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COMPARISON OF NON-MAXIMAL TESTS FOR EXERCISE PRESCRIPTION AND
OUTCOME ASSESSMENT

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the
Degree of Master of Science

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College of Science and Health
Clinical Exercise Physiology

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COMPARISON OF NON-MAXIMAL TESTS FOR EXERCISE PRESCRIPTION AND OUTCOME ASSESSMENT

By Reem Alajmi

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology.

The candidate has completed the oral defense of the thesis.

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This study examined the accuracy of non-maximal tests: the Talk Test (TT), Rating of Perceived Exertion (RPE) extrapolation, Rockport Walking Test (RWT) and non-exercise VO$_2$max prediction equation for predicting exercise capacity (VO$_2$max and VT). Subjects (N=20) were 18-50 yrs. of low to moderate fitness level. Subjects performed three exercise sessions. Test 1 was a maximal incremental test to measure VO$_2$max and VT. Test 2 was a submaximal incremental exercise test without respiratory gas exchange measurements, using the TT and RPE. Test 3 was the RWT. Also, VO$_2$max was calculated using the non-exercise prediction equation of Matthews et al. (1997). The results showed that there was no significant difference between measured VO$_2$max and predicted VO$_2$max using the non-exercise equation, extrapolation to RPE19 and the RWT. However, measured VO$_2$max was significantly less than predicted VO$_2$max using extrapolation to RPE 20 (p≤0.05). There was no significant difference (p>0.05) between the VO$_2$ at VT, the LP, and EQ stages of the TT, and at RPE13 and RPE14. However, the VO$_2$ at RPE 15 was significantly higher than VO$_2$ at VT (p≤0.05). In conclusion, the results showed that the non-maximal methods could be used as primary methods for exercise prescription and outcome assessment.
ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGMENT</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td>viii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>METHODS</td>
<td>7</td>
</tr>
<tr>
<td>Subjects</td>
<td>7</td>
</tr>
<tr>
<td>Experimental Design</td>
<td>8</td>
</tr>
<tr>
<td>Statistical Analysis</td>
<td>11</td>
</tr>
<tr>
<td>RESULTS</td>
<td>12</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>19</td>
</tr>
<tr>
<td>CONCLUSION</td>
<td>27</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>28</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>33</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Descriptive characteristics of subjects</td>
<td>12</td>
</tr>
<tr>
<td>2. Comparison of measured and predicted VO₂ max</td>
<td>13</td>
</tr>
<tr>
<td>3. Comparison of measured and predicted VO₂ at VT</td>
<td>16</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>10</td>
</tr>
<tr>
<td>2.</td>
<td>14</td>
</tr>
<tr>
<td>3.</td>
<td>15</td>
</tr>
<tr>
<td>4.</td>
<td>16</td>
</tr>
<tr>
<td>5.</td>
<td>18</td>
</tr>
</tbody>
</table>

1. Example of extrapolation to RPE 19 and 20 method
2. Mean values for measured VO$_2$max and predicted VO$_2$max
3. Measured VO$_2$max vs. Predicted VO$_2$max
4. Mean values for measured VO$_2$ at VT and predicted VO$_2$ at VT
5. Measured VO$_2$ at VT vs. Predicted VO$_2$ at VT
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Informed Consent</td>
<td>33</td>
</tr>
<tr>
<td>B. Physical Activity Readiness Questionnaire (PAR-Q)</td>
<td>36</td>
</tr>
<tr>
<td>C. AHA/ACSM Preparticipation Screening Questionnaire</td>
<td>39</td>
</tr>
<tr>
<td>D. NASA Physical Activity Rating (PA-R) Questionnaire</td>
<td>42</td>
</tr>
<tr>
<td>E. Rating of Perceived Exertion (6-20) Scale</td>
<td>44</td>
</tr>
<tr>
<td>F. The Rainbow Passage</td>
<td>46</td>
</tr>
<tr>
<td>G. Review of Literature</td>
<td>48</td>
</tr>
</tbody>
</table>
INTRODUCTION

Currently there is an increased awareness regarding the benefits of exercise training. According to ACSM’s Guidelines for Exercise Testing and Prescription (2017), the frequency, intensity, time (duration), type (mode), volume and progression (FITT-VP principle) should be used for exercise prescription. Intensity is considered the major element in FITT-VP principle.

Historically, the maximal graded exercise testing (GXT) has been the standard test performed in clinical settings under a physician’s supervision. In addition to being useful for diagnosis and prognosis, it provides the data needed to address exercise prescription and to evaluate clinical progress. Maximal graded exercise testing is used to measure or estimate the maximal oxygen consumption (VO₂\text{max}), maximum heart rate (HR max), and ventilatory thresholds (VT); the first ventilatory threshold (VT1 or VT) and the second ventilatory threshold (VT2), the respiratory compensation threshold (RCT) (Mezzani et al., 2012). Although GXT is considered the gold standard for exercise prescription, it has several limitations. One is that it is primarily performed for diagnostic and prognostic purposes rather than for exercise prescription (Myers, Voodi, Umann, & Froelicher, 1989), which requires physician involvement. Also, the use of GXT is limited in individuals who have pain/fatigue or with the presence of contraindications to exercise testing (Noonan & Dean, 2000). Performing GXT is also limited by cost and the availability of suitable equipment and experienced healthcare providers.
To overcome the limitations of GXT and provide a basis for exercise prescription and outcome assessment, it would be useful to find simpler, safer, and lower cost alternatives. Several non-maximal tests have been used to estimate exercise capacity and guide exercise training intensity, including the Talk Test (TT), the Rating of Perceived Exertion (RPE), and Rockport 1-Mile Walk Test (RWT). However, how well these tests measure the same exercise capacity qualities is not established.

The TT is easily conducted by asking the participants to carry on a conversation or read a standard passage at the end of each exercise stage. If the individual can speak comfortably, they are in the lower range of exercise intensity, typically below the VT. If they have some difficulty speaking, this is considered the upper range of exercise intensity, typically above the VT. Numerous studies have been conducted demonstrating the validity of TT as a method for exercise prescription by predicting the VT and RCT in different populations including healthy sedentary individuals (Persinger, Foster, Gibson, Fater & Porcari, 2004; Foster et al., 2009), healthy active individuals (Dehart-Beverley, Foster, Porcari, Fater & Mikat, 2000; Jeans, Foster, Porcari, Gibson & Doberstein, 2011; Woltmann et al., 2015), athletes (Recalde et al., 2002; Rodriguez-Marroyo, Villa, Garcia-Lopez & Foster, 2012), patients with stable cardiovascular disease (Lyon et al., 2014; Brawner et al., 2006; Voelker et al., 2002), and in relation to the ischemic threshold in patients who had exertional ischemia during incremental exercise (Cannon et al., 2004). The TT is frequently measured during a submaximal incremental exercise test using either treadmill or cycle ergometer protocols.

The RPE is a well-known method used for determining, guiding and monitoring the exercise intensity to replace other measures of intensity (Eston, 2012). According to
Eston (2012), the RPE assesses how easy or hard a physical activity feels at any point of time during the exercise. It has been reported the use of RPE in exercise, sport, and rehabilitation is based on its very robust relationship with training intensity (workload) and objective physiological markers (HR, VO$_2$, VT, RCT, & blood lactate). Thus, the RPE can be utilized as a subjective method for evaluating and monitoring training intensity. The two most commonly used RPE scales are the original scale (Borg 6-20 Category Scale) and the modified scale (Borg Category-Ratio-10 Scale (CR-10)) (Borg, 1982). Both scales are widely used in cardiac rehabilitation as methods of gauging exercise intensity, in addition to HR monitoring (Mezzani et al., 2012). Since HR can be variable, especially in patients with atrial fibrillation on medications that affect HR (e.g., beta-blockers), with chronotropic incompetence or with pacemakers, the use of RPE becomes an attractive alternative to HR (Mezzani et al., 2012). An earlier study showed that there was a good correspondence between RPE 13 ‘somewhat hard’ and the VT (Means for females: 13.1 ±0.9, males 14.2± 0.9)(Purvis & Cukiton, 1981).

Because of the strong linear relationship between RPE and VO$_2$, it has been suggested that RPE:VO$_2$ relationship can be utilized to predict the VO$_2$max from submaximal exercise tests. There are two main procedures that can be used to predict VO$_2$max from linear regression: an estimation procedure and a production procedure (Coquart, Garcin, Parfitt, Tourny-Chollet, & Eston, 2014). The estimation procedure is a passive process performed by allowing the individuals to rate their physical exertion using the RPE scale at the end of each submaximal GXT stage. Conversely, the production procedure, referred as a perceptually regulated exercise test (PRET), is an active process in which the individuals self regulate the intensity equivalent to a given
RPE during each stage of an exercise test. By using either estimation or production procedures, an individual linear regression between RPE:VO$_2$ can be extrapolated to the theoretical endpoint at RPE 20 (or RPE 19) in order to predict VO$_2$max (Coquart et al., 2014). Several studies have shown the RPE to be a valid method to estimate the VO$_2$max and to monitor exercise intensity in populations including healthy older adults (Chung, Zhao, Liu & Quach, 2015), healthy participants (Faulkner & Eston, 2007; Lambrick, Faulkner, Rowlands, & Eston, 2009; Faulkner, Lambrick, Parfitt, Rowlands, & Eston, 2009), athletes (Coquart, Eston, Grosbois, & Garcin, 2012), clinical participants (Coquart et al., 2009), and in healthy and clinical populations (Al-Rahamneh & Eston, 2011; Al-Rahamneh, Faulkner, Byrne, and Easton, 2011). Previous studies have confirmed the validity of predicting VO$_2$max from PRET using different RPE ranges in physically active and sedentary individuals (Faulkner, Parfitt, & Eston, 2007; Eston, Lambrick, Sheppard, & Parfitt, 2008; Eston et al., 2012), and healthy physically active individuals (Eston, Lamb, Parfitt, & King, 2005; Eston, Faulker, Mason, & Parfitt, 2006).

The RWT, also known as 1-Mile Walk Test (1-MWT), is a popular submaximal field test used to predict VO$_2$ max among a wide range of age categories and fitness levels (Kline et al., 1987). The RWT is a brisk walking field test performed on a level surface track, for a distance of 1 mile. The RWT was initially developed and cross-validated by Kline et al. (1987), with results dependent on the age, gender, body weight, terminal HR and time required for completion. Dolgener, Hensley, Marsh & Fjelstul (1994) found that the original RWT equation should not be used for young individuals. As a result, an age specific equation for RWT was established to predict VO$_2$max for young individuals.
Several previous studies have shown the validity of estimating VO$_{2\text{max}}$ without exercise testing using personal information collected from a questionnaire and specific equations (Jackson et al., 1990; Matthews, Heil, Freedson, & Pastides, 1999). These questionnaire-based models have been shown to be of equivalent accuracy compared to submaximal exercise tests, particularly field tests such as RWT (Jackson et al., 1990). As an example of these models, Matthews et al. (1999) developed an equation, including age, $\text{age}^2$, gender, physical activity status, height, and body mass to predict VO$_{2\text{max}}$. Therefore non-exercise questionnaire-based predictive equations can reasonably categorize individual fitness levels. Physical activity status was obtained from the NASA Physical Activity Rating (PA-R) questionnaire, which is a questionnaire tool developed at NASA’s Johnson Space Center and has been used to estimate an individual’s fitness level (Ross & Jackson, 1990; Jackson et al., 1990).

Even though these non-maximal tests have been validated by finding relationships between them and physiological markers, there is little data to determine if these methods can be used as a primary outcome measure (ACSM, 2017). There is a lack of evidence comparing these submaximal testing methods simultaneously relative to each other, and if they can be used with no need to perform a maximal GXT. Accordingly, the purpose of this study is to compare three submaximal tests: the TT, the RPE, and the RWT relative to the accuracy of predicting exercise capacity, reflected by VO$_{2\text{max}}$ and VT. The secondary aim was to examine the accuracy of questionnaire-based VO$_{2\text{max}}$ prediction equation (Matthews et al., 1999) compared to maximal as well as submaximal testing. The study was designed to test the hypothesis that there would be no significant difference between the non-maximal methods and the GXT in assessing the exercise
capacity and the non-maximal methods could be used as primary methods for assessing the exercise capacity with no need to perform the GXT.
METHODS

Subjects

The subjects in this study were 20 apparently healthy adults, 8 men and 12 women. The subjects were recruited from the University of Wisconsin-La Crosse community. All subjects were of low to moderate fitness level (no regular physical activity in the three months prior to the study). Prior to testing, there was an introductory session designed to define subjects’ characteristics and to familiarize them to the laboratory setting, exercise testing and equipment that was used. During this session, written informed consent (Appendix A) was provided by the subjects. Subjects then were required to complete the following assessment forms: (1) Physical Activity Readiness Questionnaire (PAR-Q)(Appendix B), (2) AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire (Appendix C) to identify contraindications to exercise testing (3) NASA Physical Activity Rating (PA-R)(Appendix D) to rate the subject’s last month of physical activity on a 0-7 scale. Additionally, the stages of TT as well as the RPE Borg (6-20) scale (Borg, 1982) were explained to subjects. Subjects also were given a copy of the RPE scale (Appendix E), and taught how to use it. The study protocol was approved by the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects.
Experimental Design

Subjects performed three randomly ordered tests with at least 48 hours between tests. The procedures included a maximal test, and three non-maximal tests (test 2 combined the TT and RPE). Tests 1 and 2 were performed using the treadmill using a modified Balke protocol (ACSM, 2017), and test 3 was conducted by walking on the track.

Test 1 was a maximal incremental exercise test to measure VO$_2$max, VT, and RCT. This test was conducted on the treadmill to the point of fatigue, with respiratory gas exchange measurements using open circuit spirometry (AEI, Bastrop, TX). The analyzers were calibrated with reference gases (16% O$_2$, 5% CO$_2$) and room air. The pneumotach was calibrated with a 3-L syringe. Gas analysis data were summated every 30 seconds, and the highest 30 second value was accepted as VO$_2$max. The VT and RCT were determined using both the V slope and ventilatory equivalent methods (Foster & Cotter, 2006; Schneider, Phillips, & Stoffolano, 1993). Heart rate was measured using radiotelemetry (Polar Electro Oy, Port Washington, NY) and summated every 5 seconds. The treadmill velocity/grade were initially set at 3.0 mph/0% grade for 2 minutes, and increased by 2.5% grade every 2 minutes until the subjects became fatigued. The RPE was reported at the end of each 2-minute stage using the Borg (6-20) scale, ranging from 6 (no exertion) to 20 (maximal exertion) (Borg, 1982).

Test 2 was similar to test 1, but without respiratory gas exchange measurement. As an alternative, a submaximal incremental exercise test using the TT and RPE were carried out. During the last 30 seconds of each exercise stage, the TT was performed by instructing the subjects to read a 101-word paragraph, the “Rainbow Passage”, out loud.
Immediately after reading the passage, the subjects were asked “Can you speak comfortably?” There are three possible answers for this question: “Yes” which indicates the positive (POS) stage of the TT, any equivocal or ambiguous expressions like “Yes, but” or “I am not sure”, which indicates the equivocal (EQ) stage, and “No” which indicates the negative (NEG) stage of TT. Based on the findings of previous studies (Persinger et al., 2004; Foster et al., 2009; Dehart-Beverley et al., 2000; Jeans et al., 2011; Woltmann et al., 2015; Rodriguez-Marroyo et al., 2012), the exercise intensity below the VT is indicated as POS stage of the TT, the intensity which approximates the VT is indicated as EQ, and the higher intensity, which is at or above RCT level, is indicated as NEG stage. The stage where the subject could speak comfortably for the last time is called “Last Positive (LP)”. The RPE was assessed during the last 10 seconds of each 2-minute stage, immediately following the TT. The subject kept walking on the treadmill until the NEG stage of TT (or fatigue), and the RPE was recorded until the subject reached or exceeded RPE=15. By using the estimation procedure, these submaximal RPE values reported throughout the exercise test and VO\(_2\) values calculated from metabolic calculations (ACSM, 2017) (VO\(_2\):RPE) were extrapolated to both RPE 19 and RPE 20 in order to estimate VO\(_2\)max (Faulkner et al., 2007; Lambrick, et al., 2009; Faulkner et al., 2009) as shown in Figure 1.

For Test 3, the RWT test was performed on an indoor 200m track (8 laps = 1 mile). The subjects were instructed to “walk briskly” on the flat surface track for 1 mile (1609 meters). At the end of the walk, the time and terminal HR for 1-mile were recorded. VO\(_2\)max was calculated using the Rockport formula: VO\(_2\)max (ml.kg\(^{-1}\).min\(^{-1}\)) = 132.853 + (6.315*gender) - (0.3877*age) - (0.0769*weight) - (3.2649*time) -
(0.1565*final heart rate) where gender = 1 for male, 0 for female, weight in pounds, and time in minutes (Kline et al., 1987).

Figure 1. Example of VO$_2$max prediction using the individual linear regression between RPE $\leq$ 15 and VO$_2$ calculated from metabolic calculations (ACSM, 2017) for one subject. The dotted lines represent extrapolation of the individual RPE $\leq$ 15 : VO$_2$ linear regression to a. RPE 19 (predicted VO$_2$max: 1.81(19) – 1.19 = 33.2 mL.kg.min$^{-1}$), and to b. maximal theoretical RPE (i.e., RPE 20) (predicted VO$_2$max: 1.81(20) – 1.19 = 35 mL.kg.min$^{-1}$).

Additionally, The VO$_2$max was calculated using the non-exercise prediction equation of Matthews et al. (1999): VO$_2$max (ml.kg$^{-1}$.min$^{-1}$) = (0.133× age)-(.005×
age\(^3\)+\((11.403 \times \text{gender})+ (1.463 \times \text{PA-R score})+(9.17 \times \text{height})-\(0.254 \times \text{body mass}\)+34.142, where \text{gender = 1} for male, 0 for female, the height in meters (m) and the body mass in kilograms (kg). The PA-R score was obtained from the NASA PA-R questionnaire (Appendix B).

**Statistical Analysis**

Individual linear regression analysis between the VO\(_2\) values calculated from metabolic calculations (ACSM, 2017) and RPE ≤ 15 values was made for each subject. The resultant equation (\(\text{VO}_2\text{max} = a + b \times \text{RPE} \leq 15\)) was used to extrapolate values from the submaximal estimation procedure to predict \(\text{VO}_2\text{max}\) at RPE 19 and RPE 20 (Figure 1).

As supportive analysis, linear regressions of measured \(\text{VO}_2\text{max}\) versus predicted \(\text{VO}_2\text{max}\) from each of RPE extrapolated, the RWT, and Matthews et al. (1999) equation were computed. Likewise, linear regressions were made between the \(\text{VO}_2\) at VT and the \(\text{VO}_2\) at the LP and EQ stages of TT, and at RPE 13, 14, and 15.

All data was analyzed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA). Standard descriptive statistics were used to assess the baseline physical characteristics of the subjects. Comparisons between measured \(\text{VO}_2\text{max}\) and predicted \(\text{VO}_2\text{max}\), and \(\text{VO}_2\) at VT and predicted \(\text{VO}_2\) at VT were made by using repeated measures analysis of variance (ANOVA). If the ANOVA showed a significant difference between the means (\(p \leq 0.05\)), post hoc analyses were performed using the Tukey honestly significance difference (HSD) test. An alpha level of \(p \leq 0.05\) was considered statistically significant. Pearson product moment correlations between the actual and predicted values was used to make additional analyses.
RESULTS

Descriptive statistics of subject characteristics and maximal exercise test data are presented in Table 1. Initially, there were 21 subjects in the study. One subject’s data was removed due to technical problem during the maximal test when the nose clip was not properly placed, which resulted in leaking of gas. Therefore, twenty subjects completed the study. VO$_2$@RCT was indeterminate in 6 subjects; thus, VO$_2$@RCT and VO$_2$@NEG stage of the TT were not analyzed in the study.

Table 1. Descriptive characteristics of subjects (N=20).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n=8)</th>
<th>Female (n=12)</th>
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<tbody>
<tr>
<td>Age (yrs.)</td>
<td>25.2 ± 7.90</td>
<td>28.3 ± 9.37</td>
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<tr>
<td>Height (cm)</td>
<td>181.5 ± 6.42</td>
<td>164.8 ± 8.67</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>87.3 ± 11.85</td>
<td>66.9 ± 14.80</td>
</tr>
<tr>
<td>VO$_2$max (L.min$^{-1}$)</td>
<td>3.67 ± 0.689</td>
<td>2.33 ± 0.426</td>
</tr>
<tr>
<td>VO$_2$max (mL.kg$^{-1}$.min$^{-1}$)</td>
<td>42.1 ± 5.84</td>
<td>35.5 ± 5.71</td>
</tr>
<tr>
<td>VO$_2$ @ VT (L.min$^{-1}$)</td>
<td>2.55 ± 0.754</td>
<td>1.67 ± 0.373</td>
</tr>
<tr>
<td>VO$_2$@VT (mL.kg$^{-1}$.min$^{-1}$)</td>
<td>29.1 ± 6.38</td>
<td>25.4 ± 4.54</td>
</tr>
<tr>
<td>HRmax (bpm)</td>
<td>175.6 ± 14.64</td>
<td>183.7 ± 10.86</td>
</tr>
<tr>
<td>HR@VT</td>
<td>140.3 ± 22.33</td>
<td>150.9 ± 14.58</td>
</tr>
<tr>
<td>RPE@VT</td>
<td>13.6 ± 1.84</td>
<td>14.0 ± 1.78</td>
</tr>
<tr>
<td>RPEmax</td>
<td>19.2 ± 0.46</td>
<td>19.0 ± 0.28</td>
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Data are reported as mean ± standard deviation
Overall, mean measured VO$_{2\text{max}}$ was 38.1 ± 6.52 mL·kg$^{-1}$·min$^{-1}$ and mean predicted VO$_{2\text{max}}$ was 40.1 ± 6.9, 40.1 ± 7.03, 42.6 ± 7.43 & 40.0 ± 7.8 mL·kg$^{-1}$·min$^{-1}$ for the Matthews et al. (1999) equation, extrapolation to RPE 19, extrapolation to RPE 20 and the RWT equation, respectively (Table 2, Figure 2). Mauchly’s Test of Sphericity was statistically significant (p = 0.00) and thus, the assumption of sphericity was violated. Therefore, the critical F value was corrected using Greenhouse-Geisser estimates of sphericity. The means of the measured VO$_{2\text{max}}$ and predicted VO$_{2\text{max}}$ were compared using a one-way ANOVA with repeated measures. There were significant differences between the measured and predicted VO$_{2\text{max}}$ (p = 0.007). Tukey’s post-hoc test showed that there was no significant difference between measured VO$_{2\text{max}}$ and predicted VO$_{2\text{max}}$ using each of the Matthews et al. (1999) equation, extrapolation to RPE19 and the RWT equation. VO$_{2\text{max}}$ was significantly less than predicted VO$_{2\text{max}}$ using extrapolation to RPE 20 (p≤0.05).

<table>
<thead>
<tr>
<th>Test</th>
<th>Mean ± SD</th>
<th>r</th>
<th>R$^2$</th>
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<tr>
<td>Maximal test (GXT)</td>
<td>38.1 ± 6.52</td>
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<tr>
<td>Matthews et al. equation</td>
<td>40.1 ± 6.91</td>
<td>0.76</td>
<td>0.57</td>
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<tr>
<td>Extrapolation to RPE 20</td>
<td>42.6 ± 7.43*</td>
<td>0.84</td>
<td>0.70</td>
</tr>
<tr>
<td>Extrapolation to RPE 19</td>
<td>40.1 ± 7.03</td>
<td>0.85</td>
<td>0.73</td>
</tr>
<tr>
<td>RWT equation</td>
<td>40.0 ± 7.82</td>
<td>0.71</td>
<td>0.51</td>
</tr>
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r = Pearson product-moment correlation.
R$^2$= Coefficient of determination.
* Significantly different than maximal test (p < 0.05).
Figure 2. Mean (± Standard error (SE)) values for measured VO$_2$max (mL·kg$^{-1}$·min$^{-1}$) in relation to predicted VO$_2$max (mL·kg$^{-1}$·min$^{-1}$) using Matthews et al. (1999) equation, extrapolation to RPE 19 and 20, and RWT original equation. The dashed line represents a referent to the measured VO$_2$max.

Figure 3 shows the relationship between measured VO$_2$max and predicted VO$_2$max using Matthews et al. (1999) equation, extrapolation to RPE 19 and 20, and the RWT original equation presented and given the R$^2$ values. The solid line shows the line of identity. The R$^2$ values indicated a moderate to good correlation between the measured and predicted VO$_2$max, with values of R$^2$ = 0.57, 0.73, 0.70, and 0.51 for Matthews et al. (1999) equation, extrapolation to RPE 19, extrapolation to RPE 20, and the RWT equation, respectively. There was a good correlation between the measured and predicted VO$_2$max values using extrapolation method to RPE 19 and 20. Predicted VO$_2$max values using either Matthews et al. (1999) equation or the RWT equation were moderately correlated with the actual VO$_2$max.
The mean values of the VO$_2$ at VT and VO$_2$ at the LP and EQ stages of the TT, and at the RPE13, 14, and 15 were compared using a one-way ANOVA with repeated measures. Mauchly’s Test of Sphericity was statistically significant ($p = 0.00$) and thus, the assumption of sphericity was violated. Therefore, the critical F value was adjusted using Greenhouse-Geisser estimates of sphericity. Overall, there were significant differences in the VO$_2$ with VT, LP, EQ, RPE13, 14, and 15 ($p = 0.00$). Tukey’s post-hoc test revealed that there was no significant difference ($p > 0.05$) between the VO$_2$ in mL·kg$^{-1}$·min$^{-1}$ at VT (26.9 ± 5.51), the LP (25.7 ± 5.32), and EQ (29.4 ± 5.30) stages of
the TT, and at RPE13 (25.9 ± 5.07) and RPE14 (28.5 ± 5.26). However, the VO₂ at RPE15 (31.0 ± 5.55) was significantly higher than VO₂ at the VT (p < 0.05) (Table 3, Figure 4).

Table 3. Means (± SD) VO₂@VT (ml·kg⁻¹·min⁻¹), VO₂@LP and EQ stages of the TT, and the VO₂@RPE13, RPE14, and RPE15 (ml·kg⁻¹·min⁻¹)

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
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<tr>
<td>VO₂ @VT</td>
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<tr>
<td>VT @ LP</td>
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<td>VT @ RPE13</td>
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</tr>
<tr>
<td>VT @ RPE14</td>
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<tr>
<td>VT @ RPE15</td>
<td>31.0 ± 5.55*</td>
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</tr>
</tbody>
</table>

* Significantly different than VO₂@VT (p < 0.05).

Figure 4. Means (± SE) values for VO₂ at the VT (ml·kg·min⁻¹) in relation to the VO₂ at the LP and EQ stages of the TT, and at the RPE 13,14, and 15. The dashed line represents a referent to the measured VT.
The VO$_2$ at VT was well correlated with the VO$_2$ at the LP ($R^2 = 0.58$) and EQ ($R^2 = 0.59$) stages of the TT, and at the RPE13 ($R^2 = 0.54$), RPE14 ($R^2 = 0.51$) and RPE15 ($R^2 = 0.49$) as shown in Figure 4. The solid line represents the line of identity. The VO$_2$ values at the VT versus the VO$_2$ values at each of the EQ stage of the TT and RPE14 fit very close to the line of identity. Therefore, although the EQ stage of the TT as well as RPE14 slightly overestimated VT, they were very similar to VT. Likewise, the VO$_2$ values at the VT versus the VO$_2$ values at each of the LP stage of the TT and RPE13 fit very close to the line of identity. Although the LP stage of TT as well as RPE 13 slightly underestimated VT, they were very close to VT. Therefore, The LP and EQ stages of the TT as well as PE13 and 14 were relatively accurate predictors for VT. However, the RPE15 was significantly greater compared to VT.
Figure 5. Relationship between the VO$_2$ at VT (ml.kg.min$^{-1}$) and the VO$_2$ during the LP and EQ stages of the TT, and the VO$_2$ at each of RPE 13, RPE 14, and RPE 15 (ml.kg.min$^{-1}$).
DISCUSSION

The overall results of the current study suggest that non-maximal exercise tests can be used as relatively accurate methods for predicting VO$_2$max and VT, at least in healthy, sedentary individuals. The primary findings of this study showed that there were no significant differences between the measured and predicted VO$_2$max using the RWT original equation (Kline et al., 1987) and extrapolation to RPE 19. The extrapolation to RPE 20 method overestimated VO$_2$max. The LP and EQ stage of the TT as well as RPE13 and RPE 14 can be used interchangeably as accurate predictors of VT. The secondary finding of this study showed that a questionnaire-based VO$_2$max prediction equation (or non-exercise VO$_2$max prediction model) using the prediction equation of Mathews et al. (1999) could be used to reasonably predict the VO$_2$max and characterize the fitness level by using the activity score from NASA PA-R questionnaire (Jackson et al., 1990), (Appendix D). There were no significant differences between the predicted VO$_2$max using either the extrapolation to RPE 19, the RWT original equation or the prediction equation of Matthews et al. (1999) and measured VO$_2$max. There were also no significant differences in the predicted VO$_2$max values using each of the RWT, the Matthews et al. (1999) equation, and the RPE estimation procedure using both RPE 19 and 20 as end points.
The results of the current study confirmed that the TT is a valuable method that can be used to accurately predict the VT. Although the VO\(_2\) at VT was not significantly different than the VO\(_2\) at either the LP or EQ stages of the TT (\(p > 0.05\)), the EQ stage was more closely correlated with VT and the LP is slightly lower than VT (VT: 26.9 ± 5.51; LP: 25.7 ± 5.32; EQ: 29.4 ± 5.30 ml·kg\(^{-1}\)·min\(^{-1}\)). These results are in accordance with previous studies that have also observed that the EQ stage of the TT can be used as a surrogate of the VT in different populations including apparently healthy sedentary individuals (Persinger et al., 2004; Foster et al., 2009), physically active individuals (Dehart-Beverly et al., 2000; Jeans et al., 2011; Woltmann et al., 2015), well-trained endurance athletes (Recalde et al., 2002), highly trained cyclists (Rodriguez-Marroyo et al., 2012), and patients with cardiovascular disease (Brawner et al., 2006; Voelker et al., 2002; Cannon et al., 2004). We conclude that when subjects were at the LP or EQ stage of the TT, that they were very close to VT. However, when subjects were at the NEG stage of the TT, they were consistently above VT.

Interestingly, when the 6-20 RPE scale was used in conjunction with the TT, the results from the current study showed the relationship between the different stages of the TT (LP and EQ) and the RPE 13, 14, and 15 in predicting the VT. Even though the findings yielded a relatively high correlation between that VO\(_2\) at VT and VO\(_2\) at each of the TT stages (LP and EQ) and at the RPE 13, 14, and 15 (see Figure 4), the VO\(_2\) at the EQ stage of the TT as well as at the RPE 14 were close to the measured VO\(_2\) at VT even though they were slightly overestimated the VT (VT: 26.9 ± 5.51 versus. EQ: 29.4 ± 5.30 & RPE 14: 28.5 ± 5.26 ml·kg\(^{-1}\)·min\(^{-1}\)). This means that when subjects first showed any ambiguity in their ability to speak comfortably (EQ stage of the TT), or when they were
exercising at an RPE 14, they were very close to the VT. Exercising at the LP stage of the TT as well as RPE 13 slightly underestimated the VT, but they fit very close to VT (measured VT: 26.9 ± 5.51 versus. LP: 25.7 ± 5.32 & RPE 13: 25.9 ± 5.07 ml·kg⁻¹·min⁻¹). However, exercising at RPE 15 significantly overestimated the VT (VT: 26.9 ± 5.51 versus RPE15: 31.0 ± 5.55 ml·kg⁻¹·min⁻¹). The current results agree with the study of Purvis & Cukiton (1981) which indicated a good correlation between the VO₂ at VT and VO₂ at RPE 13 ‘somewhat hard’. One previous study discussed the relationship between VO₂ at VT, at the TT stages, and at the RPE 3 and 4 (using the Borg CR-10 scale) in clinically stable patients with cardiovascular disease (Voelker et al., 2002). This study showed that VO₂ at VT was moderately correlated with VO₂ at RPE 3 and RPE 4 (r = 0.60 and 0.66, respectively). It has shown that there were no significant differences between the VO₂ at VT and VO₂ at the LP and EQ stages of TT and at the RPE 3 and 4 (VO₂ (L·min⁻¹) at VT: 1.4 ± 0.14; LP: 1.33 ± 012; EQ: 1.61 ± 0.14; RPE 3: 1.04 ± 0.10; and RPE 4: 1.39 ± 0.16). By reviewing the literature to find relevant results, there is a lack of prior research studies on the relationship between TT stages and RPE (Borg 6-20) scale. Therefore further research needs to be done to reinforce the finding of the current study by using the RPE Borg (6-20) scale.

The results from the current study also indicated that the estimation procedure using the RPE Borg 6-20 scale for prediction of VO₂max by extrapolating RPE values (RPEs ≤ 15) to RPE 19 was not significantly different to measured VO₂max. However, extrapolation to the theoretical VO₂max at RPE 20 was significantly different than the measured VO₂max (Means of measured VO₂max: 38.1 ± 6.52, and predicted VO₂max from RPE19: 40.1 ± 7.03 and from RPE 20: 42.6 ± 7.43 ml·kg⁻¹·min⁻¹). The findings of
the current study are in agreement with previous studies in healthy participants (Faulkner et al., 2007; Lambrick et al., 2009; Faulkner et al., 2009) and competitive cyclists (Coquart et al., 2012), which showed no significant difference between the actual and predicted VO\(_2\)max when the VO\(_2\) : RPE values were extrapolated to RPE 19. However, Lambrick et al. (2009) and Faulkner et al. (2009) found that there was no significant difference between the actual and predicted VO\(_2\)max when the VO\(_2\) : RPE ≤ 13 values were extrapolated to either RPE 19 or RPE 20 as endpoint.

Adversely, the current study showed that extrapolation to RPE 20 overestimated VO\(_2\)max by 4.5 ml.kg.min\(^{-1}\). This finding is in opposition to previous studies, which used estimation procedures to predict VO\(_2\)max by extrapolation to RPE 20 and found there was no significant difference between the measured and predicted VO\(_2\)max in clinical participants (Coquart et al., 2009), and in healthy and clinical participants (Al-Rahamneh et al., 2011; Al-Rahamneh et al., 2010). The opposing finding observed in the current study when the VO\(_2\) : RPE ≤ 15 extrapolated to RPE 20 may be due to differences in the exercise test protocol and the modality used. For the current study, a GXT was used to determine the actual VO\(_2\)max and an incremental treadmill exercise test (without gas exchange measurements) was used to predict VO\(_2\)max from extrapolated RPE. However, previous studies mostly used a single GXT or ramp exercise test with gas exchange measurements to determine the actual and predicted VO\(_2\)max from extrapolated RPE. The other possible explanation for this unfavorable result of RPE extrapolation to RPE 20 in the current study is the perceptual end point of extrapolation (RPE 20). Although the RPE 20 is theoretically considered the point of maximal effort or exhaustion at exercise endpoint, a submaximal RPE, specifically RPE 19, is more often observed (Demello,
Cureton, Boineau, & Singh, 1987; Coquart et al., 2012; Eston et al., 2007). Likewise in the current study, 17 of 20 subjects (85%) reported RPE 19 and only 3 of 20 subjects (15%) reported RPE 20 at the end of testing. In this regard, it has earlier been suggested that the brain increases RPE consistently with the residual time to the end of the test, and the time to fatigue relates to the reasonably tolerated maximal RPE (i.e., RPE 19 rather than RPE 20) (Eston et al., 2007; Coquart et al., 2012; Noakes, 2004). The results of the current study (extrapolation to RPE 19 and 20) are in agreement with some studies, which used the PRET (Eston et al., 2012; Smith, Eston, Norton, & Parfitt, 2015). These studies revealed that predicting VO_{2}max by extrapolating RPE:VO_{2} values to RPE 19 during PRET is more accurate compared to RPE 20. Accordingly, based upon the results of the current study, in addition to the previous results, the RPE extrapolated to RPE19 during estimation procedures results in a more accurate prediction of VO_{2}max than extrapolation to RPE 20.

The current study revealed that measured VO_{2}max was not significantly different than predicted VO_{2}max using the RWT original equation. The results yielded a relatively good correlation (r = 0.71) and low standard of estimate (SEE = 4.6 ml\text{kg}^{-1}\text{min}^{-1}) between the actual VO_{2}max and the predicted VO_{2}max values using the original RWT equation, which is in accordance with the finding of Kline et al. (1987). When the Kline et al. (1987) prediction equation for VO_{2}max was compared to measured VO_{2}max, the correlations between the measured and predicted VO_{2}max for the validation and cross validation groups were strong (r = 0.88 and 0.88, respectively), and the SEE = 5.0 and 4.4 ml\text{kg}^{-1}\text{min}^{-1}, respectively. Consequently, the results showed that there were no significant differences between the measured and predicted VO_{2}max values. The better
results from Kline et al. (1987) study could be attributable to a large sample size (343 subjects) and a wider range of subject ages (30-69 yrs.). Another possible reason could be the testing procedure in Kline et al. (1987) which allowed the subjects to do several walks (at least 2 walks) and then the two fastest walks within 30 s of each other were used. This helped the subjects to find a suitable speed and to familiarize themselves with the test. Conversely, the current study recruited a small sample size (20 subjects), most of them were young adult subjects (18-32 yrs.) and just 4 of 20 subjects were in the range of 37-50 yrs. The RWT in the current study was performed only once for each subject. Although an age specific equation developed by Dolgener et al. (1994) might be more appropriate many of the subjects in the current study, it is only applicable for a narrow range of ages (18 – 30 years), which limits its use, and makes the original equation more attractive. The original equation is relatively accurate using age, gender, weight, height, time and terminal HR. However, HR can be highly variable depending on several factors such as age, medications, and individual variability. Therefore, there is a need to find alternative variable to HR. In this regard, a recent study was conducted by Cress et al. (2015) to develop equations to predict maxMETs and METs at VT in cardiac rehabilitation patients using the 6-Minute Walk Test (6 MWT). This equation used only two dependent variables: the distance of 6 MWT and terminal RPE. The results showed a strong correlation between the measured and predicted maxMETs (r = 0.87, SEE = 1.17 METs), and METs at VT (r = 0.82, SEE = 1.05 METs). As a result, a protocol was developed for 6 MWT which accurately predicts the maxMET and METs at VT from distance and RPE. Further research needs to be done to find accurate alternative protocols for the RWT.
An impressive secondary result for the current study showed that a non-exercise VO\textsubscript{2}\text{max} prediction model as using the prediction equation of Mathews et al. (1999) could be used to reasonably characterize the individual’s overall fitness level. The results showed that there was no significant difference between measured and predicted VO\textsubscript{2}\text{max} using Matthews et al. (1999) equation (r = 0.76, SEE = 4.3 ml\text{kg}\textsuperscript{-1}\text{min}\textsuperscript{-1}). This finding is in accordance with the results of Matthews et al. (1999), which showed a relatively higher r value but a slightly larger SEE than the current study (r = 0.86, SEE = 5.7 ml\text{kg}\textsuperscript{-1}\text{min}\textsuperscript{-1}). Again, the higher correlation in Matthews et al. (1999) study was because of the very large sample size (N = 799, healthy adults) with a wide range of ages (19 – 79 yrs). It showed that approximately 83% of all subjects were classified correctly by the prediction equation. Thus, the Matthews et al. (1999) equation is a good equation that can reasonably predict the VO\textsubscript{2}\text{max} without the need for exercise testing using data. Further studies would be useful in determining the accuracy of using this equation in different populations (e.g., cardiac patients and highly trained athletes).

There were some technical limitations in our study. For the TT, a frequent concern during the test was the subjects’ ability to correctly determine the EQ stage of TT. Another technical issue that may have had an impact on the interpretation of TT results in the current study was reading a relatively long and non-realistic passage “The Rainbow passage” in a short exercise stage duration (2 minutes). “The Pledge of Allegiance” is only 31 words and widely used in previous studies because of its simplicity and familiarity among Americans; hence it is not necessary to use a cue card throughout testing. However, a recent study (Schroeder, Foster, Porcari, & Mikat, 2017) compared using different speech passages length (31 versus 62 versus 93 words) on the TT stages.
It found that longer speech passages were most accurately predicted VT and RCT using the EQ and NEG stages of the TT. Another study was carried out by Xiong et al. (2015) to examine the effect of stage duration on the TT and gas exchange thresholds (VT and RCT). Results pointed out that stage duration affected the power output in the VT and RCT, but had no effect on the other physiological markers (HR, VO2, RPE). In our study, the LP stage of the TT was better correlated with the VT. This suggests the need for further research to indicate the stage duration that most precisely predicts the VT and RCT, accompanied using longer speech passage. In using the Borg 6-20 RPE scale, 12 of 20 our subjects (60%) had no prior experience of subjectively rating their physical effort with the RPE scale. Consequently, some subjects found it difficult to identify appropriate RPE at the end of each stage even though they had been taught and familiarized with using the scale during the introductory session. For this reason, it would be applicable to give subjects enough time by performing several trials in using the RPE scale and the last trial would possibly be the most accurate prediction (e.g., trial 1 vs. trial 2 vs. trial 3). Some subjects, particularly those who had experienced the RPE scale, seemed to underestimate RPE, although they were working hard, which can lead to overestimation of the VO2max.
CONCLUSION

The present study compared the accuracy of three non-maximal tests, the TT, RPE extrapolated, and the RWT, in predicting the exercise capacity based on VO₂max and VT. The results of the study support our hypothesis that the non-maximal exercise tests could be used as primary methods for providing reasonably accurate prediction of VO₂max and VT needed for exercise prescription as well as outcome assessment. Additionally, the non-exercise prediction models are of comparable accuracy to the non-maximal exercise test. These models are useful tools in classifying the fitness level when the exercise testing is not feasible. Based upon the results of this study, future studies are required to further support the present results by examining the accuracy of predictions of physiological markers (VO₂max and VT) provided by non-maximal exercise tests and non-exercise prediction models in different populations. Further studies on the prediction of VO₂max from RPE methods are needed to provide the most accurate measurement tools and RPE ranges for prediction. Lastly, the present subjects’ data will be added to a future research study performed at UWL in order to prepare an accurate adaptive protocol for the RWT, similar to that used by Cress et al. (2015).
REFERENCES


APPENDIX A

INFORMED CONSENT
INFORMED CONSENT FOR:

“Comparison of Submaximal Tests for Exercise Prescription and Outcome Assessment”

Principal Investigator: Reem Alajmi
3191 East Avenue South #4
La Crosse, WI  54601
608-433-8467

Emergency Contact:  Carl Foster, Ph.D.
133 Mitchell Hall
608-785-8687

1. I, __________________________, give my informed consent to participate in this study designed to compare three widely used submaximal tests designed for exercise prescription and outcome assessment against the gold standard maximal test. I have been informed that the study is under the direction of Carl Foster, Ph.D. who is a Professor in the Department of Exercise and Sport Science at the University of Wisconsin-La Crosse. I consent to the presentation, publication and other release of summary data from the study which is not individually identifiable.

2. I have been informed that my participation in this study will require me to:
   a) Perform, on 2 occasions, either progressively harder workloads on a treadmill to the point where I can’t talk comfortably and/or perceive the work to be hard, or walk a mile as quickly as possible.
   b) In another test on the treadmill, I will exercise progressively harder until I am fatigued, while breathing through a scuba breathing value that allows the investigators to measure my metabolic rate.
   c) Wear a chest strap that transmits my heart rate via radio waves to a specialized wristwatch.

3. I have been informed that there are no foreseeable risks associated with this study other than the fatigue associated with heavy exercise and the discomfort wearing the breathing value.

4. I have been informed that there are no primary benefits to myself other than knowledge about my fitness. Based on the results of this study, exercise professionals may be able to better guide the training of exercisers.
5. I have been informed that the investigator will answer questions regarding the procedures throughout the course of study.

6. I have been informed that I am free to decline to participate or to withdraw from the study at any time without penalty.

7. Concerns about any aspects of this study may be referred to the principal investigator (Reem Alajmi, 608-433-8467) or her faculty advisor (Dr. Carl Foster, 608-785-8687). Questions about the protection of human subjects may be addressed to the Chair of the UW-L Institutional Review Board for the Protection of Human Subjects, (608-785-6892).

________________________________________________________  ______________________________
Participant Name (Please Print)          Signature           Date

________________________________________________________  ______________________________
Investigator Name (Please Print)         Signature           Date
APPENDIX B

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)
Physical Activity Readiness Questionnaire (PAR-Q) and You

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

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

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

<table>
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</table>
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.

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)
APPENDIX C

AHA/ACSM PREPARTICIPATION SCREENING QUESTIONNAIRE
AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire

Assess your health status by marking all true statements

History
You have had:

- a heart attack
- heart surgery
- cardiac catheterization coronary angioplasty (PTCA)
- Pacemaker/implantable cardiac defibrillator
- rhythm disturbance
- heart valve disease
- heart failure
- heart transplantation
- congenital heart disease

Symptoms:

- You experience chest discomfort with exertion.
- You experience unreasonable breathlessness
- You experience dizziness, fainting, or blackouts
- You take heart medications

Other health issues:

- You have diabetes
- You have asthma or other lung disease
- You have burning or cramping sensation in your lower legs when walking short distances
- You have musculoskeletal problems that limit your physical activity.
- You have concerns about the safety of exercise
- You take prescription medication(s).
- You are pregnant.

If you marked any of these statements in this section, consult your physician or other appropriate health care provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

Cardiovascular risk factors

- You are a man older than 45 years.
- You are a woman older than 55 years, have had a hysterectomy, or are postmenopausal
- You smoke, or quit smoking within the previous 6 months.
- Your blood pressure is >140/90 mm Hg.
- You do not know your blood pressure.
- You take blood pressure medication.
- Your blood cholesterol level is >200 mg/dl.
You do not know your cholesterol level.

You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister).

You are physically inactive (i.e., you get <30 minutes of physical activity on at least 3 days per week).

You are >20 pounds overweight

If you marked two or more of the statements in this section you should consult your physician or other appropriate health care provider before engaging in exercise. You might benefit from using a facility with a professionally qualified exercise staff to guide your exercise Program.

None of the above

You should be able to exercise safely without consulting your physician or other appropriate health care provider in a self-guided program or almost any facility that meets your exercise program needs.

APPENDIX D

NASA PHYSICAL ACTIVITY RATING (PA-R) QUESTIONNAIRE
Name of Subject: _____________________ Date: ____________________________

NASA Physical Activity Rating (PA-R)

Use the number (0 to 7) that best describes your general activity level for the previous month.

○ Do not participate regularly in programmed recreation sport or heavy physical activity
  0 Avoid walking or exertion, for example, always use elevator, drive whenever possible instead of walking.
  1 Walk for pleasure, routinely use stairs, occasionally exercise sufficiently to cause heavy breathing or perspiration.

○ Participate regularly in recreation or work requiring modest physical activity, such as golf, horseback riding, calisthetics, gymnastics, table tennis, bowling, weightlifting, yard work.
  2 10 to 60 minutes per week
  3 Over 60 minutes per week

○ Participate regularly in heavy physical exertion such as running or jogging, swimming, cycling, rowing, skipping rope, running in place or engaging in vigorous aerobic activity exercise such as tennis, basketball, or handball.
  4 Run less than 1 mile (1.6 kilometers) per week or spend less than 30 minutes per week in comparable physical activity
  5 Run less than 1 to 5 miles (1.6 to 8 kilometers) per week or spend 30 to 60 minutes per week in comparable physical activity
  6 Run less than 5 to 10 miles (8 to 16 kilometers) per week or spend 1 hour to 3 hours per week in comparable physical activity
  7 Run over 10 miles (16 kilometers) per week or spend over 3 hours per week in comparable physical activity

Predicted VO₂max (ml.kg⁻¹.min⁻¹) = (0.133× age)-(0.005× age²)+(11.403× gender)+
(1.463× PA-R score)+(9.17× height)-(0.254× body mass)+34.142

APPENDIX E

RATING OF PERCEIVED EXERTION (6-20) SCALE
### Rating of Perceived Exertion (6-20) Scale

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<tr>
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APPENDIX F

THE RAINBOW PASSAGE
THE RAINBOW PASSAGE

"When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow."
APPENDIX G

REVIEW OF LITERATURE
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Introduction

Nowadays there is an increased awareness regarding the benefits of exercise training for healthy lifestyle and preventing chronic diseases. It has been shown that the rate of mortality and the risk of developing chronic diseases (e.g., diabetes, hypertension & cancer) are slowed when people alter to become more active (ACSM, 2014).

Before initiating any training program, the individuals should ideally undergo a comprehensive health screening and complete a well-designed exercise prescription. According to ACSM’s Guidelines for Exercise Testing and Prescription (2014), the frequency, intensity, time (duration), type (mode), volume and progression (FITT-VP principle) should be used for exercise prescription. Intensity is considered the major element in FITT-VP principle. Unfortunately, most people don’t know their appropriate exercise intensity level, which can either lead to ineffective exercise programs or to complications during exercise. It has been reported that beginners in any training program are at high risk of complications due to improper exercise leadership (Foster & Porcari, 2001).

ACSM (2014) has identified several predictive methods frequently used to define the exercise intensity, such as percent age-predicted maximum heart rate (HR_{max}), heart rate reserve (HRR), oxygen uptake reserve (VO_{2R}), percent maximal oxygen uptake (VO_{2}) metabolic equivalent ((MET), the Rating of Perceived Exertion (RPE), the omnibus RPE scale (OMNI), the Talk Test (TT), and Feeling Scale. In fact, %VO_{2R} and
%HRR are mostly recommended as objective methods for exercise prescription because the percent HR or VO₂ methods can underestimate or overestimate the actual exercise intensity (ACSM, 2014). Katch, Weltman, Sady, & Freedson (1978) reported that predictive percent HR&VO₂ formulas are not accurate methods for estimating the exercise intensity, so they need a re-assessment. However, the usage of %VO₂R or %HRR methods is not completely universal, and the accuracy of these methods is affected by the mode of measurement utilized. Therefore, the direct measurement for determination of HRₘₐₓ & VO₂ₘₐₓ through the maximal testing is the most accurate method.

**Maximal Exercise Testing**

Maximal Graded Exercise testing (GXT) is the standard test performed in the clinical settings under physician’s supervision. It provides the initial data needed to address exercise prescription. It is also utilized to evaluate the progression achieved by individuals. GXT is used to measure the maximal oxygen consumption (VO₂ₘₐₓ), maximum heart rate (HRₘₐₓ), and ventilator threshold (VT) (Mezzani et al, 2012).

Although GXT is considered as the basis for exercise prescription, it has several limitations. One is that it is mostly performed for diagnostic and prognostic purposes in patients rather than for exercise prescription. According to a survey applied to many healthcare organizations by Myers, Voodi, Umann, & Froelicher (1989), the most common indications for performing the maximal exercise testing were diagnosis and prognosis of cardiac patients or of patients at risk of having cardiovascular diseases (60%) and for preoperative assessment (10%). Less common indications were for evaluation after myocardial infarction (MI)(8.4%), and only minimally evaluation for
exercise prescription (7.1%). In addition, the use of GXT is limited in individuals whose physical performances are affected by pain or fatigue and the presence of contraindications to exercise testing (Noonan & Dean, 2000). Performing GXT at clinics is also limited by the high cost, availability of suitable equipment and experienced healthcare providers. Gibbons et al (1989) reported that even though the maximal exercise testing has a good safety record, contraindications should be recognized. The test is conducted using proper equipment and protocols, and having experienced staff perform the test. According to American Heart Association (AHA) scientific statement (2009), maximal GXT is generally considered as safe procedure, but there is possibility for complications occurred during or after the test. The rate of serous events or death is around 1 of every 10,000 tests (Myers et al., 2009).

To overcome the limitations of maximal testing, it would be beneficial to find a simpler, safer, and lower cost alternatives to GXT. Several submaximal tests can be used to estimate and guide the exercise intensity during training, including the Talk Test (TT), Borg Rating of Perceived Exertion (RPE) and Rockport 1 Mile Walk Test, and used as outcome measures to evaluate progress in exercise programs.

Talk Test (TT)

The TT has been accepted as a simple alternative for the maximal GXT. The TT is simply conducted by asking the participants to carry on a conversation or to read a passage at the end of each exercise stage. If the individual can speak comfortably, they are in the lower range of exercise intensity below the ventilatory threshold (VT). If they have some difficulty speaking, this is considered as the upper range of appropriate exercise intensity, approximating the VT. Professor Grayson established the concept of
TT in 1937. While mountain climbing in Scotland, the climbers were instructed to “climb no faster than you can talk” (Goode, Mertens, Shaiman, & Mertens, 1998). Goode et al. (1998) pointed out if the exercising individuals can “hear their breathing”, they are exercising at optimal levels of training intensity, equal 60-90% of $HR_{max}$.

Numerous studies have been conducted demonstrating the validity of TT as a method for exercise prescription by predicting the VT and respiratory compensation threshold (RCT) in different populations including healthy sedentary individuals (Persinger, Foster, Gibson, Fater & Porcari, 2004; Foster et al., 2009), healthy active individuals (Dehart-Beverley, Foster, Porcari, Fater & Mikat, 2000; Jeans, Foster, Porcari, Gibson & Doberstein, 2011; Woltmann et al., 2015), and athletes (Recalde et al., 2002; Rodriguez-Marroyo, Villa, Garcia-Lopez & Foster, 2013), patients with stable cardiovascular disease (Voelker et al., 2002), and by predicting the ischemic threshold in patients who had exertional ischemia during incremental exercise (Cannon et al., 2004). The TT is frequently obtained from a submaximal incremental exercise test using either treadmill or cycle ergometer protocols. At the end of each stage, the subject is asked to read a standard paragraph out loud. (The Pledge of Allegiance) (31 words) has mostly used in these studies because it is well known among Americans. However, recent evidence (Foss, 2016) suggests that longer speech passages are more accurate. After reading the passage out loud, the subject is asked to answer the question “Can you speak comfortably?” There are three possible answers for this question: “Yes” which indicates the positive (POS) stage of the TT, “Yes, but...” or any equivocal or ambiguous expressions, which indicates the equivocal (EQ) stage, and “No” which indicates the negative (NEG) stage.
Several studies have found the correlation of the TT with the VT and RCT. In 2000, Dehart-Beverley et al. determined the relationship between the TT and VT in healthy active individuals. Twenty-eight healthy individuals performed two maximal exercise tests (gas exchange for VT, and without gas exchange for the TT). The results showed that the relation between VO\(_2\) at VT and the VO\(_2\) at the EQ stage was similar, and concluded that the individuals’ POS stage of the TT was just at or below their VT. The NEG stage exceeded the VT. Thus, the TT was considered as valid and subjective method for exercise prescription.

Some studies were designed to determine the reduced absolute intensity from the submaximal incremental exercise test utilizing the TT to provide the suitable absolute steady-state exercise intensity for healthy sedentary individuals (Foster, 2009), cardiac rehabilitation patients (Lyon et al., 2014) & well-trained individuals (Jeans et al., 2011; Woltmann et al., 2015). In Lyon et al. (2014), at the beginning, patients carried out the TT using incremental exercise test utilizing treadmill or bicycle ergometer depending on the patient’s physical capability and choice. The uppermost stage where the patients could speak easily was called “Last Positive (LP)”, and the two stages prior to this stage were called “LP-1 & LP-2” Then, three steady-state exercise bouts of 20 minutes each were performed by patients randomly at the LP, LP-1&LP-2 absolute intensity from the incremental exercise test. Three parameters were measured every 5 minutes of exercises: Ability to speak, HR&RPE. The results showed that the exercise intensity obtained from the incremental exercise test using the TT could be smoothly and practically translated into absolute intensity for steady-state exercises in cardiac rehabilitation patients, and the suitable training intensity for cardiac patients is below the LP stage. In Jeans et al. (2011),
well-trained subjects did two incremental and three steady-state exercise bouts of 40 minutes each at the LP-1, LP& EQ stages of the TT. The end result of this study showed that the training’s recommended values of % HR_{max} & RPE were achieved at the LP-1 & LP stages, but those values were higher and undesirable in the EQ stage. They concluded that the suitable absolute exercise intensity of steady-state training for athletes and well-trained individuals are at LP-1 & LP stages of incremental exercises test using the TT.

Based on the results of previous studies, a recent study was conducted by Woltmann et al. (2015) to examine the possibility of just utilizing the TT alone to adjust the exercise intensity. Sixteen healthy, active subjects performed two maximal incremental exercise tests (respiratory gas exchange (VT, RCT&VO_{2max}), and the TT). Depending on the TT results, the subjects were assigned randomly to do three steady states runs at different speeds that matched the LP, EQ, and NEG stages, and then the results were compared with the three basic intensity indicators (HR, blood lactate &RPE). The findings of this study pointed out that all subjects completed the LP stage, 13 of 16 completed the EQ, and 12 of 16 completed the NEG stage. Thus, there was a good correlation between the actual physiological intensity indicators and the ones predicted from the TT, which indicated that the TT can be used by itself for adjusting exercise intensity. The study concluded that exercise intensity at LP was suitable for healthy individuals and for prolonged and recovery sessions in athletes, while the EQ & NEG could be used for high intensity sessions in athletes.

**Rating of Perceived Exertion (RPE)**

Rating of Perceived Exertion (RPE) is a well-known method used for determining and guiding the exercise intensity in cardiac rehabilitation (Mezzani et al, 2012). It was
initially developed by Swedish psychologist Gunnar Borg (Borg, 1970). There are numerous studies in the exercise and sport science literature using the RPE.

According to Eston (2012), the RPE gives the individuals the chance to assess how easy or hard a physical activity feels at any point of time during the exercise. It is affected by multiple factors: Psychological, circumstantial, and environmental factors. It has been reported that utilizing RPE in the exercise, sport, and rehabilitation is based on its robust relationship with training intensity and physiological markers (HR, VT, VO₂, & blood lactate). Thus, the RPE is utilized as a subjective method for evaluating and guiding the training intensity. It can also be used to regulate exercise intensity of different types of exercises. The two most commonly used RPE scales are the original scale “the Borg 6-20 Category Scale”, and the modified scale “the Borg Category-Ratio-10 scale (CR-10)”

Several studies have accepted the RPE as a valid submaximal test to estimate, monitor and guide the exercise intensity in various population including healthy older adults (Chung, Zhao, Liu & Quach, 2015), young athletes (Manoel et al, 2016), healthy sedentary individuals (Eston, Lambrick, Sheppard & Parfitt, 2008), physically active individuals (Al-Rahamneh & Eston, 2011; Madrid et al, 2016), and cardiac rehabilitation patients (Klinger, McConnell & Gardner, 2001). These studies confirmed the validity of RPE scale based on its linear relation with HR and VO₂ during exercise testing and aerobic exercises.

**Rockport Walking Test (RWT)**

The Rockport Walking Test (RWT), also known as 1-Mile Walk Test (1-MWT), is also a popular submaximal field test used to predict VO₂ max among wide range of age
categories and fitness levels (Noonan & Dean, 2000). RWT is a fast walking field test performed on a flat surface track for distance of 1 mile.

The RWT was initially validated and cross-validated by Kline et al. (1987), based on large number of subjects aged 30 to 69 years (390 healthy subjects representing 183 males & 207 females). Each subject did at least two RFWT within 30 days of each other. All subjects completed a VO$_{2\text{max}}$ test using a treadmill. Depending on the age, gender, body weight, HR and time, six equations were developed for predicting VO$_{2\text{max}}$ in L/min and ml/kg/min. The original RWT equation was established to be adequate to predict VO$_{2\text{max}}$ [VO$_{2\text{max}}$ (ml/kg/min) = 132.853 + (6.315*gender) - (0.3877*age) - (0.0769*weight) - (3.2649*time) - (0.1565*final heart rate) where gender = 1 for male, 0 for female, weight in pounds, and time in minutes](R = 0.88, SEE = 4.4 ml kg$^{-1}$ min$^{-1}$). The study concluded that RWT is a simple, practical, safe and applicable field-test for wide range of populations.

Dolgener, Hensley, Marsh & Fjelstul (1994) performed a study to compare the actual VO$_{2\text{max}}$ and predicted VO$_{2\text{max}}$ in college men and women using the equation of Kline et al. (1987). The study showed that Kline et al. equation overestimated the VO$_{2\text{max}}$ in men and women by 16-18% and 22-23%, respectively. A subsequent, age-specific equation for RWT was established to predict VO$_{2\text{max}}$ for young individuals [VO$_{2\text{max}}$ (ml/kg/min) = 88.768 + (8.892*gender) - (0.0957*weight) - (1.4537*time) - (0.1194*HR)]. The study concluded that the original RWT equation should not be used for young individuals.

The RWT requires a measured track, stopwatch and HR monitor. The participant is required to walk as fast as possible, for 1 mile (1609 meters (m)). It is ideal to maintain
a constant speed throughout the test. At the end of walk, the time for 1-mile walking is recorded in minutes as well as HR at the end of exercise. VO\textsubscript{2max} is calculated using the original or modified formulas.

A recent study was conducted by Fry (2015) to cross validate new RWT equations which used terminal RPE to accurately estimate VO\textsubscript{2max} \[\text{Predicted VO}_{2\text{max}} = (31.142 - ((1.13 \times \text{Walk Time}) - (0.305(\text{terminal RPE})))\] and VO\textsubscript{2} at VT \[\text{VO}_2 \text{ at VT} = (28.169 - (1.117 \times \text{Walk Time}) - (0.295 \times \text{terminal RPE})) \times 3.5\]. There were 89 subjects. All subjects performed two tests: a VO\textsubscript{2max} test on treadmill and a RWT. The subjects were divided into two groups: the validation group (71 subjects) and cross validation group (18 subjects). The results pointed out that there were no significant differences between the two groups, and concluded that equations performed to predict VO\textsubscript{2max} \(R^2 = 0.4859\); SEE = 6.76 ml kg\(^{-1}\) min\(^{-1}\)) and VO\textsubscript{2} at VT \(R^2 = 0.51\); SEE = 6.3 ml kg\(^{-1}\) min\(^{-1}\)) can be achieved accurately by just using the walking time of RWT and RPE. The new equations have lower \(R^2\) and higher SEE than the original equation \(R^2 = 0.7744\); SEE = 4.4 ml kg\(^{-1}\) min\(^{-1}\)), which means that new equations need working more on the data correlation. However, the new equations have less requirements (walking time & terminal RPE) than the original equation, so they are easy to calculate the predicted VO\textsubscript{2max} than the original equation.

In addition, Sonnek (2015) conducted a study to find a predictor equation for METs at VT using the 1-mile walk time and RPE on 71 subjects. As a result, stepwise regression was used to establish the equation \[\text{METs at VT} = 28.169 - (1.117 \times \text{Walk time}) - (0.295 \times \text{final RPE})\], \(R^2 = 0.51\) and SEE = 1.8 METs which was found as an accurate method to predict METs at VT. Moreover, it has been reported that adding RPE to the
new equation $[\text{Max METs} = 31.142(1.13 - \text{Walk Time}) - (0.305 \times \text{terminal RPE}), \text{SEE}=1.93 \text{ METs} \& \text{ R value}=0.697]$, which included just the walk time, significantly improve predicting max METs. This study pointed out that there is no significant difference between the new equation and the original equation in predicting the max METs with R value of 0.697 and 0.727, respectively (Beauchene, 2015).

Another study performed by Cress et al. (2015) to develop equations which used the distance of 6-Minute Walk Test (6MWT) and RPE to predict maxMETs and METs at VT in cardiac rehabilitation patients. Subjects were 36 patients (21 females & 15 males), with mean age of 58± 8.6 years. Subjects completed two tests: a VO$_{2\text{max}}$ test on treadmill and a 6MWT. At the end of the 6MWT, they used the 6-20 Borg Scale to rate their effort. As a result, two equations were developed: MaxMETS$= 3.212 + 0.016 (6\text{MWT distance}) - 0.354 (\text{RPE})$ (R$= .87$, R$^2=.75$, SEE=1.17 METS), and METs at VT$= 0.944 + 0.013 (6\text{MWT distance}) - 0.192 (\text{RPE})$ (R$= .82$, R$^2=.68$, SEE=1.05 METS). This study concluded that using the 6MWT distance and terminal RPE resulted in an acceptable accuracy of predicted MaxMET and METs at VT. The results point out that using RPE may help in determining the maximal exercise capacity.

In summary:

Even though these submaximal tests have been validated by finding relationships between them and the physiological markers, there is little data to determine if these methods can be used as a primary outcome/perspective measures (ACSM, 2014). There is a lack of evidence comparing these submaximal methods simultaneously relative to accuracy, and if they can be used with no need to perform the maximal testings. Accordingly, the purpose of this study is to make a comparison between three
submaximal tests: the TT, the RPE, and Rockport 1-Mile Walk Test to examine the accuracy of these methods for predicting the exercise capacity.
REFERENCES


