in the current study. Average estimated VO_{2max} from NHANES was 47.3 $ml \cdot kg^{-1} \cdot min^{-1}$ for males and 39.6 $ml \cdot kg^{-1} \cdot min^{-1}$ for females. Similarly, in the current study average measured

VO_{2max} was 46.1 ml·kg^{-1}·min^{-1} for males and 39.4 ml·kg^{-1}·min^{-1} for females. In addition, the sample distribution in terms of BMI of the current study was similar to the BMI of participants in the large-scale Texas Youth Fitness Study (Welk, Meredith, Ihmels, & Seeger, 2010). Middle school children from the Texas Youth Fitness Study were categorized into the Healthy Fitness Zone (HFZ) or Needs Improvement Zone based on their BMI using FITNESSGRAM® standards (Going, Lohman, & Falls, 2008). About 64% of boys and 73% of girls were categorized in the HFZ in that study. Similarly, in the current study 67% of boys and 74% of girls were categorized into the HFZ using FITNESSGRAM® Standards (Meredith & Welk, 2010).

The current study has several limitations. First, motivation to walk fast at the same pace was not always apparent in the 10-13 year old children in the present study; especially, the younger children. Most of the children, both fit and unfit, were likely trying to do their best. However, some children did not appear to try walk at a fast constant pace. This was indicated by bored facial expressions and behaviors such as looking around, slowing down, and trying to talk. Children of this age group seemed to get bored after the half-mile walk distance, which prevented them from focusing on the walk test for the remaining half-mile. Second, pacing ability differed slightly among children. Pacing speed seemed to be based on fitness and physical activity level. Younger children tended to have difficulty keeping the same pace for the entire one-mile walk, unless the child was fit and participated in regular physical activity or sports. This pacing problem might be related to the motivation of a particular child. Most children could walk at the same pace they chose before the test for the entire test. Those who could not keep a constant walking pace tended to walk fast for the first lap and to slow down slightly for the rest of laps. Some other children kept changing their walking pace randomly, though this was rare. However, this pacing problem might be attenuated in the quarter-mile walk test, especially for overweight children who may find it hard to keep the same pace while walking one-mile. Lastly, sample size (*N* = 61) was small compared to some other studies of field tests of aerobic fitness, but does represent the largest sample of this age group to be studied with respect to walking tests used to estimate aerobic fitness.

For estimation of VO_{2max} in young children, it is recommended that the Models 2, 4, 6, and 8 developed in the current study be used, depending on the purpose of testing, which may differ depending on intentions and situations. Model 2 is recommended because it is the most accurate regression equation of current study. Model 2 could be appropriately used in a clinical setting where children would be more likely than in a mass testing environment to provide a true answer for their self-reported physical activity. Model 4 is recommended for researchers who do not want to measure or use self-reported physical activity and heart rate. Model 4 might be appropriate in a school setting where it might be difficult to assess many students on self-reported physical activity or where students might be tempted to overestimate their physical activity to achieve a higher predicted VO_{2max}. Model 6 is recommended for researchers who do not want to use body mass as a predictor, and Model 8 is recommended for researchers who do not want to measure or use body mass, heart rate, and self-reported physical activity. Model 8 appears to be as accurate as other field tests such as one-mile run/walk and PACER, based on a comparison of correlations between measured and estimated VO_{2max}, but is less accurate than the Model 2. The four recommended models are as follows:

Model 2: VO_{2max} $(ml \cdot kg^{-1} \cdot min^{-1})$ = 64.481 – 0.143*(body mass [lb]) + 3.930*(gender [F = 0, M = 1]) – 3.835*(walk time [min]) + 1.363*(30-Day PAR)

Model 4: VO_{2max} $(ml \cdot kg^{-1} \cdot min^{-1})$ = 78.865 – 0.162*(body mass [lb]) + 3.095*(gender [F = 0, M = 1]) – 4.879*(walk time [min])

Model 6: VO_{2max} $(ml \cdot kg^{-1} \cdot min^{-1})$ = 71.544 + 5.847*(gender [F = 0, M = 1]) –

10.406(walk time [min]) + 1.862*(30-Day PAR)*

Model 8: $VO_{2max}\,(ml \cdot kg^{-1} \cdot min^{-1}) = 90.700 + 5.018*(gender\ [F = 0, M = 1]) - 13.173*(walk\ time\ [min])$

In summary, the new quarter-mile walk test regression equations developed in the current study provide valid and reliable estimates of VO_{2max} in children aged 10-13 years. Results demonstrated that the quarter-mile walk test was a long enough distance to provide accurate estimates of VO_{2max}. Future research should examine the effect of motivation and pacing education on the validity of walk tests for children. In addition, the impact of walking just one-quarter mile, rather than an entire mile, when developing a quarter-mile walk test should be examined. Validity of regression equations developed from a walk test developed on quarter-mile walk data may differ from the current study because participants may walk faster if they know they only need to complete one-quarter mile. Because average walking speed in the current study (i.e., ~ 4 mph) appears to be close to a slow running speed for children of this age, results developed from having participants walk only a quarter-mile are likely to be similar to findings in the current study. Development of a quarter-mile walk test with more overweight children should be examined because such a test may be most appropriate for this population of children. Most children who take youth fitness tests are likely to complete the PACER or mile run/walk to estimate aerobic fitness.

Validity of the quarter-mile walk test in settings where large numbers of children walk at the same time rather than individually should be also examined. Children may tend to walk faster in a setting surrounded by other children than in an individual test situation because of perceived competition with other children. Alternatively, children may tend to walk in clusters with similarly fit peers. The role of the teacher or test administrator in such a situation to teach children the importance of walking at a constant fast pace and what brisk walking feels like is paramount.

In conclusion, two primary purposes were examined. One-quarter mile, one-half mile, and one-mile walk test regression equations to estimate aerobic fitness in children aged 10-13 years were developed and shown to have evidence of reliability and validity. Additionally, two previously published regression equations were cross-validated on participants in the current study, and results showed that the new regression equations were more accurate than previously published equations. The quarter-mile walk test regression equations developed in the current study appear to be at least as accurate as the one-mile run/walk and PACER tests for children. The quarter-mile walk test is easy to administer and time-efficient compared to other field tests. The current study is the first study to develop walk tests to estimate aerobic fitness in young children. The quarter-mile walk test might be particularly useful when estimates of aerobic fitness are desired for unmotivated, unfit, obese, or overweight children who may not be able to complete a field test of aerobic fitness that requires a maximal effort.

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Appendix A: IRB Approval Form

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
4N-70 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** ·
www.ecu.edu/irb

Notification of Initial Approval: Expedited

From: Biomedical IRB
To: Matthew Mahar
CC: Hoyong Sung
Date: 10/12/2012
Re: UMCIRB 12-001355
Walking Test and Youth Fitness

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) is for the period of 10/11/2012 to 10/10/2013. The research study is eligible for review under expedited category #4. The Chairperson (or designee) deemed this study no more than minimal risk.

Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The Investigator must adhere to all reporting requirements for this study.

The approval includes the following items:

Name	Description
30-day PAR | History	Surveys and Questionnaires
Assent Document | History	Consent Forms
Informed Consent Form | History	Consent Forms
LTEQ | History	Surveys and Questionnaires
PAQ-C | History	Surveys and Questionnaires
Study Flyer | History	Recruitment Documents/Scripts
Study Protocol | History	Study Protocol or Grant Application
YRBS | History	Surveys and Questionnaires

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418 IRB00004973

Appendix B: Physical Activity Readiness Questionnaire

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

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 (for example, back, knee or hip) 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 with 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 – begin 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. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

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 then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

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

NAME ____

SIGNATURE ____ DATE ______________________

SIGNATURE OF PARENT ____ WITNESS ______________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

1:12

 Supported by: Health Canada Santé Canada

continued on other side...

Appendix C: 30-Day Physical Activity Recall

Name:

30-DAY PHYSICAL ACTIVITY RECALL

Check if you are in the A, B, or C activity category. Place a check next to that letter.
Then circle the appropriate number (0 to 7) that best describes your general
ACTIVITY LEVEL for the *PREVIOUS MONTH*

Circle only one number

_____A. *Do Not participate regularly in programmed recreation, sport or heavy physical activity.*

0 - Avoid walking or exertion, e.g., always use elevator, ride whenever possible instead of walking.

1 - Walk for pleasure, routinely use stairs, occasionally exercise sufficiently to cause heavy breathing or perspiration.

_____B. *Participate regularly in recreation or work requiring modest physical activity, such as gymnastics, horseback riding, calisthenics, table tennis, softball, baseball, weight lifting, yard work.*

2 - Spend 10 to 60 minutes per week in these types of physical activity.

3 - Spend over 1 hour per week in these types of physical activity.

_____C. *Participate regularly in heavy physical exercise, e.g., running or jogging, swimming, cycling, rowing, jumping rope, or engaging in vigorous aerobic activity type exercise such as tennis, basketball, soccer, or other similar sports activities.*

4 - Spend less than 30 minutes per week in these types of physical activity.

5 - Spend 30 to 60 minutes per week in these types of physical activity.

6 - Spend 1 to 3 hours per week in these types of physical activity.

7 - Spend over 3 hours per week in these types of physical activity.

Appendix D: Youth Risk Behavior Survey

YRBS
Selected Questions

Name:

Circle the number of the answer that you feel is correct for you.

1. On how many of the past 7 days did you participate in physical activity for a total of 30-60 minutes, or more, over the course of the day?
This includes moderate activities (walking, slow bicycling, or outdoor play) as well as vigorous activities (jogging, active games or sports such as basketball, soccer, or tennis).
Circle one number

0 1 2 3 4 5 6 7

2. On how many of the past 7 days did you do exercises to strengthen or tone your muscles, such as push-ups, sit-ups, or weight lifting? **Circle one number**

0 1 2 3 4 5 6 7

3. On how many of the past 7 days did you walk, jog, or bicycle for at least 30 minutes at a time? **Circle one number**

0 1 2 3 4 5 6 7

4. During the past 7 days, on an average week day, how many hours **a day** did you watch television and videos or play computer or video games? **Circle one number**

1. None
2. 1 or less
3. 2 or 3 hours
4. 4 to 5 hours
5. 6 or more hours

5. Compared to others of your same age and gender how much physical activity do **you** get? **Circle one number**

1	2	3	4	5
Much less than others		The same as others		Much more than others

Circle the number of the answer that you feel is correct for you.

6. During the past 12 months (1 year), how many team or individual sports or activities did you participate in on a **competitive** level, such as school sports, intramurals, YMCA, city league teams, or other out-of-school programs?

1. None
2. 1 activity
3. 2 activities
4. 3 activities
5. 4 or more activities

What activities did you compete in? 1. ____________________________

2. ____________________________ 3. ____________________________

4. ____________________________ 5. ____________________________

6. ____________________________ 7. ____________________________

7. Check all activities you did **MORE THAN 10 TIMES IN THE PAST YEAR**. Do not include time spent in school physical education classes. Make sure you include all sport teams that you participated in during the past year.

_____Aerobics	_____Gymnastics	_____Swimming (Laps)
_____Band/Drill Team	_____Hiking	_____Tennis
_____Baseball	_____Ice Skating	_____Volleyball
_____Basketball	_____Roller Skating	_____Water Skiing
_____Bicycling	_____Running for Exercise	_____Weight Training
_____Bowling	_____Skateboarding	_____Wrestling (Competitive)
_____Cheerleading	_____Snow Skiing	_____Others
_____Dance Class	_____Soccer	________________________
_____Football	_____Softball	________________________
_____Garden/Yard Work	_____Street Hockey	

Question 8 asks about your **mother** (leave blank if you do not have one).

8. Compared to other women her same age, how much physical activity does your mother get? **Circle one number**

1	2	3	4	5
Much less than others		The same as others		Much more than others

Question 9 asks about your **father** (leave blank if you do not have one).

9. Compared to other men his same age, how much physical activity does your father get? **Circle one number**

1	2	3	4	5
Much less than others		The same as others		Much more than others

For question 10, circle the letter that is accurate for **you**.

10. How do you think of yourself?

A. very underweight (too thin)

B. slightly underweight

C. about the right weight

D. slightly overweight

E. very overweight (too fat)

11. In an average week when you are in school, on how many days do you go to physical education (PE) classes? **Circle one number**

0 1 2 3 4 5 6 7

12. During an average physical education class, how many minutes do you spend actually exercising or playing sports? **Circle one**

< 10 minutes 10-20 minutes 21-30 minutes

Appendix E: Physical Activity Readiness Questionnaire

PAR PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

Name: _______________

Physical Activity Questions
I am going to ask you several questions to describe your typical physical activity level. Please try to answer as accurately as possible. Please wait until I read all three questions before you give me your answer.

1. Would you say that you did **little or no regular** recreation, sport, or physical activity?

OR

2. Would you say that you participated **regularly** in recreation or work requiring **modest physical activity**?

OR

3. Would you say that you participated **regularly** in **heavy physical exercise**?

Modest physical activities include: walking, calisthenics, bowling, weight lifting, yard work.
Heavy physical activities include jogging, swimming, cycling, rowing, tennis, and basketball.

<Little or no regular>
1. Would you say that you avoid walking or exertion (for example, always use the elevator, drive whenever possible instead of walking.)?

OR

2. Would you say that you walk for pleasure, routinely use stairs, occasionally exercise sufficiently to cause heavy breathing or perspiration?

<Regular modest PA>
Would you say that you participated regularly in recreation or modest physical activity for:
1. **10 to 60 minutes per week?**

OR

2. **More than 60 minutes per week?**

<Heavy>
Now I am going to ask for some more detail on the amount of heavy physical exercise you did. I am going to give you four options.

Would you say that you participated regularly in heavy physical activity for

1. **less than 30 minutes per week**
OR
2. **30 to 60 minutes per week**
OR
3. **1 to 3 hours per week**
OR
4. **more than 3 hours per week**

Appendix F: Physical Activity Questionnaire for Older Children

Physical Activity Questionnaire-C

Name:_________________________ Age:___________

Gender (check one): Male_______ Female_______ Grade:__________

We are trying to find out about your level of physical activity from ***the last 7 days*** (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.

Remember:

1. There are no right and wrong answers **-** this is not a test.
2. Please answer all the questions as honestly and accurately as you can **-** this is very important.

---

1. Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Mark only one circle per row.)

	No	1-2	3-4	5-6	7 times or more
Skipping	○	○	○	○	○
Rowing/canoeing	○	○	○	○	○
In-line skating	○	○	○	○	○
Tag	○	○	○	○	○
Walking for exercise	○	○	○	○	○
Bicycling	○	○	○	○	○
Jogging or running	○	○	○	○	○
Aerobics	○	○	○	○	○
Swimming	○	○	○	○	○
Baseball, softball	○	○	○	○	○
Dance	○	○	○	○	○
Football	○	○	○	○	○
Badminton	○	○	○	○	○
Skateboarding	○	○	○	○	○
Soccer	○	○	○	○	○
Street hockey	○	○	○	○	○
Volleyball	○	○	○	○	○
Floor hockey	○	○	○	○	○
Basketball	○	○	○	○	○
Ice skating	○	○	○	○	○
Cross-country skiing	○	○	○	○	○
Ice hockey/ringette	○	○	○	○	○
Other: _______________________.....	○	○	○	○	○
____________________________......	○	○	○	○	○

2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one only.)

- I don't do PE .... ○
- Hardly ever .... ○
- Sometimes .... ○
- Quite often .... ○
- Always .... ○

3. In the last 7 days, what did you do most of the time *at recess*? (Check one only.)

- Sat down (talking, reading, doing schoolwork)…… ○
- Stood around or walked around .... ○
- Ran or played a little bit .... ○
- Ran around and played quite a bit .... ○
- Ran and played hard most of the time .... ○

4. In the last 7 days, what did you normally do *at lunch* (besides eating lunch)? (Check one only.)

- Sat down (talking, reading, doing schoolwork).…... ○
- Stood around or walked around .... ○
- Ran or played a little bit .... ○
- Ran around and played quite a bit .... ○
- Ran and played hard most of the time .... ○

5. In the last 7 days, on how many days *right after school*, did you do sports, dance, or play games in which you were very active? (Check one only.)

- None ....… ○
- 1 time last week .... ○
- 2 or 3 times last week .... ○
- 4 times last week .... ○
- 5 times last week .... ○

6. In the last 7 days, on how many *evenings* did you do sports, dance, or play games in which you were very active? (Check one only.)

- None .... ○
- 1 time last week .... ○
- 2 or 3 times last week .... ○
- 4 or 5 last week .... ○
- 6 or 7 times last week .... ○

7. *On the last weekend*, how many times did you do sports, dance, or play games in which you were very active? (Check one only.)

None .... ○
1 time .... ○
2 - 3 times .... ○
4 - 5 times .... ○
6 or more times .... ○

8. Which *one* of the following describes you best for the last 7 days? Read *all five* statements before deciding on the *one* answer that describes you.

A. All or most of my free time was spent doing things that involve little physical effort .... ○
B. I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) .... ○
C. I often (3 — 4 times last week) did physical things in my free time .... ○
D. I quite often (5 — 6 times last week) did physical things in my free time ………… ○
E. I very often (7 or more times last week) did physical things in my free time…........ ○

9. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

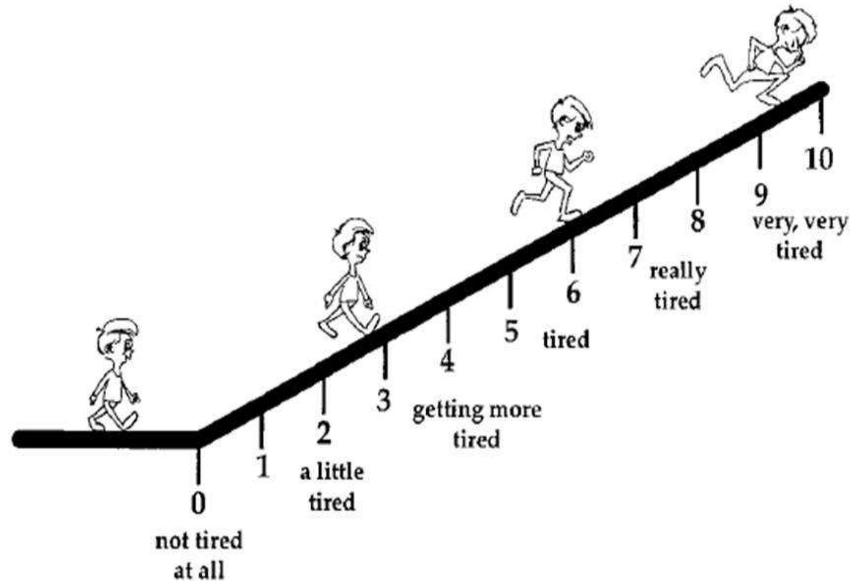
	None	Little bit	Medium	Often	Very often
Monday	○	○	○	○	○
Tuesday	○	○	○	○	○
Wednesday	○	○	○	○	○
Thursday	○	○	○	○	○
Friday	○	○	○	○	○
Saturday	○	○	○	○	○
Sunday	○	○	○	○	○

10. Were you sick last week, or did anything prevent you from doing your normal physical activities? (Check one.)

Yes ……………………………………………… ○
No .... ○

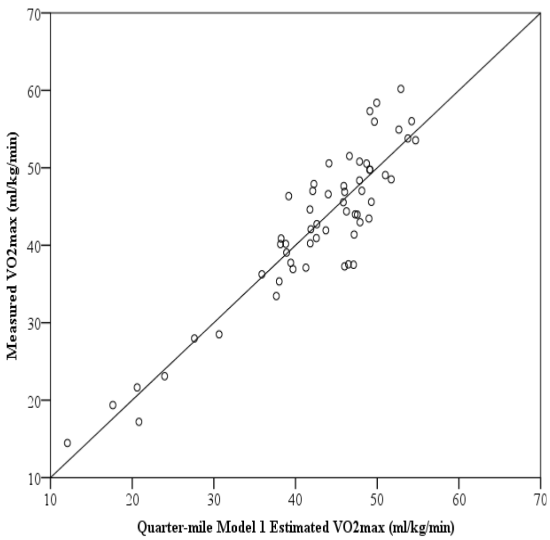
If Yes, what prevented you? ________________________________

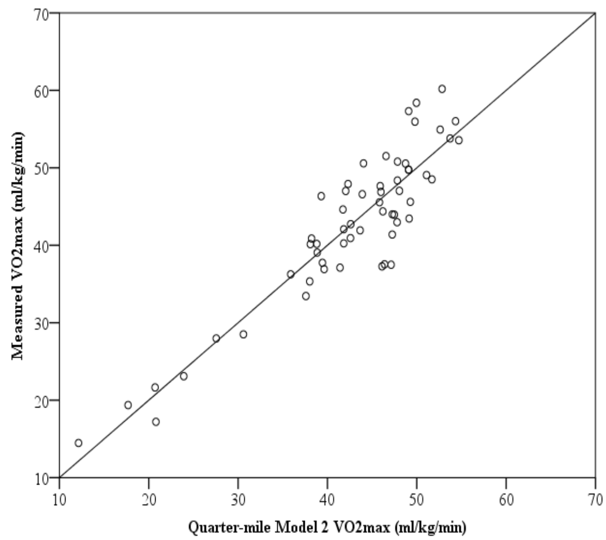
Appendix G: OMNI scale

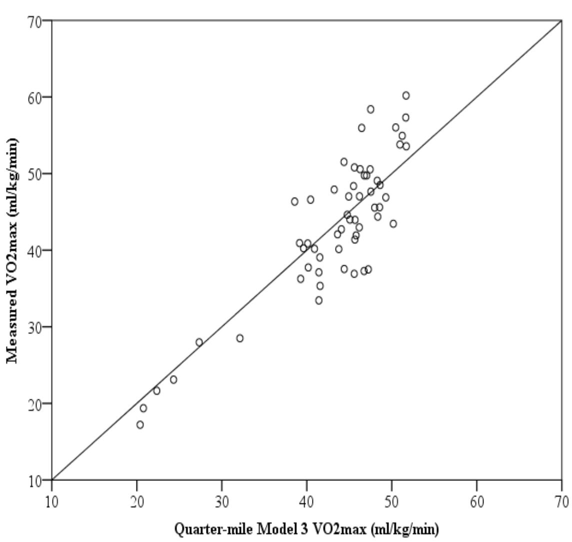


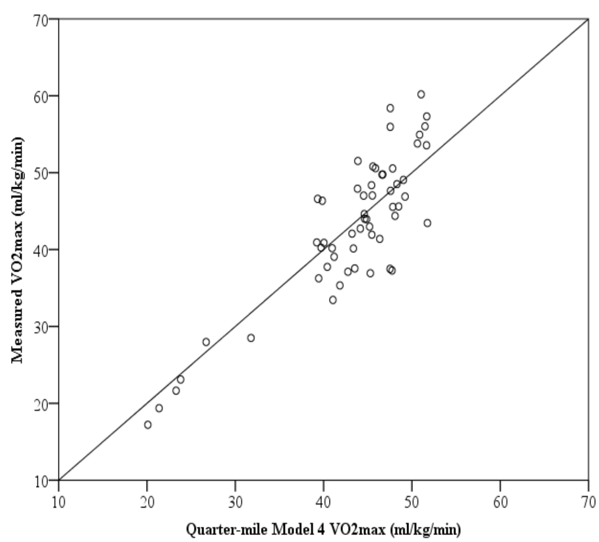
Appendix H: Scatter Plots of Measured and Estimated VO_{2max}

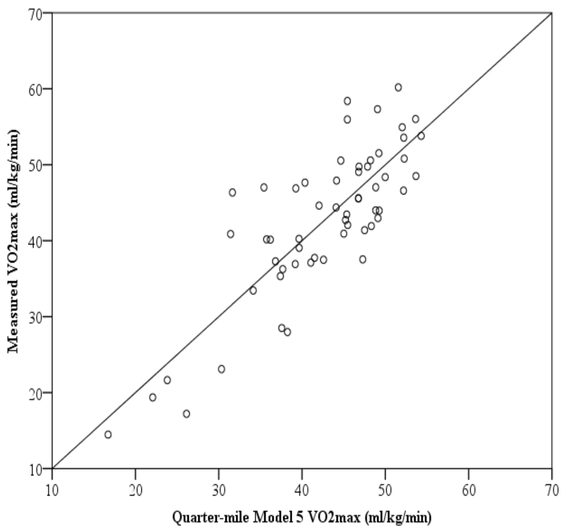
from Quarter-mile Models 1 to 8

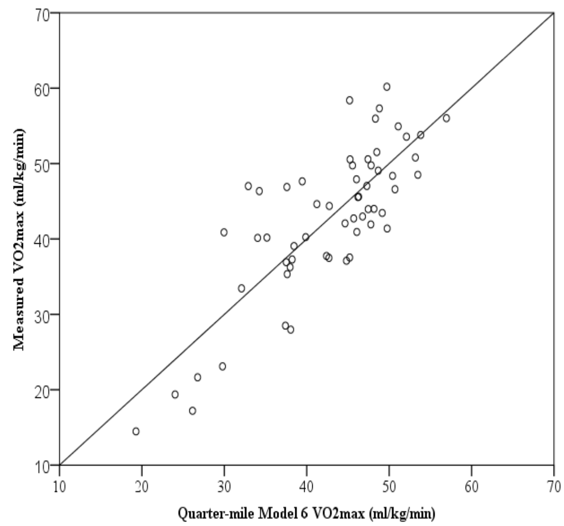


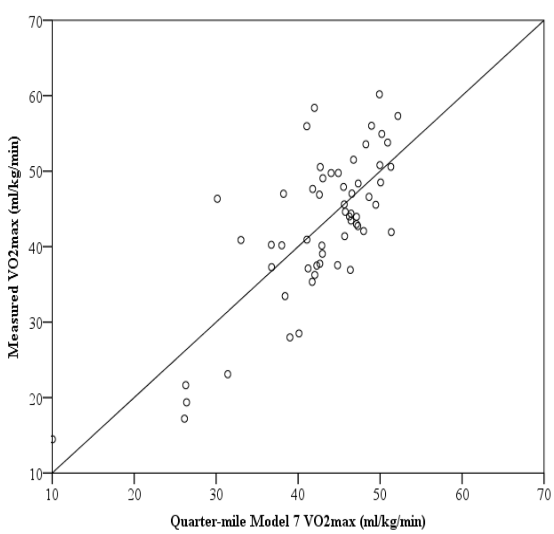


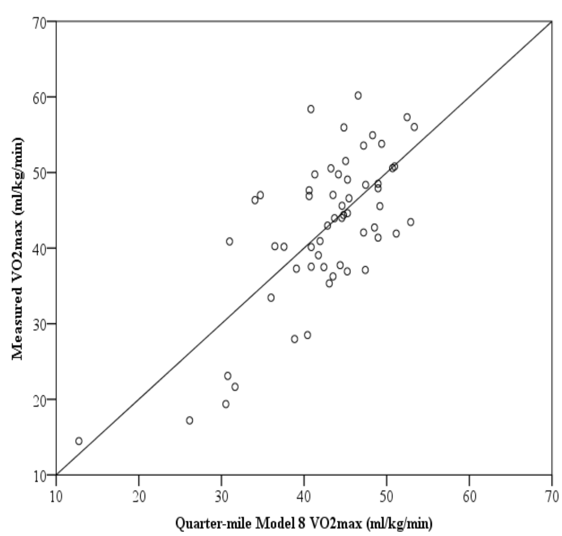





Measured VO2max (ml/kg/min)
Quarter-mile Model 5 VO2max (ml/kg/min)


Measured VO2max (ml/kg/min)
Quarter-mile Model 6 VO2max (ml/kg/min)


Measured VO2max (ml/kg/min)
Quarter-mile Model 7 VO2max (ml/kg/min)


Measured VO2max (ml/kg/min)
Quarter-mile Model 8 VO2max (ml/kg/min)

Appendix I: Half-mile and One-mile Multiple Regression Models (1st session data)

Table I1

Half-mile Multiple Regression Models to Estimate VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) (n = 57)

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	69.704	68.193	91.330	83.096
Weight (lb)	-0.144*	-0.145*	-0.159*	-0.169*
Gender	3.814*	3.844*	2.960*	3.086*
Time (min)	-2.332*	-2.258*	-3.482*	-3.086*
HR ($b \cdot min^{-1}$)	-0.007	-	-0.043	-
30-Day PAR	1.256*	1.273*	-	-
R	.91	.91	.87	.87
R^2	.82	.82	.76	.76
SEE ($ml \cdot kg^{-1} \cdot min^{-1}$)	4.01	4.01	4.59	4.64
R_p^2	.77	.79	.71	.72
SEE_p ($ml \cdot kg^{-1} \cdot min^{-1}$)	4.45	4.31	5.02	4.92

Note. Gender: 0 = girl, 1 = boy; HR, heart rate; *SEE*, standard error of estimate; R_p^2 and SEE_p are PRESS R^2 *and* PRESS *SEE* respectively; *$p < .05$, statistically significant variable for prediction

Table I2

Half-mile Multiple Regression Models to Estimate VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) (n = 57)

Variable	Model 5	Model 6	Model 7	Model 8
Intercept	84.964	65.103	117.588	90.062
Weight (lb)	-	-	-	-
Gender	5.082*	5.688*	4.075*	4.912*
Time (min)	-5.005*	-4.289*	-7.020*	-6.320*
HR ($b \cdot min^{-1}$)	-0.088	-	-0.150*	-
30-Day PAR	1.695*	1.997*	-	-
R	.80	.78	.73	.66
R^2	.64	.61	.53	.44
SEE ($ml \cdot kg^{-1} \cdot min^{-1}$)	5.69	5.89	6.46	7.05
R_p^2	.56	.55	.45	.37
SEE_p ($ml \cdot kg^{-1} \cdot min^{-1}$)	6.21	6.29	6.91	7.39

Note. Gender: 0 = girl, 1 = boy; HR, heart rate; *SEE*, standard error of estimate; R_p^2 and SEE_p are PRESS R^2 *and* PRESS *SEE* respectively; *$p < .05$, statistically significant variable for prediction

Table I3

One-mile Multiple Regression Models to Estimate VO_{2max} (ml·kg^{-1}·min^{-1}) (n = 57)

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	68.610	66.459	86.500	80.615
Weight (lb)	-0.143*	-0.145*	-0.165*	-0.171*
Gender	3.916*	3.945*	3.143*	3.208*
Time (min)	-1.066*	-1.005*	-1.520*	-1.352*
HR (b·min^{-1})	-0.009	-	-0.026	-
30-Day PAR	1.278*	1.290*	-	-
R	.91	.91	.87	.87
R^2	.82	.82	.76	.76
SEE (ml·kg^{-1}·min^{-1})	4.01	4.16	4.64	4.66
R_p^2	.77	.79	.71	.72
SEE_p (ml·kg^{-1}·min^{-1})	4.43	4.31	5.05	4.94

Note. Gender: 0 = girl, 1 = boy; HR, heart rate; *SEE*, standard error of estimate; R_p^2 and SEE_p are PRESS R^2 *and* PRESS *SEE* respectively; *p < .05, statistically significant variable for prediction

Table I4

One-mile Multiple Regression Models to Estimate VO_{2max} (ml·kg^{-1}·min^{-1}) (n = 57)

Variable	Model 5	Model 6	Model 7	Model 8
Intercept	81.298	61.510	111.796	84.891
Weight (lb)	-	-	-	-
Gender	5.404*	5.892*	4.554*	5.200*
Time (min)	-2.334*	-1.897*	-3.324*	-2.785*
HR (b·min^{-1})	-0.080	-	-0.123*	-
30- Day PAR	1.842*	2.039*	-	-
R	.80	.78	.71	.65
R^2	.64	.61	.50	.43
SEE (ml·kg^{-1}·min^{-1})	5.69	5.90	6.68	7.12
R_p^2	.56	.54	.42	.36
SEE_p (ml·kg^{-1}·min^{-1})	6.20	6.30	7.12	7.47

Note. Gender: 0 = girl, 1 = boy; HR, heart rate; *SEE*, standard error of estimate; R_p^2 and SEE_p are PRESS R^2 *and* PRESS *SEE* respectively; *p < .05, statistically significant variable for prediction

Appendix J: Quarter-mile, Half-mile, and One-mile Multiple Regression Models (2nd session data)

Table J1

Quarter-mile Multiple Regression Models to Estimate VO_{2max} (ml·kg^{-1}·min^{-1}) (n = 59)

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	71.592	66.472	85.295	75.450
Weight (lb)	-0.146*	-0.151*	-0.143*	-0.156*
Gender	3.217*	3.278*	3.050*	3.166*
Time (min)	-4.104*	-3.599*	-5.716*	-4.810*
HR (b·min^{-1})	-0.023	-	-0.053	-
30-Day PAR	0.776*	0.850*	-	-
R	.90	.90	.89	.88
R^2	.81	.81	.79	.78
SEE (ml·kg^{-1}·min^{-1})	4.38	4.40	4.57	4.66
R_p^2	.75	.76	.74	.74
SEE_p (ml·kg^{-1}·min^{-1})	4.93	4.82	5.05	5.02

Note. Gender: 0 = girl, 1 = boy; HR, heart rate; *SEE*, standard error of estimate; R_p^2 and SEE_p are PRESS R^2 *and* PRESS *SEE* respectively; *$p < .05$, statistically significant variable for prediction

Table J2

Quarter-mile Multiple Regression Models to Estimate VO_{2max} (ml·kg^{-1}·min^{-1}) (n = 59)

Variable	Model 5	Model 6	Model 7	Model 8
Intercept	99.945	70.515	110.293	82.412
Weight (lb)	-	-	-	-
Gender	4.284*	5.003*	4.135*	4.926*
Time (min)	-11.215*	-9.445*	-12.370*	-11.260*
HR (b·min^{-1})	-0.139*	-	-0.160*	-
30-Day PAR	0.610	1.102*	-	-
R	.79	.76	.79	.73
R^2	.63	.58	.62	.54
SEE (ml·kg^{-1}·min^{-1})	6.06	6.51	6.15	6.81
R_p^2	.56	.51	.56	.48
SEE_p (ml·kg^{-1}·min^{-1})	6.57	6.91	6.55	7.11

Note. Gender: 0 = girl, 1 = boy; HR, heart rate; *SEE*, standard error of estimate; R_p^2 and SEE_p are PRESS R^2 *and* PRESS *SEE* respectively; *$p < .05$, statistically significant variable for prediction

Table J3

Half-mile Multiple Regression Models to Estimate VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) ($n$ = 58)

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	80.126	70.619	92.644	79.605
Weight (lb)	-0.152*	-0.161*	-0.150*	-0.167*
Gender	3.194*	3.305*	3.049*	3.202*
Time (min)	-2.631*	-2.161*	-3.353*	-2.759*
HR ($b \cdot min^{-1}$)	-0.041	-	-0.070	-
30-Day PAR	0.648	0.806*	-	-
R	.89	.89	.88	.87
R^2	.79	.79	.78	.76
SEE ($ml \cdot kg^{-1} \cdot min^{-1}$)	4.27	4.32	4.40	4.56
R_p^2	.74	.75	.73	.73
SEE_p ($ml \cdot kg^{-1} \cdot min^{-1}$)	4.76	4.67	4.77	4.83

Note. Gender: 0 = girl, 1 = boy; HR, heart rate; *SEE*, standard error of estimate; R_p^2 and SEE_p are PRESS R^2 *and* PRESS *SEE* respectively; *$p < .05$, statistically significant variable for prediction

Table J4

Half-mile Multiple Regression Models to Estimate VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) ($n$ = 58)

Variable	Model 5	Model 6	Model 7	Model 8
Intercept	103.690	69.073	113.733	82.313
Weight (lb)	-	-	-	-
Gender	4.227*	4.951*	4.098*	4.896*
Time (min)	-5.703*	-4.458*	-6.266*	-5.480*
HR ($b \cdot min^{-1}$)	-0.149*	-	-0.171*	-
30-Day PAR	0.530	1.174*	-	-
R	.76	.71	.75	.67
R^2	.57	.50	.57	.45
SEE ($ml \cdot kg^{-1} \cdot min^{-1}$)	6.09	6.59	6.16	6.94
R_p^2	.48	.42	.49	.38
SEE_p ($ml \cdot kg^{-1} \cdot min^{-1}$)	6.70	7.05	6.63	7.30

Note. Gender: 0 = girl, 1 = boy; HR, heart rate; *SEE*, standard error of estimate; R_p^2 and SEE_p are PRESS R^2 *and* PRESS *SEE* respectively; *$p < .05$, statistically significant variable for prediction

Table J5

One-mile Multiple Regression Models to Estimate VO_{2max} *(ml·kg^{-1}·min^{-1}) (n* = 58*)*

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	74.092	70.586	88.467	80.006
Weight (lb)	-0.159*	-0.161*	-0.159*	-0.168*
Gender	3.098*	3.136*	2.898*	2.979*
Time (min)	-1.139*	-1.061*	-1.539*	-1.370*
HR (b·min^{-1})	-0.015	-	-0.046	-
30-Day PAR	0.774*	0.835*	-	-
R	.89	.89	.87	.87
R^2	.78	.78	.76	.76
SEE (ml·kg^{-1}·min^{-1})	4.34	4.35	4.54	4.61
R_p^2	.73	.74	.72	.72
SEE_p (ml·kg^{-1}·min^{-1})	4.81	4.71	4.89	4.88

Note. Gender: 0 = girl, 1 = boy; HR, heart rate; *SEE*, standard error of estimate; R_p^2 and SEE_p are PRESS R^2 *and* PRESS *SEE* respectively; *p < .05, statistically significant variable for prediction

Table J6

One-mile Multiple Regression Models to Estimate VO_{2max} *(ml·kg^{-1}·min^{-1}) (n* = 58*)*

Variable	Model 5	Model 6	Model 7	Model 8
Intercept	91.682	70.487	106.637	84.277
Weight (lb)	-	-	-	-
Gender	4.207*	4.570*	4.003*	4.427*
Time (min)	-2.642*	-2.277*	-3.060*	-2.804*
HR (b·min^{-1})	-0.092	-	-0.124*	-
30-Day PAR	0.803	1.200*	-	-
R	.73	.71	.71	.67
R^2	.53	.50	.51	.44
SEE (ml·kg^{-1}·min^{-1})	6.40	6.60	6.54	6.97
R_p^2	.44	.42	.44	.38
SEE_p (ml·kg^{-1}·min^{-1})	6.94	7.06	6.94	7.31

Note. Gender: 0 = girl, 1 = boy; HR, heart rate; *SEE*, standard error of estimate; R_p^2 and SEE_p are PRESS R^2 *and* PRESS *SEE* respectively; *p < .05, statistically significant variable for prediction