PREDICTING VO₂MAX AND VENTILATORY THRESHOLD IN CARDIAC REHABILITATION PATIENTS USING THE SIX-MINUTE WALK TEST AND RATING OF PERCEIVED EXERTION

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

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December, 2016
PREDICTING $VO_2$ MAX AND VENTILATORY THRESHOLD IN CARDIAC REHABILITATION PATIENTS USING THE SIX-MINUTE WALK TEST AND RATING OF PERCEIVED EXERTION

By Rachel E. Shaw

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

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ABSTRACT

Shaw, R.E. Predicting VO$_{2}$max and ventilatory threshold in cardiac rehabilitation patients using the 6-minute walk test and terminal rating of perceived exertion. MS in Clinical Exercise Physiology, December 2016, 55pp. (C. Foster)

The purpose of this study was to cross-validate the equation of Cress (2015) to predict VO$_{2}$max and ventilatory threshold using the 6-minute walk test (6MWT) and terminal RPE. Subjects (N=23) were 35-80 yrs of age and were in the late phases of Phase II cardiac rehabilitation with VO$_{2}$max ranging from 13.7-30.2 ml/kg/min. Each subject performed an incremental maximal treadmill test using protocols that best suited the patient’s capacity. Within a few days, subjects performed the 6MWT and gave a terminal RPE using the Borg 6-20 scale. The Cress (2015) prediction equation and measured maxMETs yielded a fair correlation (r=0.4) with an SEE of 1.49 METs. Predicted METs@VT and measured METs@VT presented a fair correlation (r=0.53) with an SEE of 0.58 METs. The mean measured maximal METs was 5.8±1.3 and mean predicted maximal METs was 7.4±1.6. There was a significant difference between the means (p<0.05). The mean measured METs@VT was 4.4±0.65 and mean predicted METs@VT was 5.5±1.3. There was a significant difference between the means (p<0.05).
ACKNOWLEDGEMENTS

I would first like to thank all of my subjects. Thank you for giving me your time and patience and for providing me the opportunity to practice my skills. Thank you for all of your hard work and understanding. I want to thank Gundersen Health Systems and especially the Cardiac Rehab staff for allowing me to perform my study at their facility. Thank you for all of your understanding, flexibility, and wonderful communication.

Secondly, I want to thank my thesis chair, Carl Foster for guiding me through this long process. Thank you for reading what seemed like a million edits and taking your time to help me be the best researcher, student and professional I could be. Also, thank you for sharing your wealth of knowledge with me. Learning from you has been the best experience and I am grateful to have had you guide me through this process.

Thirdly, I would like to send a special thanks to John Porcari for giving me this opportunity as a graduate student. You took a chance by letting a seasoned kid that had been out of school for a while chase her dreams. I am forever grateful for this opportunity you gave me. Thank you for the coffee breaks and chats. I would like to thank Kim Radtke for all you have done for the LEHP and myself. Your clinical and personal guidance have helped me in many ways and I will continue to carry that guidance into my professional career. I would like to thank my third committee member, Teresa Eber-Lee.

Finally I want to thank my parents, family, friends, and my better half. Words cannot express how thankful I am to have an amazing support system. Thank you for believing in me when I had doubts and reminding me daily that I could do this. Thank you for being there for me even though 7 hours separates us. I love all of you so much; I could not have done this without you.
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INTRODUCTION

The American College of Sports Medicine (ACSM) has set forth recommended exercise prescription guidelines for healthy individuals and patients with cardiovascular disease (CVD). These guidelines suggest outpatient cardiac rehabilitation programs base exercise intensity on the results from a graded exercise test at 40-80% of exercise capacity, using heart rate reserve (%HRR), oxygen uptake reserve (VO₂R) or peak oxygen uptake (VO₂peak) (ACSM, 2013).

The role of outpatient cardiac rehabilitation programs is to increase exercise capacity, reduce risk factors, and help improve cardiac function for individuals with cardiovascular diseases such as coronary artery disease (CAD), congestive heart failure (CHF) and post-operative procedures including coronary artery bypass graft surgery (CABG), percutaneous transluminal coronary angioplasty (PTCA), stents, and many other diagnoses. In the majority of patients where graded exercise testing is not available, the exercise prescription is determined via a 6-minute walk test (6MWT) or a functional assessment using a sub-maximal exercise test. However, the gold standard for prescribing exercise remains the maximal exercise test. This is particularly complicated in cardiac populations due to the effect of medications, handrail support (Foster, 1984), low baseline functional capacities, post even restrictions, and the profound difficulty scheduling frequent maximal tests.

The idea of a time based best effort field test as an alternative to a maximal exercise test first began with Balke in 1963. Balke needed an efficient way to test functional
capacity in military personnel. This meant testing a large population, in a timely fashion, with a method that would be reproducible. Balke developed a 15-minute best effort run that accurately assessed VO$_2$max (Balke, 1963).

Subsequently, Cooper correlated a 12-minute run/walk field test to maximal treadmill testing in 115 US Air Force male officers versus measured maximal oxygen consumption (VO$_2$max). The correlation was 0.897, which is considered “good” (Cooper, 1968). Cooper confirmed that this type of field test is readily adaptable to large groups, required minimum equipment and appeared to be a better indicator of cardiovascular fitness than the 600-yard run that was currently accepted at the time, primarily in school aged populations.

The 12-minute “Cooper” test was adapted to a walk test for patients with chronic disease. McGavin (1976) tested patients with chronic bronchitis. The distance covered in 12 minutes was used to test exercise tolerance. McGavin found that the distance walked had a poor correlation to FEV$_1$. However, there was a significant correlation with the FVC, VO$_2$max and ventilation during maximal cycle ergometer testing (McGavin, Gupta, & McHardy 1976). They concluded that the test may be an effective way to assess functional capacity in patients with bronchitis.

Twelve minutes can be a long time for an apparently healthy adult, and is likely too long in chronically ill populations. Butland (1982) hypothesized that a shorter test would be adequate for clinical populations. He correlated distance with VO$_2$max for 2, 6 and 12-minute tests in a patient with chronic obstructive pulmonary disorder (COPD). He found that the correlation coefficients indicated that all three time based tests were similar measures of exercise tolerance. He also found that the longer the patient walked, the
greater the variability. The 12-minute test was highly reproducible but required two practice walks due to initial training effect. Shorter times were easier for both patient and investigator, thus the 6-minute test represented a sensible compromise (Butland, Pang, Woodcock, Geddes, 1982).

The 6MWT is well documented for use with chronically ill patients. Cycle and treadmill exercise tests are unsuitable for these patients and may not be appropriate indicators of how well they can perform activities of daily living, which is the main non-diagnostic goal of testing. Guyatt (1985) used the 6MWT as an objective measure of exercise capacity in patients with chronic heart failure and chronic lung disease. Guyatt administered the 6MWT six times over 12 weeks and performed cycle ergometer testing to measure maximal exercise capacity. The results showed that the 6MWT was highly acceptable to the patients and reproducible results were achieved after the first two walks. Guyatt concluded that the 6MWT was a useful measure of functional exercise capacity and was sufficient to serve as an outcome measure for patients with chronic heart failure. Since Guyatt's work, the 6MWT has been applied to a progressively wider population of patients. Studies have shown that 6MWT can be useful as a predictor of VO₂peak, however the standard error of the estimate (SEE) is large. Ross (2010) conducted a retrospective analysis on cardiopulmonary patients that included 11 studies, which correlated 6MWT distance to VO₂peak. The correlation of all subjects combined was 0.59. The results showed that 4% of the SEE was due to inter-site testing differences and the majority of the SEE was attributed to the inherent variability related to the two tests. Ross developed a prediction equation that can be used to estimate peak VO₂ from 6MWT distance. Within the studies used, standard deviations ranged from 4.2%, (which is a
difference of 34 meters), to 6%, (which means a 40-meter difference). Since the subjects had cardiopulmonary disease, their 6MWT distance ranged from 200-600 meters. This range of standard deviations could lead to as much as 20% variability in 6MWT distance in patients with the same VO\(_2\)max (Ross, Nurthy, Wollack, & Jackson, 2010).

One strategy for improving the accuracy of the 6MWT is to combine 6MWT distance with terminal RPE. A conceptually similar approach was applied to the Rockport 1-mile walk test using terminal heart rate as an augmenter of test time (Kline et al., 1987). The Rockport 1-mile test was developed to estimate VO\(_2\)max that utilized a less demanding protocol for the clinical population (Kline et al., 1987). The researchers used gender, age, body weight and time required to complete the walk to develop a prediction for VO\(_2\)max equation. However, the SEE value of the study was 5.0 ml/kg. With cardiac medications this would not be suitable because of the effect of medications on HR. The prediction can potentially be improved by incorporating other values such as RPE instead at HR (Eston, Lamb, Patiff & King, 2005). Walking tests can also potentially be used to predict VT, which is a potentially superior method of exercise prescription (Mezzani et al., 2012).

Recently Cress et al. (2015) demonstrated the value of applying terminal RPE to the 6MWT with maintenance cardiac patients to estimate both VO\(_2\)max and VT. Some of these patients were 20+ years post intervention, and some were apparently healthy older individuals, or individuals that have been through phase II cardiac rehabilitation in the last 5 years. Both maximal METs and METs at VT could be predicted with reasonable accuracy using the 6MWT distance and terminal RPE. The correlation when predicting METs at VT using 6MWT distance and RPE was 0.82 (Cress et al., 2015). When predicting maximal METs, the correlation was stronger at 0.87. This suggests that the
addition of RPE to 6MWT distance may aid in identifying maximal and sustainable exercise ability.

Previous studies have concluded that the use of RPE scale as a guide to exercise intensity is an effective way to improve cardiovascular and health fitness. When overall RPE on a cycle ergometer test was correlated to VO2max, there was no difference between predicted and measured VO2max from extrapolated RPE (Partiff et al., 2007). The RPE as an indicator of exercise intensity has been used in exercise prescriptions. An 8-week training study with intensity of a terminal RPE of 13 resulted in measures in VT and VO2max. The end results of the test concluded that the average intensity based on RPE was approximately 61% of VO2max at week one and 64% at week eight. (Parfitt, Evans & Eston, 2012). These intensities are within the ACSM guidelines for moderate to vigorous exercise. Thus, an exercise prescription involving an RPE of 13 can improve aerobic fitness and reduce cardiovascular risk factors (Patriff, Evans & Eston, 2012).

Today, the 6MWT is used in cardiac rehabilitation programs to determine exercise prescriptions and for outcomes upon graduation. However it is unknown if it is an accurate enough indicator of VO2max in the clinical population, particularly in relative healthier patients who may be more limited by walking mechanics than cardiovascular function. The American Thoracic Society states that the strongest indication for the 6MWT is for measuring the response to medical interventions in patients with moderate to severe heart or lung disease. The 6MWT is also a good predictor of morbidity and mortality (ATS, 2002). However as previously explained, the correlation between 6MWT distance and VO2max in large series data is low (Ross et al., 2010), and may be
particularly limited in recruiting more fit populations who are as likely to be limited by walking mechanics as by oxygen transport capacity.

Predicting VO\textsubscript{2}max from 6MWT distance and terminal RPE may yield an improved regression equation that can be used to estimate VO\textsubscript{2}max better than using only the distance during 6MWT. Preliminary results with the approach have shown promise (Cress et al., 2015). Maximal stress tests are costly and require the supervision of a physician. With an improved prediction equation, clinician may also be able to estimate VT without the need for maximal test and be better able to accurately prescribe an exercise plan (Mezzani et al., 2012). Thus, the purpose of this study was to cross-validate the equation developed by Cress et al. to predict maximal METs and METs@VT. These equations were:

maximal METs = 3.12 + (0.016 x 6MWT distance in meters) – (0.354 x RPE) and METs@VT = 0.944 + 0.013(6MWT distance in meters) – 0.192(RPE).
METHODS

The subjects for this study were 23 cardiac rehabilitation patients, 20 men and 3 women, in the phase II program at Gundersen Health System in La Crosse, WI. Subjects provided written informed consent prior to participating. The protocol was approved by the Institutional Review Board for the Protection of Human Subjects at the University of Wisconsin-La Crosse and at Gundersen Health System. The subject’s height, weight and age and gender were obtained.

The subjects performed a maximal functional exercise test towards the end of their prescribed rehabilitation sessions under the supervision of clinic staff. Various treadmill protocols were used depending on the patient’s abilities. Protocols included were Bruce, modified Bruce, Branching and modified Naughton protocols. The protocols (chosen to suit the patient) were incremental in speed and grade in two or three-minute stages until the patient became fatigued, became symptomatic or displayed significant electrocardiographic (EKG) changes.

Oxygen intake was measured using open circuit spirometry (Oxycon, Franklin Lakes, NJ). The device measured ventilation and gas concentration data through a mask and sent it wirelessly to a host computer system. The Oxycon™ was calibrated before each subject using reference gases (16% O₂, 5% CO₂, room air) and volume calibration. Heart rate, blood pressure and RPE were measured at each stage while the staff monitored the patient’s EKG. Ventilatory threshold (VT) was calculated from the gas exchange using
the v-slope and ventilatory equivalent method (Foster et al., 2005). Maximal METs were calculated by dividing measured VO$_2$max in ml/kg by 3.5.

Within days of completing the maximal exercise test, the patient performed a 6MWT at the cardiac rehabilitation facility. The patient walked in a hallway that was 100 feet in length for 6 minutes. Verbal cues were given at each minute according to the American Thoracic Society Guidelines (ATS, 2002). Distance walked and terminal RPE were recorded at the end of the test. The Borg Rating of Perceived Exertion scale (6-20) (Borg, 1998) was used to determine RPE.

Comparisons between maximal METs and predicted maximal METs, and METs@VT and predicted METs@VT were compared using a paired t-test, Pearson product moment correlations, and standard error of the estimate (SEE).
RESULTS

Descriptive characteristics of subject characteristics are presented in Table 1. Maximal heart rate, VO₂, and VT data was achieved from information was obtained from the subject’s incremental maximal treadmill test. 6MWT distance and terminal RPE were obtained from a 6MWT.

Table 1. Descriptive characteristics of subjects (N=23).

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<tr>
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<th><strong>Male</strong> (n=20)</th>
<th><strong>Female</strong> (n=3)</th>
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<tr>
<td><strong>Age</strong></td>
<td>61.5±10.2</td>
<td>57.7±20.5</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>177±8.6</td>
<td>160±4.04</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>95±15</td>
<td>60.7±6.8</td>
</tr>
<tr>
<td><strong>VO₂max (mL/kg/min)</strong></td>
<td>20.7±4.83</td>
<td>21.3±6.8</td>
</tr>
<tr>
<td><strong>VO₂ @VT (mL/kg/min)</strong></td>
<td>15.4±2.2</td>
<td>15.4±3.4</td>
</tr>
<tr>
<td><strong>6MWD (m)</strong></td>
<td>521±106</td>
<td>529±83.9</td>
</tr>
<tr>
<td><strong>Terminal RPE (6-20 Borg)</strong></td>
<td>11.9±1.9</td>
<td>11.3±1.5</td>
</tr>
<tr>
<td><strong>Maximal METS</strong></td>
<td>5.9±1.3</td>
<td>6.1±1.4</td>
</tr>
<tr>
<td><strong>Maximal Heart Rate (bpm)</strong></td>
<td>139±19.1</td>
<td>150±29.4</td>
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The relationship between VO$_{2}$ max and 6MWT distance is presented in Table 1a-b. The correlation was found to be 0.30.

**Figure 1a.** Relationship between VO$_{2}$ max (ml/kg/min) and 6MWT distance (meters)

**Figure 1b.** Relationship between maximal METs and 6MWT distance (meters)
Figure 1c represents the relationship between VO₂max and 6MWT distance compared to the retrospective data collected by Ross et al. (2010). The correlation of Ross et al. (2010) was found to be 0.59. The small circles are the current study and the connected box points represents the grouping of data around the “cloud” of points updated by Ross et al.

The relationship between RPE and maximal METs is presented in Figure 2. The correlation was found to be -0.22.
Figure 2. Relationship between RPE (Borg 6-20) and maximal METs

Cross-validation of measured maximal METs and predicted maximal METs using the equation of Cress et al. is presented in Figure 3. The dashed line shows the line of identity. Mean measured maximal METs was 5.8±1.3 and mean predicted maximal METs was 7.4±1.6, there was a significant difference (p<0.05) between the two. The SEE was 1.49 METs.

Figure 3. Relationship between measured maximal METs and predicted maximal METs using the equation of Cress et al.
The relationship between 6MWT distance and METs@VT are presented in Figure 4. The correlation was found to be 0.53.

The relationship between METs@VT and terminal RPE of the 6MWT is presented in Figure 5. The correlation was found to be -0.06.
The relationship between measured maximal METs@VT and predicted METs at VT using the equation of Cress et al. is presented in Figure 6. The correlation was 0.57. The dashed line shows the line of identity. The mean measured METs@VT was 4.4±0.65 and mean predicted METs@VT was 5.5±1.3, there was a significant difference (p<0.05) between the two. The SEE was 0.58 METs (p<0.05).

Figure 6. Relationship between measured METs@VT and predicted MET@VT using equation of Cress et al.
DISCUSSION

The purpose of this study was to cross validate the prediction equation of Cress et al. (2015) for predicting maximal METs and METs@VT from the 6MWT and terminal RPE in cardiac rehabilitation patients. The equation used distance walked in the 6MWT and terminal RPE at the end of the 6MWT to predict maximal METs and METs@VT. In the study by Cress et al. (2015) the equation was found to have a correlation between 6MWT distance plus RPE and VO2max to be 0.87, which is a strong correlation. Secondly, the correlation for the prediction equation for METs@VT was 0.82, which is a good correlation. The subjects for the Cress et al. study included adult physical fitness and maintenance cardiac rehabilitation participants with an average age for both men and women of approximately 57 years. Most of these participants have had multiple cardiac interventions and multiple exposures to phase II cardiac rehabilitation, thus they are familiar with the 6MWT and the 6-20 Borg RPE scale. Other subjects were participants in the La Crosse Exercise and Health Program and have been reporting their RPE for many years and have a clear understanding of the 6-20 Borg scale. It was hypothesized that the prediction equation could be made better with a stronger correlation by adding more subjects to increase sample size and adding late phase II cardiac rehabilitation patients in order to broaden the range of the data. Phase II patients are considered "sicker" patients and typically have lower functional capacity compared to the subjects that are considered apparently healthy or have been in a maintenance cardiac rehabilitation for years.
The results of this study yielded relatively weak correlations between predicted and measured 6MWT distance and maximal METs and METs@VT. The results in Figure 1 show the relationship between 6MWT distance and VO2max (maximal METs) to be 0.30, which is considered a low correlation. This means there was a weak relationship between how far the subject walked during the 6MWT and their VO2peak achieved during a maximal treadmill test. The results in Figure 2 show the relationship between maximal METs and terminal RPE at the end of the 6MWT to be -0.22, which is also a low correlation. This means there was not a strong relationship between how hard the subjects worked during the 6MWT and their MET capacity achieved during treadmill testing. When the Cress et al. (2015) prediction equation for maximal METs was compared to the measured maximal METs, the correlation was 0.40 and the means were found to be significantly different. The SEE indicates that the prediction equation over predicts by 1.4 METs (Mean measured maximal METs 5.8±1.3 and mean predicted METs 7.4 ±1.6). The coefficient of variation was 51% (ideal is 5-15%). When comparing maximal METs@VT using the prediction equation to the measured METs at VT, the correlation was found to be 0.57 with a coefficient of variation of 51% and was found to be significantly different Mean METs@VT: 4.4±0.65 and mean predicted METs@VT: 5.5±1.3).

There is a large gap in correlations between the two studies. This difference in correlations from Cress et al. (2015) to this study could be due to three main points: obtaining VO2peak instead of a true VO2max, a familiarity of the 6MWT and a clear understanding of the RPE 6-20 Borg scale.
VO2peak is the highest level of oxygen consumption that can be achieved during a mode of exercise. VO2max is the largest VO2peak for an individual. In order to be considered a VO2max, the subject must obtain an RER of ≥1.1, obtain a maximal HR of ≥90% of age-predicted max HR, and demonstrate a plateau in VO2 with increased intensity. Not every subject in this study met all criteria to be a true VO2max. Multiple cardiopulmonary staff members conducted the treadmill tests, which causes variability of termination criteria—some staff exercised the patient to an RPE of 15 and some staff stopped the patient at an RPE of 18 on the 6-20 Borg scale. There were multiple protocols used during this study depending on the subject’s previous exercise before completing cardiac rehabilitation. The study by Cress et al. did a uniform Bruce protocol, resulting less inherent variability, although clinical tests rarely satisfy all criteria for achieving VO2max.

Both prediction equations use 6MWT distance and RPE to predict METs or METs at VT. The subjects in the Cress et al. (2015) study were all familiar with the RPE (Borg 6-20) scale. These subjects have used the scale multiple times in cardiac rehabilitation, in graduate student studies, and daily in a Phase III cardiac rehabilitation program. The subjects in the present study had been exposed to the RPE scale a few weeks. The explanation of the scale was based on the cardiopulmonary rehabilitation staff, not the researcher. A recent study by Brown (2014) tested the modified Borg scale (0-10) in this population. It was found to have a slightly lower correlation to MET capacity than the Borg 6-20 scale. Considering the ease of using the Borg scale, the presence of verbal anchors and that the current patients had used the Borg scale for
several weeks, unfamiliarity with the RPE scale seemed a possible reason for the low correlations observed in this study.

The 6MWT can be a good predictor of functional capacity. The subjects in the Cress et al. (2015) study had either received multiple cardiac interventions and were familiar with the test or were exposed to it in the exercise and health program. All of the subjects in this study had never performed the 6MWT before and were not familiar with the test. The American Thoracic Society (ATS) has noted within-test variability with the 6MWT. Sources of variability for a higher 6MWT distance could include male sex and longer legs. The majority of the subjects in this study were men (n=20) with longer legs than the small amount of women (n=3) causing variability in distance. Guyett et al. (1985) suggested that the 6MWT is more reliable after two practice trials. However, the recent clinical use of the 6MWT as an outcome measure in cardiac rehabilitation programs, including the Cress et al. (2015) data, has been to use a single 6MWT without prior practice.

The data presented in Table 1 reports higher values than previous literature regarding VO$_2$ max and 6MWT distance (Ross et al. 2010). The VO$_2$ max collected in this study was 20.7 ml/kg/min for males and 21.3 ml/kg/min for females. When compared to previous literature such as Ross et al. (2010), which combined 11 different studies using a clinical population, the average VO$_2$ max was 14.3 ml/kg/min with a standard deviation of 4.8 ml/kg/min. Of the 11 studies included in the Ross et al. data, the highest reported mean VO$_2$ peak was 16.8 ml/kg/min with a standard deviation of 4.5 ml/kg/min (Roul et al., 1998). This is still lower than the VO$_2$ max measured in this study. This could be due to the diagnoses incorporated in each study. This study included all cardiac rehabilitation
diagnosis including PCI, MI, CABG, valve replacements and minimally invasive cardiac surgery (MICS). Roul et al. (1998) only included CHF patients. These patients tend to have lower functional capacities than a patient with a PCI that is prescribed 18 cardiac rehabilitation sessions. It could also reflect the history of the 6MWT, which was originally used as a test for pulmonary and heart failure patients (with very low exercise capacities), compare to the more contemporary use of the 6MWT, which is used in clinical populations.

Figure 1c represents the current data in conjunction with the data reported by Ross et al (2010). The points were found by the high and low ends of VO2max for each 100 meters walked around the trendline and connecting each point making an “egg” shape. Most of the data collected fits within the “egg” shape of the Ross et al. (2010) data and is consistent with previous research. This suggests that the measured VO2max was accurate, without calibration error and proper MET levels achieved, and the high SEE is due to the misunderstanding of the RPE scale or the 6MWT.

Historically, the 6MWT has been modified to assess functional capacity in healthy adults. Over time, the test has been manipulated for the clinical populations. Today it is used as a submaximal exercise test to assess functional capacity and for outcome measures in cardiopulmonary rehabilitation. The mean 6MWT distance in this study was 521 meters for males and 529 meters for females. Ross reported the highest average 6MWT distance of the 11 studies was 463 meters (Zugck, 2000) with the highest individual value at approximately 725 meters. This could be due to the diagnosis of the subjects; used subjects with dilated cardiomyopathy. Dilated cardiomyopathy is a condition in which the heart’s ability to pump blood is decreased because the left
ventricle is enlarged and weakened, thus lowering stroke volume and cardiac output. The inability to efficiently profuse the tissues would cause measured VO2peak and 6MWT distance to be lower.

Figure 1 represents the measured VO2max versus the 6MWT distance. The correlation was found to be poor at 0.304. Ross et al. (2010) found a correlation was found to be 0.59, which is a fair correlation with the SEE of 3.82 ml/kg. This could be due to previous studies incorporating a learning period for the 6MWT. Many of the studies included a two-trial learning period to become familiar with the 6MWT, whereas most patients in this study (or most clinical studies) had never been exposed to the 6MWT. Not all cardiac rehabilitation programs require a 6MWT pre and post prescribed sessions for outcome assessments. In the cardiac rehabilitation program where this study was conducted, only pulmonary rehabilitation patients routinely perform the 6MWT.

The other plausible reason for the large scatter of the data, both in this study and the pooled analysis of Ross (2010), is that the ability of terminal RPE to augment 6MWT may be speed dependent. Biomechanically limited, the transition speed from a walk to a run typically occurs at about 4.2-4.7mph in young and healthy adults (Rotstein, Inbar, Berginsky & Meckel, 2005). The transition speed is likely to be lower for the older clinical populations however there is no current research. At higher walking speeds, the ability of terminal RPE to augment the prediction of VO2max is likely larger. This needs to be explained in a larger data set.

In conclusion, the purpose of this study was to cross-validate the prediction equations of Cress et al. (2015). The equations predicted maximal METs and METs@VT using 6MWT distance and terminal RPE in long-term maintenance cardiac rehabilitation
patients and adult physical fitness participants. The goal of this study was to add late
phase II cardiac rehabilitation patients to the population in hopes of improving the
accuracy of the equation developed by Cress et al. Because of the low correlations, the
data was inconclusive with previous research and a significant difference between
predicted and measured values. This proposes the question of the clarity of the Borg 6-20
scale and the understanding of the 6MWT in this population.
REFERENCES


APPENDIX A

INFORMED CONSENT

UNIVERSITY OF WISCONSIN-LA CROSSE
Protocol Title: Predicting VO$_2$\textsubscript{max} in Late Phase II Cardiac Rehabilitation Patients using 6MWT and Terminal RPE

Principal Investigator: Rachel Shaw
776 N. 23rd St.
La Crosse, WI 54601
765-729-3250

Emergency Contact: Dr. Carl Foster
133 Mitchell Hall
University of Wisconsin-La Crosse
608-785-8687

Why have you been asked to take part in this research?
This study is evaluating maximal oxygen intake in Phase II Cardiac Rehab participants. You have been invited to participate in this study because you meet the appropriate criteria that we are interested in studying. Participating in this study is voluntary, and you may quit this study at any time. Please do not hesitate to ask questions about this consent form or the procedures if you do not understand something.

How many people will be in this study and how long will it last?
There will be approximately 20-30 patients with varying diagnoses and varying age ranges participating in this study. The study will last approximately four months, and your participation time will include an extra approximately 15 minutes one-time test.

What will happen if you agree to be part of this study?
If you agree to be part of this study, you will exercise one extra time in addition to your maximal stress test conducted by Gundersen faculty. Per protocol, all Phase II cardiac rehab patients are required to perform a maximal stress test at the end of his or her prescribed sessions. To collect oxygen uptake, a wireless gas exchange mask will be put over your mouth and nose during the stress test. The participant will be able to speak freely. The mask will be attached to a small pack on your back and weigh approximately 2 pounds. This will not effect the outcome of the study, or effect your stress test.

Additionally, there will be one 6-minute walk test that we ask you to walk a few days after your stress test. The test will be held in the Gundersen cardiac rehab facility. We want you to walk briskly as fast as you can but at your own pace. During the walk, we will monitor your electrocardiogram (EKG) using the telemetry monitor system. After the 6-minute walk, we will record heart rates, distance walked, and ask you a rate of perceived exertion (RPE) using two different described scales.

What are the possible risks and discomforts from this study?
Similar to any type of exercise, you will get tired and your muscles may be sore. However, these effects will only be temporary. A doctor will be present during your maximal stress test as well as Gundersen faculty. Exercise Physiologists will be present during your 6-minute walk test as well. The researcher will be trained in CPR, Advanced Cardiac Life Support, and First Aid.
How will you benefit from participating in this study?

By participating in this study, you could potentially help reform current exercise prescriptions in cardiac rehabilitation programs. You will also help other researchers correlate the 6-minute walk test to maximal oxygen uptake. Knowing your aerobic capacity and motivation to continue a healthy lifestyle that includes exercise.

Do you have to participate?

Participation in this study is completely voluntary. You may stop participating at any point without penalty.

What are the costs of participating?

There are no costs for you to participate in this study.

What are your right and confidentiality during this study?

All of the data will be kept confidential through the use of number codes. If this study is published or presented for scientists and teachers, your data will not be personally identifiable.

Questions regarding the requirements of this study will be answered by Rachel Shaw, (765-729-3250), or her advisor, Dr. Carl Foster (608-785-8687). Questions regarding the protection of human subjects may be addressed to the UW-La Crosse Institutional Review Board for the Protection of Human Subjects (608-785-8124).

Subject’s Understanding:

Have all of your questions regarding how the research study might affect you been answered?  
YES / NO  (circle one)

If you are interested in participating in this study please sign your name. You will not be penalized or treated differently for not participating in this study.

Participant’s name: ________________________________

Participant’s signature: ____________________________ Date: ____________

Researcher’s signature: ___________________________ Date: ____________
APPENDIX B

INFORMED CONSENT

GUNDERSEN HEALTH SYSTEMS
INFORMED CONSENT

Protocol Title: Predicting VO\(_2\)max and Ventilatory Threshold from the 6-minute Walk Test

Principal Investigator: Carl Foster, Ph.D.                      Rachel Shaw, BS
Department of Exercise and Sport Science                      CEP Graduate Student
Mitchell Hall 133                                             UW-La Crosse
University of Wisconsin-La Crosse                              (765) 729-3250 cell
La Crosse, WI 54601                                           (608) 792 2170 cell

Purpose and Procedure

The purpose of this study is to determine whether markers of exercise capacity, VO\(_2\)max and ventilatory threshold, can be predicted from the more simple measurements such as how far you can walk in 6 minutes and how hard that walk feels to you.

Your participation will involve performing a progressively harder test on a treadmill, until you are fatigued or until the health care provider responsible for the test thinks you should stop. This test is exactly the same as you would ordinarily perform at the end of your rehabilitation program at Gundersen Health Systems. During this test you will have patches on your chest and a blood pressure cuff on your arm. This is also routine practice at Gundersen Health Systems. During this test, you will breathe through a mask that looks like one a pilot would wear so that your VO\(_2\)max and ventilatory threshold (gold standard markers of my exercise capacity) can be measured. Breathing through the facemask is a measure that you would not ordinarily undergo, although no known risk is involved with this technique.

On a different day, you will perform a test by walking as far as you can in 6 minutes. During this test, you may also have patches on your chest, and the investigators will ask you how hard the effort was. The 6 minute walk test is also widely used clinically around the world, but is not routinely used at this time at Gundersen Health Systems. During this test, you will become moderately fatigued/out of breath. There are no other known risks associated with the 6-minute walk test, which for most people represents moderate exercise.

These tests will be performed at Gundersen Health System, as part of the cardiac rehabilitation program in which you are enrolled. The exercise test is an absolutely normal part of your rehabilitation program. The only research component is to wear the facemask and to do the 6-minute walk, so that the investigators can compare the results of the test.
Potential Risks

Exercise testing will cause you to become somewhat fatigued. The risk of cardiac complications is about 1 per 10,000 tests and probably lower during the 6-minute walk. However, these are routine tests that are part of your cardiac rehabilitation program at Gundersen Health System.

Individuals trained in CPR and advanced cardiac life support will be part of the staff administering the test.

Rights and Confidentiality

Your participation is a normal part of my cardiac rehabilitation program, except for using the facemask and the 6-minute walk. The data obtained from this will be analyzed in a way where you cannot be identified. You can refuse to participate in the research portion of the study, and still participate in the rehabilitation program at Gundersen Health System. You may withdraw at any point with no penalty. If you do participate, the staff of the cardiac rehabilitation program at Gundersen Health System will have access to your data (in addition to the researchers), as the information might improve their ability to help you.

The results of this study may be published in the scientific literature or presented at professional meetings, so that the practice of cardiac rehabilitation can be improved. Information that might identify you personally will not be published.

Possible Benefits

The practice of cardiac rehabilitation may be improved by the rehabilitation team having a simpler method to estimate exercise capacity. There may be no personal benefits.

Questions regarding study procedures may be directed to Carl Foster, Ph.D., who is a Professor in the Department of Exercise and Sport Science at the University of Wisconsin-La Crosse (608) 785 8687 or cfoster@uwlax.edu. Questions regarding the protection of human subjects may be addressed to the UW-La Crosse Institutional Review Board for the Protection of Human Subjects, (608) 785 8124 or irb@uwlax.edu.

For more information about your rights as a research participant, you may contact Bernard J. Hammes, Ph.D., Chairperson of the Gundersen Clinic Ltd Institutional board at (608) 782-7300 or 1-800-362-9567.

Participant _______________________________ Date ______________
Researcher _______________________________ Date ______________
APPENDIX C

RATING OF PERCEIVED EXERTION SCALE
<table>
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<tr>
<th></th>
<th>No exertion</th>
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<td>Light</td>
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<tr>
<td>13</td>
<td>Somewhat hard</td>
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<tr>
<td>15</td>
<td>Hard (heavy)</td>
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<td>16</td>
<td></td>
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<tr>
<td>17</td>
<td>Very hard</td>
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<td></td>
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<tr>
<td>19</td>
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APPENDIX D

REVIEW OF RELATED LITERATURE
REVIEW OF RELATED LITERATURE

Introduction

The purpose of this paper is to review the literature related to estimating exercise capacity and ventilatory threshold in late Phase II cardiac rehabilitation patients using the Rate of Perceived Exertion scale (RPE) in adjunction with the 6-Minute Walk Test (6MWT). The 6MWT is used as a gold standard in many cardiac rehabilitation programs to prescribe an individual’s exercise prescription. The test is also used as an outcome study to show progression pre and post rehabilitation. By adding terminal RPE to the 6MWT along with a maximal oxygen intake (VO\text{max}) stress test, exercise physiologist will be able to quickly determine the exercise capacity of patients with coronary artery disease (CAD), congestive heart failure (CHF), post coronary artery bypass grafts (CABG), post stent placement and many others.

\textbf{VO\text{max}}

Maximal oxygen intake was first described by A.V. Hill, who conducted experiments on active men in Manchester, England in the 1920s (Bassett & Howley 1997). According to Hill, maximal oxygen intake is reached when oxygen intake per unite time has attained its maximum and remains constant, owing to the limitation of the circulatory and respiratory systems (Hill 1927). Jeremy Mitchell examined the cardiovascular capacity relationships set forth by Hill by using direct measurement to better understand the physiological meaning of the VO\text{max} test (Mitchell, Sproule, & Chapman, 1957). Mitchell tested 65 apparently healthy men on a motorized treadmill
protocol was a 10-minute warm up followed by 10 minutes of rest. The first test was performed at 6 mph with no grade. Expired air was collected in a Douglas bag. After another 10-minute rest the next test was the same speed with a 2.5% grade. The researchers continued this pattern until the oxygen leveled off. They concluded that VO$_{2\text{max}}$ decreases with age and ventilation reaches it's highest value at maximal oxygen intake level. Maximal oxygen uptake is "dependent on both cardiac output and AV oxygen difference. They also concluded that the ability to increase cardiac output is the most important factor of the physiological determinant of VO$_{2\text{max}}$ (Mitchell, Sproule & Chapman, 1957).

Three years later, the infamous Balke stated that “size of physical reserves” and “general adaptability to great physical demands” was the two main factors of physical fitness. He also stated that physical fitness was dependent on functional and metabolic potentials. Balke hypothesized that functional limitations become recognizable when the heart rate (HR) reaches 180bpm. The relationship between VO$_{2\text{max}}$ and intensity is linear, so Balke had subjects run or walk on a treadmill and outside. Balke then put the data in a regression line to predict outdoor run times. Balke concluded that trained men utilized fat more efficiently and rarely achieved complete exhaustion because they could continue at a reduced activity level. His sedentary subjects fatigued faster and would have a difficult time as they aged (Balke, 1960).

Kenneth Cooper continued conducting research involving VO$_{2\text{max}}$ and regression equations. Cooper tested the aerobic endurance of 115 U.S. Air Force men using a 12-minute run test as well as a treadmill test. Distance was recorded for the 12-minute run. Oxygen intake was collected via Douglas Bag or Tissot gasometer. The treadmill
protocol consisted of 3-minute runs followed by a 10-minute rest period. Speed and incline were increased based on the individual’s fitness level. When Cooper put his data into a regression equation, the correlation factor was strong, therefore suggesting that his regression equation was a good indicator of VO$_2$max (Cooper, 1968). However, since Cooper used healthy young males, he cites that the equation could be an issue with older adults. The test can be used in large groups and is more cost effective than treadmill exercise testing. This test is a good indicator of physical fitness and measuring changes in physical fitness.

For decades, maximal intake testing was only done on apparently healthy individuals with no previous history. It was not till 1982 when William Haskell decided to perform VO$_2$max testing on cardiac patients. Haskell recruited patients post myocardial infarction (MI) for is study. Patients performed a standard modified Balke protocol as well as an accelerated but similar protocol three and eleven weeks post event. Haskell found that there was no significant difference in the measured and predicted VO$_2$max at three weeks. However, estimated VO$_2$max was significantly higher using the accelerated protocol than measured data at eleven weeks post even. Haskell concluded that this was due to the use in handrails. When retested without the use of handrails, the subject’s measured and estimated were almost identical. The results of Haskell’s test concluded that exercise capacity in post MI patients can be estimated from healthy individual data, and exercise intensity should be increased slowly when performing a maximal test.

A few years later, Carl Foster extended on Haskell’s previous research. Foster experimented with post-operative cardiac patients with CAD comparing estimated and measured VO$_2$max. The protocol was a VO$_2$max test using the Bruce protocol on a
treadmill. Subjects would perform the test at 2, 8 and 24 weeks post surgery. Foster found that the predicted VO_{max} was overestimated compared to the measured VO_{max} (Foster et al., 1984). Foster’s research concluded that the appropriate regression equations should be applied to the appropriate populations. His findings also support Haskell’s idea of increasing intensity in smaller increments when performing stress tests in the clinical population.

The next to tackle VO_{max} testing in the clinical world was Jonathon Myers. Myers performed more research on patients with CAD and CHF. He conducted a comparison study on “the hemodynamic and gas exchange response of ramp treadmill and cycle ergometer tests with standard exercise protocols used clinically” (Myers et al., 1991). Myers compared different protocols to obtain VO_{max} including the Bruce protocol, Balke protocol, and individualized ramp protocol on a treadmill and cycle ergometer. Myers found that VO_{max} was significantly higher using the treadmill protocols as opposed to the cycle ergometer, however the protocols used on the treadmill showed no significant difference.

Recently, Mezzani, Hamm, Jones, McBride, Moholdt, Stone, Urhausen and Williams (2012) published an article on exercise prescription in cardiac rehabilitation. We know that peak VO_{2} first and second ventilatory threshold are gold standards for the evaluation of aerobic metabolism function, exercise assessment and prescription. Mezzani explains that first ventilatory threshold (1st VT) is considered when “blood lactate and pH start to increase and decrease respectively”. The second ventilatory threshold is achieved around 70-80% VO_{2}peak and 80-90% peak HR. Steady state is achieved much faster in trained athletes compared to sedentary individuals.
6-Minute Walk Test

The 6-minute walk test (6MWT) has been used for decades for the clinically ill population. Physicians would ask their patients “how many flights of stairs can you walk?” In the 1960s, Balke decided to put a time cap on the idea. He would ask “how far can you walk in a certain time?” Kenneth Cooper, discussed previously, tested military men with a 12-minute run/walk test. He took the distance his men ran or walked in the given 12 minutes and correlated that to their VO\(_{\text{max}}\). Maegavin started using a similar 12-minute walk test on patients with chronic bronchitis. However, 12 minutes seemed to be too long and strenuous for the clinically ill. Butland is credited with shortening the test to 6 minutes. Butland found that there was no significant difference in the results of the 12-minute walk test versus the 6-minute walk test. Finally in 1985 Guyatt decided to try the test on heart disease patients. He had two groups consisting of individuals who were fatigued or experienced dyspnea with activities of daily living (ADL). The one group used encouragement during each test and the other did not. Each person was tested 6 times and time of day and level of encouragement were noted. A 2-minute and 6-minute walk test was performed with 20 minutes rest between each test. The study concluded that during the second and third 2-minute segments the effect of encouragement was greater, whereas encouragement had no effect on the first 2 minutes. He found it was a sufficient way to quickly determine exercise capacity and prescribe an exercise prescription.

The use of the 6MWT to predict VO\(_{\text{max}}\) was first look at in 2005 by Ingle, Goode, Rigby, Cleland and Clark. All participants were males with CHF and were stable. Subjects performed at VO\(_{\text{max}}\) test using a modified Bruce protocol. The study
concluded that FEV1 and FVC were significant predictors of VO2peak. The article also stated that the regression equation used was moderately accurate.

In 2007, Arslan et al. performed a study with cardiac patients in association with the 6MWT. A follow up period of approximately 18 months was documented. The mortality rate was higher in patients who walked 300 meters or less. The study concluded that the 6MWT was a safe test. As far as mortality rate, the study concluded the distance walked during the 6MWT was a highly reliable and independent predictor of cardiac death.

The 6MWT is argued to be a maximal or submaximal test (Jehn, et al.). In Jehn’s study, patients had different stages of CHF. Patients were required to perform two tests: a maximal test on a cycle ergometer and the 6MWT with a 2-hour recovery period. The cycle ergometer used the 10W/min ramp protocol. The study found high correlations between distance walked and VO2peak. The data suggested that patients with mild heart failure did not reach maximal heart rate (HR) and patients with severe CHF yielded maximal responses. The study concluded that patients with reduced exercise capacity reach “higher peak respiratory parameters” during the 6MWT than the cycle ergometer test. The researchers found the 6MWT to be highly dependable.

In 2002, the Thoracic Society stated that the 6MWT was found to perform as well as the 12-minuet walk test. The environment for the 6MWT is dependent on the facility and what is available. The minimum requirement is a flat hallway 100 feet in length. The test measures the distance and speed that the patient can walk for 6 minutes. The patient is allowed to stop at any point if needed. The 6MWT is a submaximal exercise test to determine functional capacity and sometimes used as a tool to determine exercise
prescription. The test has not been proven to be clinically useful as of 2002. Since the test is not maximal and does not determine VO$_2$max, the test is considered complementary to cardiopulmonary exercise testing. The test should be terminated if the patient experiences chest pain, severe dyspnea, discomfort walking or becomes symptomatic. The only absolute contraindications are unstable angina and myocardial infarction within the last month. The 6MWT has increased in popularity for testing older adults with cardiopulmonary diseases (Rasekaba, Lee, Naughton, Williams and Holland 2009).

Along with other roles, the 6MWT is used to assess functional movement. Since the test is submaximal, low risk and performed in high volumes, a physician is not needed. Data suggests that only a few medications may alter the outcome of the test. A limitation of the 6MWT is that it does not inform on exercise limitation and thus cannot aid in diagnosis.

A retrospective study by Ross et al. (2010) combined 11 different studies ($N=1,083$) that included different cardiac diseases such as congestive heart failure, dilated cardiomyopathy and lung diseases such as COPD, end state lung disease and pulmonary hypertension. Each study compared 6MWT distance to measured VO$_2$peak in a linear regression. Ross et al. (2010) combined all previous studies into one linear regression. The correlation observed was 0.59, which is a fair correlation. The issue with these types of studies is a historically high standard error of the estimate (SEE), which means how accurate the prediction equation is. This could be due to the interest variability of the 6MWT or this specific population.
Rate of Perceived Exertion

The last important factor of this study is Rate of perceived exertion (RPE). There are a handful of scales used to determine exercise intensity. This study focuses on the Borg scale (6-20). Many studies have tested the validity of the scales and the ACSM has recognized the Borg 6-20 scale as a reliable measure to quantify, monitor and assess an individual's exercise tolerance and level of exertion (ACSM, 2013).

In 2005, Eston, Lamb, Partiff and King conducted a study to assess the validity of predicting VO$_{\text{max}}$ from submaximal VO$_{\text{2}}$ testing. The subjects were ten healthy male university students. Subjects were required to perform 4 different tests: a maximal test and three submaximal tests. All tests were completed on a cycle ergometer and were capped off at an RPE of 9, 11, 13, 15 and 17. The study found no significant difference between the measured and estimated VO$_{\text{max}}$. The data supports the idea that sub maximal testing can provide acceptable estimates of aerobic power.

Two years later in 2007, Faulkner and Eston did a study to analyze the relationship between HR and RPE during two exercise tests on a cycle ergometer. There were 16 men and 9 women considered high fitness level and 14 men and 10 women considered low fitness level. The cycle ergometer tests started at 40W and increases in increments of 40W every 3 minutes. Overall RPE was correlated to VO$_{\text{max}}$ as much as VO$_{\text{max}}$ and HR. The study concluded no difference between predicted and measured VO$_{\text{max}}$ from extrapolated RPE. The study also concluded that RPE is not gender specific.

Another two years in 2009, after Faulkner and Eston conducted their study, they teamed with Lambrick and Rowlands to determine the efficiency of RPE 13 during submaximal exercise. The study included 11 sedentary women, each performed a cycle
ergometer test to find VO\textsubscript{max}. The pace was kept constant at 60rpm. The intensity was increased 1W every 4 seconds. The researchers extrapolated RPE 13 to 19 for VO\textsubscript{max} predictions. The researchers found that RPE 19 prediction values were lower than measured, and GET 20 predicted was above measured values. The researchers concluded that a continuous test was more accurate at predicted VO\textsubscript{max}.

Lastly, in 2012, Partiff, Evans and Elston conducted a study to confirm the efficacy of an 8 week training program with the intensity level capped off at an RPE of 13. Researchers were curious to find if the cut off of intensity using the RPE scale improved aerobic fitness and cardiovascular health. This is important because most cardiac rehabilitation programs protocol for exercise prescription is an RPE of 11-13. The subjects were middle-aged sedentary individuals and were assigned at random to a control or training group. Baseline maximal stress test was performed pre and post intervention using the Balke-Ware protocol. The training group exercise 3 days per week for 30 minutes at an RPE of 13. The study concluded the training group improved their VO\textsubscript{max}, mean arterial pressure, total cholesterol and body mass index within the 8 weeks of training. The results of the maximal stress test worsened in the sedentary group. The average intensity found based off RPE reports were approximately 61% of VO\textsubscript{max} at week one and 64% at week eight. These intensities are within the ACSM guidelines for borderline moderate and vigorous intensity. Thus, an exercise program involving an intensity of RPE 13 can improve aerobic fitness and retard cardiovascular risk factors.
**Ventilatory Threshold**

Ventilatory threshold (VT) is the point of transition between predominantly aerobic energy production to anaerobic energy production. There are two VTs that can be identified. The first ventilatory threshold is the intensity at which ventilation starts to increase in a non-linear fashion. The second VT is the point at which high-intensity exercise can no longer be sustained due to an accumulation of lactate.

As early as 1927, Douglas described a ventilatory response during submaximal exercise that was related to excess carbon dioxide production relative to oxygen utilization and to an increase in blood lactate. Wasserman and McIlroy (1984) termed this non-linear response the anerobic threshold because excess carbon dioxide resulted from the buffering of lactate released from exercising muscles that had switched on anerobic-glycosis causing a significant increase in lactate. Excess CO₂ is generated when lactate is increased during exercise because hydrogen ions are being buffed primarily by bicarbonate (Beaver, Wasserman, & Whipp 1986). This increase in hydrogen ions further stimulate ventilation by stimulating central and peripheral chemoreceptors resulting in an increase in ventilation. Thus, anaerobic threshold is also known as the lactate threshold. The anaerobic threshold can be detected by using a computerized regression analysis of the slopes of the CO₂ intake versus O₂ uptake plot, which detects the beginning of the excess CO₂ output generated from the bicarbonate buffering hydrogen ions. This method is called the v-slope method (Beaver, Wasserman, & Whipp 1986). The older methods for anaerobic threshold detection include visual inspection of graphical plots of ventilatory equivalents, end-tidal gas concentrations, and respiratory exchange ratios.

It has been observed that individuals with similar VO₂max have variability in
endurance capacity and that highly trained athletes perform at a high percentage of their VO\textsubscript{max} with minimum lactate accumulation (Withers, Sherman, Miller & Costill 1981). Trained athletes accumulate less lactate than untrained athletes at any given submaximal workload. Thus anaerobic/lactate threshold can be considered a determinant of physiological fitness.

The first VT occurs during light to moderate intensity exercise above which blood lactate begins to increase and pH starts to decrease (Mezzani et al., 2012). During this intensity, aerobic metabolism satisfies almost all of the body’s energy needs and blood lactate is not elevated enough above resting value at this level. Bicarbonate is used as a buffer to counteract this elevation in pH causing CO\textsubscript{2} to be produced by anaerobic metabolism. This increase in VCO\textsubscript{2} causes the relationship between VCO\textsubscript{2} and VO\textsubscript{2} to become steeper due to VO\textsubscript{2} staying the same. The first VT can be determined using the slope of the VCO\textsubscript{2} versus VO\textsubscript{2} relationship and can be identified as the point of transition in the VCO\textsubscript{2} versus VO\textsubscript{2} (Mezzani et al., 2009). The second VT is the point at which intracellular bicarbonates are no longer available to adequately counteract exercise induced metabolic acidosis. At this point, VE increases in excess of VCO\textsubscript{2} (Mezzani et al., 2012). The second VT is usually found around 70-80% of VO\textsubscript{2 peak} and 80-90% peak HR reached during an incremental exercise test, and is related to the upper intensity limited for prolonged aerobic exercise (Mezzani et al., 2012).

Many studies have looked at the effectiveness of ventilatory and anaerobic threshold in endurance athletes with much promise. However, ventilatory threshold has recently shown effectiveness in the clinical population. Using a threshold-based aerobic exercise intensity prescription compared to range-based exercise allows professionals to
match the unique physiological responses to different exercise intensity domains to the
individual patient pathological and clinical status (Mezzani et al., 2012).

The talk test (TT) has been a useful tool in measuring VT (Dehart-Beverly, Foster, Porcari, Fater & Mikat, 2000). Researchers tested 28 healthy subjects with two VO\textsubscript{max} tests- the first used a gas analyzer to obtain VT and VO\textsubscript{max} and the second used the “Rainbow Passage” at the end of each stage. The researchers compared the results of the two tests. They found that at the patient’s VT they were not able to speak comfortably. This gave researchers an opportunity to further research as VT as an intensity-based method for exercise.

The idea of using VT in the clinical population started with a study by Voekler, Foster, Skemp-Arlt and Backes (2002). The study tested ten post cardiac rehab patients who were clinically stable. Two exercise tests were conducted to determine VT using the v-slope method and using the TT. The results concluded that the when the patient is not able to speak comfortably, they are at their VT and within ACSM guidelines. (Voelker, Foster, Skemp-Arlt & Backes, 2002).

Recently, a study by University of Wisconsin-La Crosse students Katie Doro and Mallory Engen (2015) has shown the talk test and ventilatory threshold can be used to self-monitor appropriate exercise intensity levels in cardiac rehab patients. The study included 16 patients in phase II cardiac rehab and had them complete three treadmill stages. The first test was a submaximal exercise test used to determine the patient’s ventilatory threshold. The second test was a 20-minute exercise bout where the patient adjusted their intensity based on their talk test responses. The third was a maximal exercise test used to determine maximal heart rate. The study found that the subjects were
within the ACSM intensity guidelines for percent HR reserve, steady state MET levels and rate of perceived exertion when compared to maximal values. The study strongly suggested that ventilatory threshold and the talk test can be used in the clinical population for appropriate intensity levels.
REFERENCES


