UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

EFFECTS OF SPEECH PASSAGE DURATION ON TALK TEST RESPONSE

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

Megan Foss

College of Science and Health
Clinical Exercise Physiology

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EFFECTS OF SPEECH PASSAGE DURATION ON TALK TEST RESPONSE

By Megan M. Foss

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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ABSTRACT

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The Talk Test (TT) is a simple technique for prescribing exercise training intensity, based on the ability to ‘speak comfortably’ after reciting a standard speech provoking stimulus. **Purpose**: This study compares the duration of the speech provoking stimulus on Power Output (PO) at standard TT speech comfort markers (Last Positive (LP), Equivocal (EQ), Negative (NEG). **Methods**: Eighteen healthy subjects performed incremental (25W/2 min) exercise with gas exchange to measure ventilatory (VT) and respiratory compensation (RCT) thresholds. They also performed incremental exercise (random order) while repeating a standard speech provoking stimulus (31 words) 1x, 2x or 3x to allow identification of LP, EQ & NEG. The PO at LP, EQ & NEG, in relation to the PO at VT & RCT were compared. **Results**: The relationship between PO@VT vs LP1,2,3 (r=0.73, 0.65, 0.56) and EQ1,2,3 (r=0.74, 0.65, 0.56) and RCT vs NEG1,2,3 (r=0.78, 0.80.0.71) were reasonably strong. The mean error for predicting PO@VT was smaller with longer speech passage durations for LP1,2,3 (11.22±29.67, -11.00±34.17, -24.89+34.65 W), for EQ1,2,3 (36.22±29.67, 14.00±34.17, 0.11±36.65 W), and for NEG1,2,3 vs RCT (17.94±24.83, 11.00±23.23, −0.11±28.95 W). **Conclusion**: The results suggest that longer duration speech passages (9.6 vs 19.9 vs 28.7s) optimize TT vs gas exchange identification of VT & RCT.

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INTRODUCTION

The American College of Sports Medicine (ACSM) and American Heart Association (AHA) have set forth recommended physical activity guidelines for healthy adults aged 18 to 65 years old. These guidelines suggest that individuals attain at least 30 minutes of moderate-intensity activity five days each week or achieve at least 20 minutes of high-intensity aerobic activity 3 days per week (ACSM, 2013). These guidelines are recommended to improve overall health and decrease the risk factors for chronic diseases. Exercise is often prescribed in terms of the F.I.T.T. (frequency, intensity, time and type) principle.

The gold standard recommendation for exercise intensity is 40%-60% heart rate reserve (HRR) or VO_2 for moderate intensity exercise and 60%-90% HRR or VO_2 for vigorous intensity exercise. These ranges can be derived from a maximal exercise test, in which maximum heart rate (HR_{max}) and maximum oxygen uptake (VO_{2max}) are determined. Although a maximal exercise test is preferred, it is not always a realistic option. Maximal exercise tests are expensive, must be administered by trained professionals and they can present danger to certain populations, including those with cardiovascular disease. Therefore the need of finding a subjective form of prescribing exercise intensity is evident.

Subjective measurements for determining exercise intensity include the Rating of Perceived Exertion (RPE) Scale (Gunnar Borg, 1998) and the Talk Test (TT). Both of these tests are simple and easy to perform; and the RPE scale is the most common subjective method used in clinical exercise physiology. Therefore a standard TT protocol needs to be developed so that it can be more readily used to prescribe exercise intensity.

Previous research on this topic has concluded that the Talk Test is effective at identifying intensities below the Ventilatory Threshold (VT), if the subjects were able to speak comfortably. Likewise, if subjects were unable to speak comfortably they are at or above their VT (Dehart-Beverley, Foster, Porcari, Fater, & Mikat, 2000). A similar relationship between the Talk Test and the VT was also seen in populations including well-trained cyclists (Rodriguez-Marroyo, Villa, Garcia-Lopez, & Foster, 2013), patients with coronary artery disease (Brawner et al., 2006; Voelker, 2001), sedentary individuals (Foster et al., 2009) and patients with a recent myocardial revascularization (Zanettini et al., 2013). ACSM recommends exercising below VT, therefore the TT may be a suitable method for prescribing exercise intensity.

Even with experimental manipulation of the VT, the TT has still shown to be a reliable marker of VT (Foster et al., 2008). Although the TT continues to be used as a simple and cost-effective method for prescribing exercise intensity, more research needs to be done to standardize the TT protocol. Current research has utilized many methods for provoking speech. These include the reciting of a standard speech passage (Pledge of Allegiance or the Rainbow Passage), the counting method and responding to pre-recorded questions. These methods vary in length and provoking stimulus.

The TT protocol has used many different passages varying in speech duration. To avoid the need for a cue card, Schafer et a. (2000) suggested the use of the Pledge of Allegiance (POA) as the standard speech provoking stimulus for the TT. This is an ideal speech passage because it is well known and does not require subjects to read during testing. Most research on the TT has favored the use of the POA for its simplicity and practicality. However, studies using the POA as a speech provoker have led to confusing results where either the LP or the EQ stage of the TT was equivalent to the VT. This suggested that the very short POA might be introducing a problem with the TT.

Research has confirmed the validity and reliability of the TT. Yet, more research needs to be done to standardize the TT protocol so it can be easily used to prescribe exercise intensity. Many different methods of provoking speech have been used in TT protocols. Since speaking requires suppressed breathing frequency at an intensity (VT) where the breathing frequency would naturally be increasing, it would be reasonable to suspect that longer speech provoking stimuli might be more difficult and would lead to earlier difficulty with comfortable speech. These methods vary in length and provoking stimulus (e.g. standard speech passage). Therefore, the purpose of this study was to see how manipulating speech passage duration affects the TT response. It is hypothesized that as the speech passage duration increases there will be a decrease in Power Output (PO) at the Last Positive (LP) stage.

METHODS

Subjects

The subjects for this study included eighteen healthy, young adult volunteers from the University of Wisconsin-La Crosse. The descriptive statistics of the subjects are included in Table 1. The UW-La Crosse Institutional Review Board for Protection of Human Subjects (IRB) reviewed and approved this study. Prior to testing, the participants provided written informed consent and filled out a Physical Activity Readiness Questionnaire (PAR-Q) to determine health status.

Table 1. Descriptive Characteristics of Subjects (mean ± SD)

	Men (N = 6)	Women (N = 12)
Age (yrs)	29.3 ± 17.97	22.1 ± 1.56
Height (cm)	180.6 ± 8.36	167.2 ± 5.56
Weight (kg)	90.3 ± 18.83	65.6 ± 6.32
BMI	27.7 ± 5.80	23.4 ± 1.46
PPO (W)	222.0 ± 51.32	212.1 ± 44.40
VO_2 max (ml/kg/min)	43.1 ± 10.84	43.6 ± 6.69
Max HR (bpm)	177 ± 30.8	184 ± 8.6
PO @ VT (W)	145.8 ± 43.06	118.6 ± 41.96
PO @ RCT (W)	185.5 ± 34.77	164.9 ± 38.70

Testing Procedure

Subjects completed four incremental exercise tests on an electronically braked cycle ergometer (Lode Excalibur, Groningen, Netherlands), starting at a Power Output (PO) of 25 Watts, with an increase of 25 Watts at the end of each 2 minute stage. Heart rate was monitored throughout all the tests using radiotelemetry. One of these tests was a maximal exercise test during which respiratory gas exchange was measured in order to objectively determine VT and Respiratory Compensation Threshold (RCT). Respiratory gas exchange was measured using open circuit spirometry with a mixing chamber based system (AEI, Pittsburgh, PA). Standard calibration procedures were used and VT and RCT were detected using both v-slope and ventilatory equivalent methods (Foster & Cotter, 1995)

The other three tests followed the same exercise protocol but without using the respiratory gas apparatus. Instead subjects performed the Talk Test in the last 30 seconds of each stage. The speech passage was the Pledge of Allegiance, which was recited one, two or three times. The order of speech passage duration was assigned in a counter-balance method to eliminate an order effect. The experimenter asked the subject at the conclusion of each recitation if they could "speak comfortably." The test was terminated when the subject could no longer speak comfortably (e.g. provided a negative response). Heart rate (HR), Power Output (PO), duration of speech passage, and Rating of Perceived Exertion (RPE) (G. Borg, 1970) were measured during each test.

Statistical Analysis

The data were analyzed using repeated measures ANOVA to test the effect of speech passage duration on TT response. Tukey's post-hoc test ($p < 0.05$) was used when justified by ANOVA. Additional analyses compared the three speech durations, and their relationship to thresholds (VT and RCT).

RESULTS

The effects of the TT using 31, 62 and 93 word speech provoking stimuli on Power Output at the three Talk Test stages (LP, EQ and NEG) can be seen in Figure 1. It was found that LP over predicts VT when reciting a 31 word stimulus, whereas the LP under predicts VT when reciting a 62 or 93 word stimulus. When reciting a 31 or 62 word speech stimulus, the EQ stage over predicts VT. A 93 word speech stimulus at the EQ stage is most accurate at predicting VT. It was found that both 31 and 62 word speech stimuli over predict RCT at the NEG stage. The 93 word speech stimulus most accurately predicts RCT at the NEG stage.

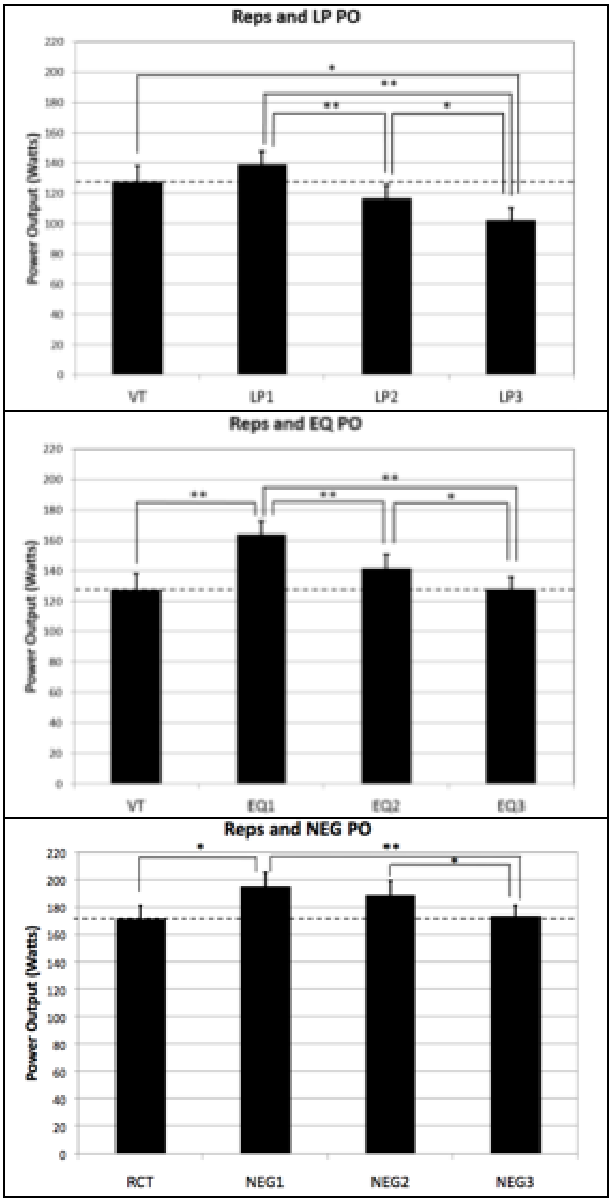

Figure 1. Power Output in Watts at LP, EQ and NEG stages of the TT using 31, 62 and 93 word speech provoking stimuli.
* Significantly different (p<.05)
** Significantly different (p<.01)

The average duration of the 31, 62 and 93 word speech stimuli +/- SD at the different TT stages (LP, EQ and NEG) can be seen in Figure 2. The recitation of a 31 word speech stimulus took 9.6 ± 1.24 s. A 62 word speech stimulus took 19.9 ± 2.80 s to recite. A 93 word speech stimulus took 28.7 ± 3.64 s to recite. For each speech length (31, 62, 93 words) there was a slight increase in recitation time from the LP, EQ and NEG TT stages.

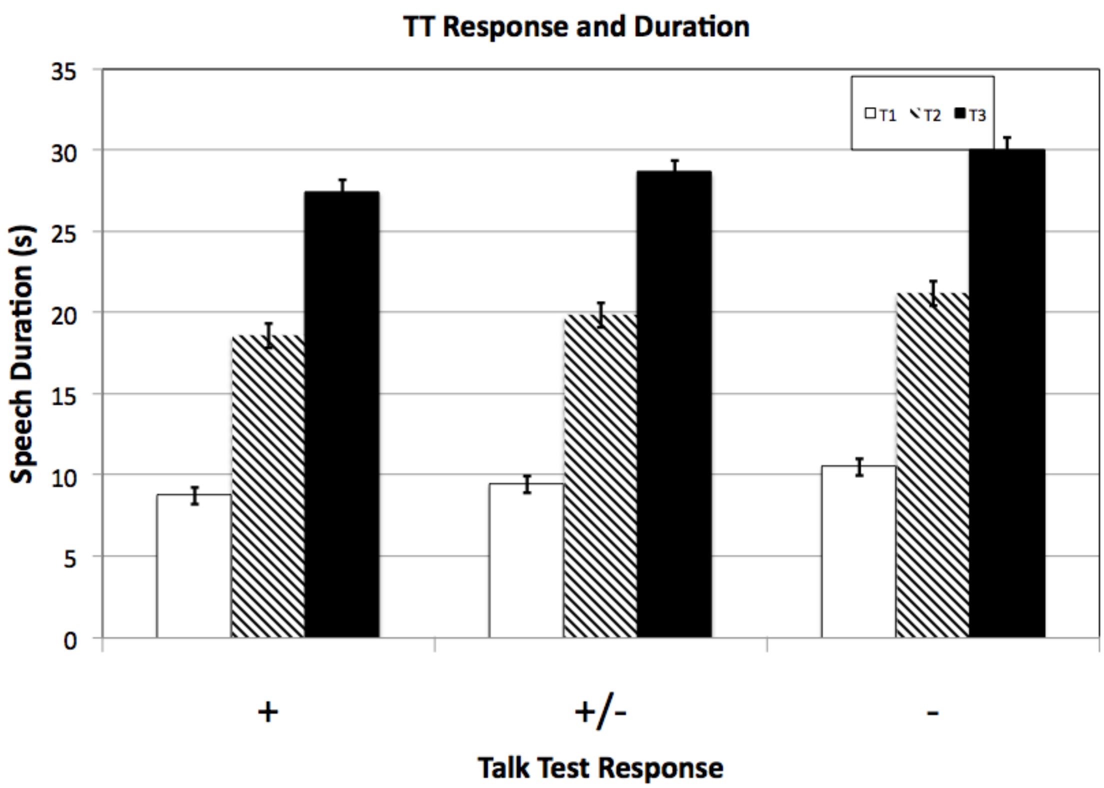

Figure 2. Average duration of 31, 62 and 93 word speech stimuli +/- SD at LP, EQ and NEG stages of the TT.

Figure 3 shows the relationship between the PO at VT and RCT and the PO at the LP, EQ and NEG stages of the TT using 31, 62 and 93 word speech provoking stimuli and gives the R^2 values. The R^2 values indicate that there is a low to moderate correlation between the VT and RCT and the PO at the different TT stages using varying speech provoking stimuli. The 31 word speech passage and the thresholds are moderately correlated. There is low to moderate correlation when looking at the relationship between the 62 word speech passage and the thresholds. There is low correlation when looking at the relationship between using the 93 word speech stimulus and thresholds.

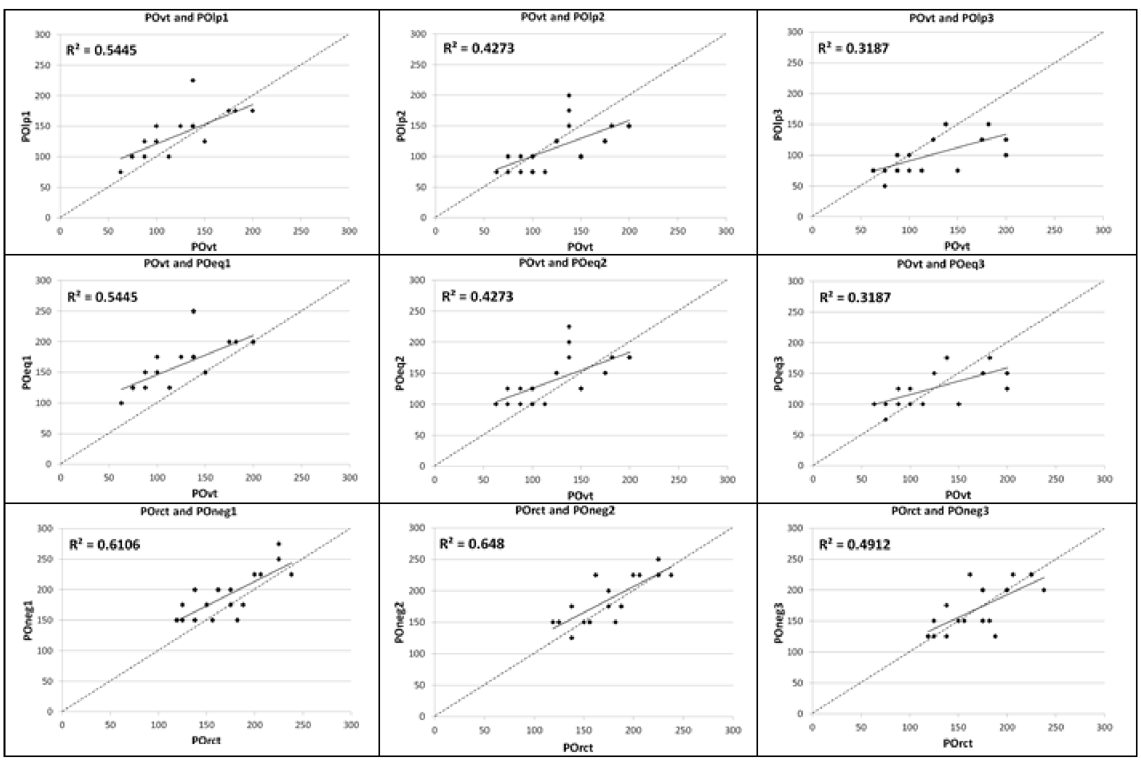

Figure 3. The relationship between the PO at VT and RCT and the PO at the LP, EQ and NEG stages of the TT using 31, 62 and 93 word speech provoking stimuli.

Figure 4 shows the error in Watts of the TT stages (LP, EQ, NEG) of 31, 62 and 93 word speech provoking stimulus. The LP stage of the 31 word speech stimuli has a positive error when used to predict VT PO. Whereas the 62 and 93 word speech stimuli have a negative error when used to predict VT PO. The EQ stage of the 31 and 62 word speech stimuli have a positive error when predicting VT PO. When using a 93 word speech stimuli there is a small error when predicting VT PO. The NEG stage of the TT when using a 31 and 62 word has a positive error when used to predict RCT PO. A 93 word speech stimulus at the NEG stage has a small error when used to predict PO at RCT.

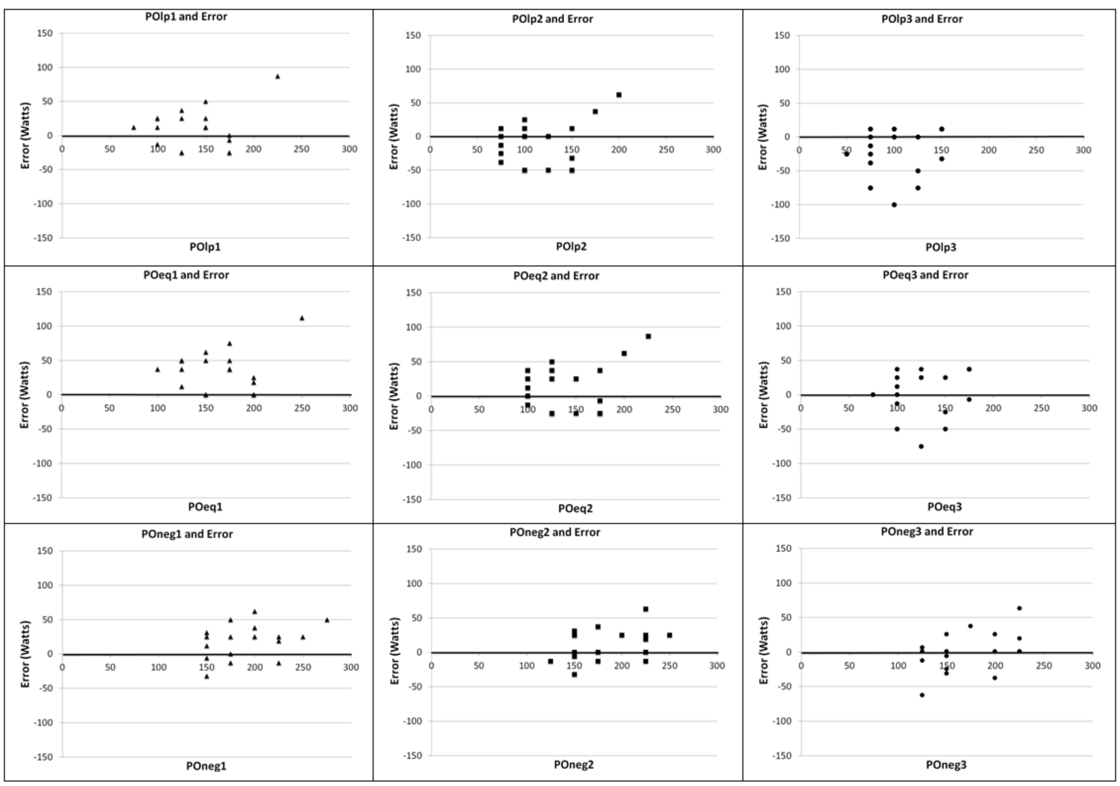

Figure 4. Error in Watts of power output at the LP, EQ and NEG stages of the TT using 31, 62 and 93 word speech provoking stimuli.

The 95% confidence interval when estimating Watts at VT and RCT from different TT duration stages (LP, EQ, NEG) and varying speech stimulus lengths (31, 62 and 93 words) can be seen in Figure 5. When using the LP stage to predict VT there is a positive error (over estimation) when using a 31 word speech passage and a negative error when using a 62 or 93 word passage (11.22±29.67, -11.00±34.17, -24.89+34.65 W). When using the EQ stage to predict VT there is a positive error when using a 31 or 62 word passage (36.22±29.67, 14.00±34.17 W). There is minimal error when using a 93 word speech passage at the EQ stage to predict VT (0.11±36.65 W). Similarly, when using the NEG stage to predict RCT there is a positive error when using a 31 or 62 word passage (17.94±24.83, 11.00±23.23 W). There is minimal error when using the 93 word speech passage at the NEG stage to predict RCT (−0.11±28.95 W).

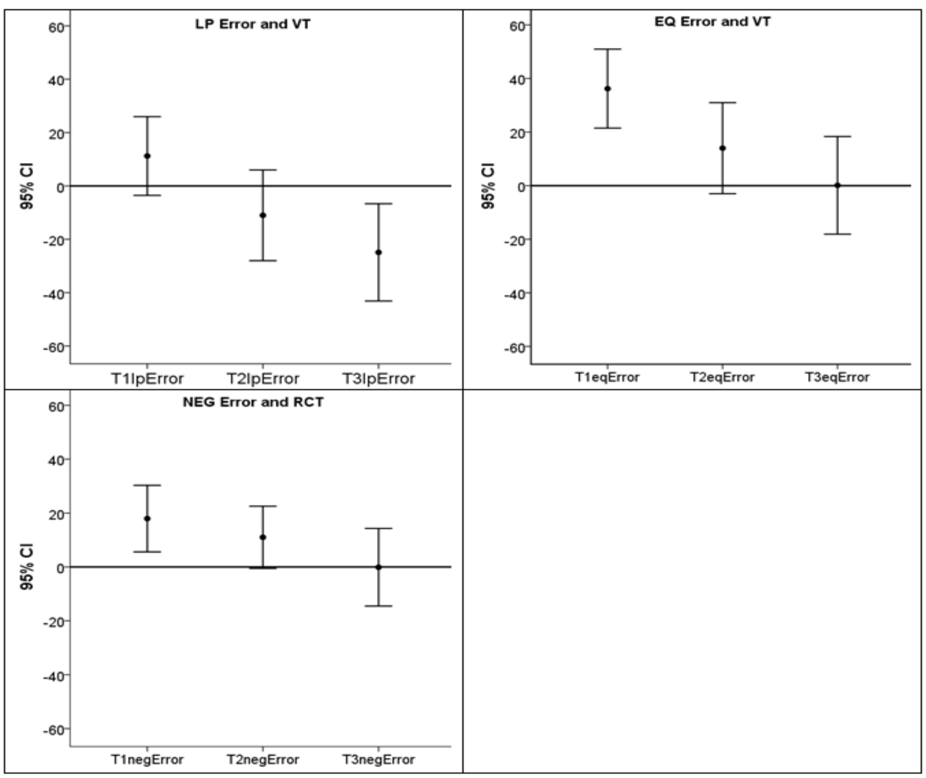

Figure 5. Means with 95% confidence interval in estimating Watts at VT & RCT from LP, EQ, and NEG stages of the TT using a 31, 62 and 93 word speech stimulus.

DISCUSSION

Results from this study suggest that the TT can be used to accurately predict VT and RCT. It was concluded that the TT most accurately predicts these thresholds when using longer speech passage durations (31 vs. 62 vs. 93 words). Results showed that with the 93 word stimulus when subjects first showed any uncertainty in their ability to speak comfortably (EQ stage of TT), they were at their VT. Likewise, when subjects were first clearly unable to produce comfortable speech (NEG stage of TT), this corresponded to their RCT.

The RPE scale continues to be the most common subjective measurement of exercise intensity. Results from this study show the relationship between the different TT stages (LP, EQ and NEG) and RPE. This study shows that when subjects were first unable to speak comfortably they were exercising at an RPE of 4; this most closely corresponded to the VT. Likewise, when subjects were first unable to speak comfortably this most closely corresponded to an RPE of 6. It is recommended for individuals to exercise below VT and therefore at an intensity corresponding to an RPE of 3.

Previous research has shown that when subjects are at an intensity at which they can speak comfortably, they are below their VT. Likewise, if a subject is definitely unable to speak comfortably they are working at an intensity above their RCT (Recalde et al., 2002). The EQ stage of the TT corresponds to an intensity close to VT. This relationship was also seen when using a longer speech passage (101 words) (Dehart-Beverley et al., 2000). These previous findings are in agreement with the present study.

The present study's results disagree with a study conducted by Persinger (2004), in which subjects recited a 31 word speech passage. A 31 word speech passage, the POA, has been the passage of choice for many TT studies because of its simplicity. Persinger concluded that the LP stage of the TT corresponds to VT, and the EQ stage of the TT is consistently above VT for a speech passage that is 31 words (Persinger, 2004). The results of this study are inconsistent with findings from the present study. In this study it was concluded that a 31 word speech passage over predicts VT and RCT. Nevertheless, the TT has been shown to be an effective objective method for prescribing exercise intensity.

A technical issue that may have affected the interpretation of the present results is the influence of stage duration. A recent study conducted by Xiong (in press) using a 31 word speech stimulus, examined the relationship between stage duration on the TT and gas exchange (GE) thresholds. Results showed that stage duration affected PO at thresholds (VT, RCT) but had no affect on physiological markers (HR, VO_2, RPE) (Xiong, Foster, Porcari, & Mikat, in press). Therefore further research needs to be done to determine the stage duration that most accurately predicts VT and RCT using a longer speech passage.

In conclusion, the present study has compared speech passages of varying lengths to threshold markers. Speech passages that are longer in duration (93 words) most accurately predict VT and RCT using the EQ and NEG stages of the TT. When subjects are first unsure of their ability to speak comfortably (EQ stage) they are at VT. When subjects cannot speak comfortably (NEG stage) they are at RCT. These TT markers are accurate at determining thresholds. These results can help prescribe exercise intensity and ensure that people are exercising in the recommended range.

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APPENDIX A

INFORMED CONSENT

Informed Consent

Protocol Title: Effects of Speech Passage Duration on Talk Test Response

Principal Investigator: Megan Foss
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La Crosse, WI 54601
(651)468-1236

Emergency Contact: Carl Foster, Ph. D.
(608)785-8687

Purpose and Procedures:

- The purpose of this study is to examine the length of speech passage duration on the Talk Test response.
- My participation will involve four tests on the cycle ergometer, all of which will be very fatiguing. These tests will involve a progressive workload until exhaustion.
- The total time requirement is 4 hours over 3 weeks.
- All testing will occur in 225 Mitchell Hall, UW-L.
- During one test I will wear a snorkel-like device to assess respiration. In all four tests I will wear a heart rate monitor, strapped around my chest, to monitor my heart rate.
- I will be instructed to recite a standard speech passage during exercise, and will be asked if I can speak comfortably.

Potential Risks:

- I may experience fatigue. The risk of serious complications (e.g. heart attack) approximates zero in healthy, physically active people like myself.
- Individuals trained in CPR, First Aid and Advanced Cardiac Life Support will present during testing.
- The test will be stopped if complications arise.

Rights and Confidentiality:

- My participation in this study is voluntary.
- I can refuse to answer any question at any time without consequence.
- I will not be penalized if I choose to withdraw from the study.
- The results of this study may be published in scientific literature or presented in a professional setting using only grouped data.
- All information and results will remain confidential and will not be associated with personally identifiable information.

Any questions involving study protocol may be directed to Megan Foss (651-468-1236), the principal investigator, or to the faculty advisor Dr. Carl Foster, a professor in the Department of Exercise and Sports Science, UW-L (608-785-8687). Questions involving the protection of Human Subjects may be directed to the University of Wisconsin – La

Crosse Institutional Review Board for the Protection of Human Subjects (irb@uwlax.edu).

Participant_____________________________________ Date____________________

Researcher_____________________________________ Date____________________

APPENDIX B

PAR-Q

<u>**Physical Activity Readiness Questionnaire (PAR-Q)**</u>

- 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 more physically active. **Please read these questions carefully and answer each question honestly.**

(**Please mark YES or No to the following)**	**YES**	**NO**
Has your doctor ever said that you have a heart condition and recommended only medically supervised physical activity?	____	____
Do you frequently have pains in your chest when you perform physical activity?	____	____
Have you had chest pain when you were not doing physical activity?	____	____
Have you had a stroke?	____	____
Do you lose your balance due to dizziness or do you ever lose consciousness?	____	____
Do you have a bone, joint or any other health problem that causes you pain or limitations that could be made worse by a change in your physical activity?	____	____
Are you pregnant now or have given birth within the last 6 months?	____	____
Do you have asthma or exercise induced asthma?	____	____
Do you have low blood sugar levels (hypoglycemia)?	____	____
Do you have diabetes?	____	____
Is your doctor currently prescribing drugs (i.e. water pills) for your blood pressure or heart condition?	____	____
Have you had a recent surgery?	____	____

If you have marked YES to any of the above, please elaborate below:

____

____

Do you take any medications, either prescription or non-prescription, on a regular basis? Yes/No

What is the medication for?
How does this medication affect your ability to exercise or achieve your fitness goals?

____
____
____
____

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

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

Print Name: ________________________ Signature: ________________________________

Date: ____

APPENDIX C

RATING OF PERCEIVED EXERTION

Borg's Rating of Perceived Exertion Scale

0	No Effort (Standing At Rest)
0.5	Very, Very Easy
1	Very Easy
2	Easy
3	Moderate
4	Somewhat Hard
5	Hard
6	
7	Very Hard
8	
9	Very, Very Hard (Nearly Maximal)
10	Maximal Effort

APPENDIX D

PLEDGE OF ALLEGIANCE

Pledge of Allegiance

"I pledge allegiance to the flag of the United States of America and to the Republic for which it stands, one Nation under God, indivisible with liberty and justice for all."

APPENDIX E

REVIEW OF LITERATURE

Review of the Literature

Introduction

In 1995 national guidelines for physical activity and public health were published by the Center for Disease Control (CDC) and by the American College of Sports Medicine (ACSM). These preliminary guidelines stated that every US adults should accumulate at least 30 minutes of moderate-intensity physical activity on most, if not all, days of the week. This recommendation sparked interest in incorporating physical activity into people's daily lives. Yet sedentary behavior continued to be a prevalent public health issue. After compiling new scientific evidence relating the benefits of physical activity to health, the American Heart Association (AHA) and the ACSM set forth new physical activity guidelines in 2007. These revised guidelines stated that all healthy adults, age 18-65 years, should attain at least 30 minutes of moderate-intensity activity five days each week or achieve at least 20 minutes of high-intensity aerobic activity 3 days per week. The revised recommendation also included incorporating activities that maintain or increase muscular strength and endurance; this should be done at least twice per week. For individuals seeking additional health improvements or to further reduce their risk for chronic diseases, it is suggested to exceed these minimum physical activity recommendations (ACSM, 2013) Although there has been extensive research in the field of Exercise Science, there is still a need for a simple yet effective way to prescribe exercise.

ACSM recommends using the F.I.T.T. principle when prescribing exercise. The F.I.T.T. principle incorporates frequency (how often), intensity (how hard), time (duration) and type (what kind). All these components are important when prescribing exercise. Yet intensity continues to be the hardest to prescribe, since it is subjective. Extensive research has been done to find a standard method to prescribe exercise intensity to all populations.

Currently ACSM recommends 40%-60% heart rate reserve (HRR) or VO_2 for moderate intensity exercise and 60%-90% HRR or VO_2 for vigorous intensity exercise. These ranges can be derived from a maximal exercise test, in which maximum heart rate (HR_{max}) and maximum oxygen uptake (VO_{2max}) are determined. Although this method is preferred, it is not always realistic to perform a maximal exercise test. Maximal exercise tests are costly, time consuming, and may not be readily available. The results can also vary based on a subject's current physical fitness, which may change over time. A maximal exercise test may also be harmful to certain populations, including those with cardiovascular disease. A simpler method used to predict HR_{max} is through the use of a formula. The most common formula used for predicting HR_{max} is (220-age). This formula gives a good prediction of HR_{max} but it can overestimate or underestimate.

Each person has a unique physiology that produces variable objective measurements. Therefore the need of finding a subjective form of prescribing exercise intensity is evident. This has led to the development and research into subjective measurements of exercise intensity. These methods include the Rating of Perceived Exertion Scale (RPE) (G. Borg, 1970) and the Talk Test (TT). Both of these tests are simple and easy to perform; and the RPE scale continues to be the most common subjective method used in the field of clinical exercise physiology. Therefore more research needs to be done to better understand how the TT might be used to correctly prescribe exercise intensity.

Exercise Prescription

The current Gold Standard for prescribing exercise is based on relative percentages that can be derived from an incremental exercise test. Maximal exercise tests produce patient-specific data including maximum heart rate (HR_{max}), heart rate reserve (HRR), oxygen uptake (VO_{2max}), Power Output (PO), lactate threshold (LT), ventilatory threshold (VT), and respiratory compensation threshold (RCT). Using these results clinicians can prescribe an individualized exercise intensity that is unique to a patients physiologic and pathophysiologic response (Mezzani et al., 2012). These results can help maximize the aerobic exercise training benefits.

Although graded exercise tests (GXT) are the Gold Standard for prescribing exercise, this method is not without error. Through research performed by Katch et al. (1978), it was determined that the relative percents determined during a bicycle ergometer test can produce enormous error when prescribing exercise. This data suggests that subjects that were all exercising at the same relative HR percent saw the onset of metabolic acidosis at varying times. Therefore prescribing exercise intensity through the use of percentages of HR_{max} can be inconsistent. Additionally, these tests are expensive, they require trained professionals, and can be dangerous to certain populations. Therefore the demand for a simple and effective method to prescribe exercise is needed.

The most common subjective method for monitoring exercise intensity is through the use of the Borg Rating of Perceived Exertion scale. Evidence suggests that an RPE range of 12-15 can be used to prescribe exercise in various populations (Birk & Birk, 1987). This perceived exertion corresponds to 50-85% of VO_{2max}, which is what is recommended by ACSM to obtain a training effect. Although, the Borg RPE scale has been highly accepted for measuring exertion, it still has its flaws. It has been shown that in order for the ratings to be accurate, the subject must visually see Borg scale (Abadie, 1996). This study suggested that subjects that were not able to see the RPE scale while exercising at moderate to high intensity exercise underestimated their RPE. Therefore it is impractical to suggest the Borg scale as an everyday measure of exercise intensity since the scale is usually unavailable.

Professor Henry Joseph Grayson originally suggested the concept of the Talk Test (TT) in 1939. Professor Grayson instructed British mountaineers to "climb no faster than you can speak." This was the basis for the current TT and it has sparked much interest and research into using subjective methods to evaluate exercise intensity. In 1991, ACSM published Guidelines for Exercise and Training that included the use of the TT. But soon after, the TT was withdrawn from these guidelines due to lack of research and support. Since then, a great deal of research has been done confirming the validity of the TT and its use in prescribing exercise.

Goode et al. (1998) first looked at controlling exercise through a breathing sound check. In this study, young male subjects completed exercise tests on a cycle ergometer. During these tests the workload (WL) was increased by 25 Watts every minute and subjects were instructed to raise their hand when they could "hear your breathing." At this point the WL was held constant and the subject continued to peddle for five minutes. In the final test subjects were instructed to jog on the track at a pace which they could “hear your breathing,” at which point they were instructed to continue jogging for an additional ten minutes while maintaining the same breathing sound. Heart rate was measured during each test. At the end of the study, the VO_2 was determined by matching the HR achieved during both tests to the HR achieved during the maximal exercise test. The results suggest that when subjects could hear their breathing they were at or close to the VT. Additionally, this intensity corresponds to a HR that is within ACSM’s recommended range of 60-90% of maximal HR. These results support the hypothesis that there is a relationship between breathing (speech) and exercise (Goode, Mertens, Shariman, & Mertens, 1998).

Speech Production

Before the TT could be standardized, there had to be research into whether there was a relationship between speech production and exercise. Ventilation is necessary for both gas exchange and oxygen delivery. Another function of breathing is the production of speech. During speech there is a lengthening of the expiration phase, which results in a reduction in breathing frequency. Doust and Patrick (1981) conducted a study in which ventilation was measured at five different treadmill speeds, in which each stage lasted for 7 minutes. The treadmill speed was controlled by keeping each subjects HR at a consistent 85, 95, 125, 150 and 165 beats per minute (BPM). During the fifth minute of each treadmill speed, the six male subjects read a printed 100 word passage, taking approximately 30 seconds. A respiratory inductance plethysmograph was used to detect ventilation volume. Results showed that during each stage, ventilation was reduced to 55% during speech. Whereas after speech, there was a ventilation overshoot of about 14%, followed by a return to baseline. This study concluded that after speech production at all intensities, there was a reduction in exercise ventilation and breathing frequency (Doust & Patrick, 1981).

The next step was to determine how controlling ventilation affects exercise intensity. Mertens et al. (2001) determined that when subjects "can hear your breathing" (the Breath Sound check) they are within 15% of the VT1. This intensity also correlates with a HR that is within the recommended range to achieve health benefits according to ACSM guidelines. Thus, the "Breath Sound check" and the "Talk Test" are a simple and easy way for subjects to control exercise intensity without the use of equipment.

During exercise, ventilation is crucial for the removal of toxins in the body and for the delivery of oxygen to the muscles. A study conducted by Meckel et al. (2002) investigated the physiological responses after speech production during sub-maximal exercise. Subjects ran at work intensities corresponding to percentages of their VO_{max}, 65%, 75%, and 85%, respectively. These intensities were tested with and without talking. It was concluded that speech production during exercise results in a subsequent reduction in oxygen consumption (VO_2) and minute ventilation, with an increase in lactic acid and blood pressure (BP). To meet the phonatory requirements there is a reduction in ventilation. This study suggests that by adjusting speech we will observe significant physiologic responses (Meckel, Rotstein, & Inbar, 2002).

Rotsein et al (2004) wished to find a method suitable for prescribing exercise based on perceived speech difficulty (PSPD). In their study participants preformed an incremental running test during which subjects were asked to read a written text and grade their PSPD on a 13 level scale. Various physiological markers were measured throughout the test. The results suggested a statistically significant correlation between various physiological responses and PSPD. However, individual variability existed between ventilatory aerobic threshold (VAT) and PSPD. This study questions the ability to use the TT as a measure of VAT, HR and thus for prescribing exercise intensity. Although this study contradicts the TT, it has raised a better question whether there is a standardized method for provoking speech that can be used to prescribe exercise intensity (Rotstein, Meckel, & Inbar, 2004).

Talk Test

The TT procedure starts with subjects performing an incremental exercise test, varying from two to three minutes in stage duration. Near the end of each stage, usually about 30 seconds from the end, the subject is given a standard speech provoking stimulus. The most common protocols for initiating speech production are the use of a standard paragraph (Pledge of Allegiance (POA) or Rainbow passage(RP)) or by having the subjects listen to pre-recorded questions, which they will answer out loud. Following speech, the subjects were asked, “can you speak comfortably?” The possible responses are “yes,” “I’m not sure,” or “no.” To achieve a positive TT, which is indicated by the Last Positive stage (LP) or the stage before the LP stage (LP-1), the subject must be able to speak clearly and comfortably. An Equivocal test (EQ TT) is attained if the subject is unsure of whether they can speak comfortably. Lastly, if the patient cannot respond comfortably to the TT then the result is a negative test (NEG TT).

After the withdrawal of the TT from ACSM literature there has been extensive research on the validity and reproducibility of the TT for prescribing exercise intensity. In 2000, Dehart-Beverly et al. conducted a study to test the relationship between VT and the TT. The test protocol included two maximal exercise tests, one with respiratory gas analysis which was used to determine the VT, the other test had subjects read “the Rainbow Passage” during the last one minute of each stage. Subjects were asked if they could speak comfortably and their responses were recorded. If the subject was able to speak comfortably they were determined to be below their VT. Likewise, if the subject was unable to speak clearly then the results showed that they were exercising above their VT. The EQ stage corresponded to intensities close to VT (Dehart-Beverley et al., 2000). This relationship can also be seen in well-trained cyclists. ACSM recommends exercising below VT, therefore the TT may be a suitable method for prescribing exercise intensity.

In an attempt to simplify the TT protocol Shafer (2000) suggested using the commonly known Pledge of Allegiance (31 words). In this study Shafer looked at if the relationship between VT and EQ still existed in a sedentary population. This study also looked at if the RP or POA had an effect on predicting VT. Subjects preformed incremental treadmill exercise in which gas exchange was analyzed. These results were used to determine VT. Subjects then followed the same exercise protocol, this time reciting the POA and the RP. It was determined that the EQ stage of the TT surpassed VT. However, if the subject could speak comfortably they were within ACSM’s guidelines for %VO2max and %HRmax. This was the first research suggesting that the simpler POA could be used instead of the lengthier RP (Shafer, 2000).

It was shown previously in a study conducted by Mertens et al. (2002) that ventilation was related to VT1, but more research needed to be done to show what the affects were if VT was manipulated. Foster et al. (2008) examined how changing the VT would affect TT, by conducting four independent studies. Healthy young adults had their VT decreased (via donation of 500ml whole blood), increased (via six week aerobic training program) or varied above and below VT (by performing two interval exercise training sessions on a cycle ergometer or by running on a treadmill while VT was manipulated). The protocol for these studies included two maximal exercise tests on a motorized treadmill, one control test and one test with the treatment. All four studies showed VT and TT to be "robustly related." This supports the hypothesis that the TT is reliable at marker of VT (Foster, Porcari, Anderson, Paulson, Smaczny, Webber, Doberstein, Udermann, 2008).

More research needed to go into using the TT to prescribe exercise. In a study conducted by Quinn & Coons (2011), fifteen participants were submitted to a research protocol in which their VT was determined by a treadmill lactate threshold test and maximal oxygen consumption test. On another day, the subjects were administered the TT while performing the same treadmill protocol, they were then asked the ease of speech production. This study concluded the TT was more strongly related to the VO_{2max}, HR_{max} and RPE corresponding to the LT rather than VT. At the last positive stage of the TT, the values for these physiologic and perceptual markers were all within the recommended intensity range prescribed my ACSM. Therefore the TT can be used as a simple method for prescribing exercise intensity.

Next it was important to relate the TT results to different populations. Brawner et al. (2006) used two different methods of the TT in patients with coronary artery disease (CAD). Twenty-four subjects completed one maximal exercise test, followed by two submaximal exercise tests with different methods for provoking speech. One method for speech production was the treadmill TT (TT-TM) during which the subject read a standard passage, the POA, during the last 30 seconds of each stage; they were then asked if they could speak comfortably. The second method for provoking speech was through the indoor track TT (TT-track). During this protocol subjects were instructed to walk or jog on a track but to only go as fast as they could comfortably speak. Speech was initiated by a personal cassette player that played questions that subjects were required to answer out loud. When the subjects reported they could no longer speak comfortably, 89% of subjects were exercising above VT. The results of this study show the TT to result in HR and RPE that are within the range for exercise intensity for patients with CAD. This study also showed there to be no difference between speech provoking strategy and the physiologic markers. The HR achieved by the TT method was also consistent with the HR at VT. Although the TT method is helpful for prescribing exercise it should not be the only method used since there is variability in HR response. Therefore the TT may be most beneficial to help patients recognize when they are exercising beyond their VT (Brawner, Vanzant, Ehrman, Foster, Porcari, Kelso, Keteyian, 2006).

A study by Foster and colleagues used the TT to evaluate the translation of submaximal exercise test responses to prescribing exercise in a sedentary population. This study examined exercise training intensity when the TT is applied to steady state exercise. Subjects first completed an incremental treadmill test to determine the intensities that corresponded to each stage of the TT. Next, subjects preformed three 20 minute exercise sessions with the last 10 minutes of each session held constant at the LP-1 stage, LP stage or the EQ stage. The results showed that all three steady-state intensities produced results within ACSM guidelines for MET and $\%HR_{max}$. Yet the subjective results (TT response) surpassed the recommended intensity guidelines unless intensity was decreased to the LP-1 stage. Therefore exercise intensity should not be solely based on objective measurements (Foster, Porcari, Gibson, Wright, Greany, Talati, Recalde 2009).

To further understand the TT and its use in special populations, Zanettini et al. (2013) looked at patients with a recent myocardial revascularization. Patients were enrolled in a 5 week cardiac rehab program in which their initial WL was set around a 4 on the 10 point Borg scale. Weekly 5-10 Watt increases were made to keep patients RPE between 4 and 5 on the Borg scale. In the fourth week of the program patients underwent three TT's, on three different days, administered by three different testers. A final cardiopulmonary exercise test was administered at the end of the fifth week. The workloads from the final submaximal test and TT were compared to see if the range between aerobic threshold (AeT) and anaerobic threshold (AnT) were within the recommended training range. The results showed that 88% of patients were within the recommended training range when they were exercising at an intensity equivalent to the LP stage. This study also looked at the perception of workloads between the subject and experimenter at different TT stages. Results showed that experimenters usually underestimated a subjects LP and EQ, as compared to the subject perception, but these results were not statistically significant (Zanettini, Centeleghe, Franzelli, Mori, Benna, Penati, Sorlini, 2013). A similar study was done by Nielsen and colleagues on patients with ischemic heart disease (IHD). This study showed that using the TT during a graded cycle test (GCT) was well tolerate by patients with IHD. The TT also produced results that were consistent between trials (Nielsen et al., 2014).

More recently, in a study by Xiong (in press), the stage duration of the TT was manipulated to observe the physiologic response. In this study, 24 healthy subjects completed six incremental exercise tests on a cycle ergometer. In each test HR was measured in addition to recording RPE at the end of each stage. The first three tests were completed while measuring gas exchange to determine VT and RCT. The remaining three tests were completed using the TT protocol with 1, 2 or 3 minute stage durations. The subjects were prompted to recite the POA with 30 seconds remaining in the stage, followed by being asked if they could "speak comfortably." The results indicated that stage duration impacted PO at VT, RCT and during maximal effort, yet physiological markers including HR, VO_2 and RPE remained consistent at the same comparative markers. The results also showed the rating of speech comfort to be consistent between subject and experimenter (Xiong, Foster, Porcari, & Mikat, in press).

In conclusion, we are in need of a simple and cost effective method for prescribing exercise intensity. A great deal of research has been done confirming the validity and reliability of the TT. Yet, more research still needs to be done to standardize the TT protocol so it can be utilized as a method for prescribing exercise intensity. Many different methods of speech initiation have been used in TT protocols. These methods vary in length and provoking stimulus (i.e. tape recorder vs. standard speech passages). By completing this study, we hope to help standardize the TT to a length that best matches physiologic markers to thresholds.

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