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USE OF THE TALK TEST TO TRACK CHANGES IN VENTILATORY
THRESHOLD

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

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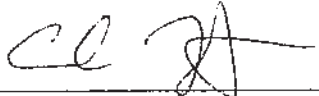
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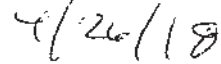
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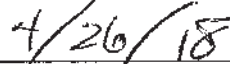
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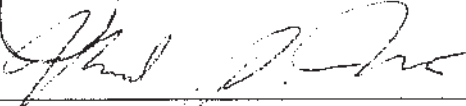
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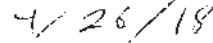
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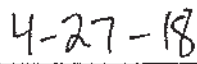


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ABSTRACT

Linzmeier, K. Use of the talk test to track changes in ventilatory threshold. MS in Clinical Exercise Physiology, December 2018, 61 pp. (C. Foster)

This study was designed to determine whether the Talk Test (TT) would be able to track changes in ventilatory threshold (VT) measured using open-circuit spirometry. The TT is a simple protocol where an individual exercises until they are not able to talk comfortably. Previous studies found that the TT tracks changes in VT after training or donating blood (Foster et al., 2008). In this thesis, a replication study, fourteen healthy individuals were tested before and after six weeks of training or detraining. It was found that there was no significant difference between the values obtained between the TT and the VO_2 at VT. Ventilatory threshold and the equivocal stage (EQ) of the TT were not significantly different. There was no significant difference between baseline exercise time and the training or detraining exercise time. However, there was a significant change in RPE and TRIMP during the study. The results of this study suggest that the TT can be used as a substitute to an objective maximum test to evaluate increasing or decreasing in exercise capacity.

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INTRODUCTION

The prescription of exercise has been standardized by the American College of Sports Medicine (ACSM) to assist the public in improving health and contributing to a healthy lifestyle. The ACSM recommends exercise 3-5 times (or 75-150 minutes) per week at a moderate to vigorous intensity (ACSM, 2017). The intensity prescription is based on percentage of maximum HR reserve (%HRR). However, to obtain maximum HR one must complete a maximum effort test which requires trained personnel and expensive equipment. This may not be the most practical way to obtain this information. There are alternative methods for obtaining maximum HR without the use of a maximal test. These would be age dependent formulas such as $220 - \text{age}$ or $220 - (.7 * \text{age})$. These values give acceptable population estimates of maximum HR but are not very accurate on an individual basis. Cardiac patients may have a particular difficulty using HR to determine exercise intensity as drugs such as β -blockers affect their heart rate with their effect varying based on the time from the last dosage. Katch, Weltman, Sady, and Freedson (1978) noted that using the %HRR training method may not stress individuals to the same degree in relation to energy metabolism. Similarly, Scharhag-Rosenberger, Meyer, Gäßler, Faude, Kunderman (2010) found that exercising at a standard % VO_2 max for long periods of time leads to inhomogeneous metabolic strain and large variability even in groups of similar exercise capacity.

Goode et al. (2000, 2008) noticed this flaw and sought to find a solution. They found that simply asking an individual if they could “hear their breathing” while they were exercising was a reliable avenue for prescribing exercise intensity. This formed the background of the Talk Test (TT), which has been in the forefront of research in exercise prescription recently (Foster et al., 2018). The TT is simple as it asks the individual, after they have completed speaking, if they are able to “talk comfortably”. If they can still speak it is considered a positive (POS) stage and the intensity is below the ventilatory threshold. Once the individual is not sure if they can speak comfortably, the stage is called the equivocal (EQ) stage and as soon as the individual definitely cannot speak comfortably they’ve entered the negative (NEG) stage of the TT.

The TT works because of the body’s natural physiological mechanisms. At rest, speech production causes a reduction in total ventilation, particularly breathing frequency. This also holds true during exercise (Rostein, Meckel, and Inbar, 2004). When a person is exercising their body has an increase in neutrally-mediated ventilation, which is augmented by an increase in H⁺ ions, norepinephrine, and epinephrine in their blood (Goode, 2008). When the intensity increases beyond the VT it causes more H⁺ ions to be released and creates the need further increases in ventilation. With very high intensity exercise the voluntary respiratory control system takes over and makes it difficult to suppress breathing frequency, which is necessary for speech. A decrease in minute ventilation (V_E) during speech causes a reduction in VO_2 and VCO_2 . Doust and Patrick (1981) found that there was a reduction in minute ventilation while speaking. Respiratory frequency was also reduced, but tidal volume was not. Immediately after speaking, ventilation increased by 14% and then returned to normal within 30 seconds of

completing the stage (Doust & Patrick, 1981). Creemers et al. (2017) studied the effect of speech on breathing rate and end tidal CO₂ levels, which is a surrogate of arterial CO₂. Their study, along with Meckel et al., (2001) showed that VO₂, VCO₂, and V_E significantly decreased during speech and increased immediately after speech had concluded. However, end-tidal CO₂, a marker of arterial CO₂, increased during speech. Therefore, Creemers et.al. (2017) suggested that the loss in speech comfort was caused by a retention of CO₂.

The simplicity of the TT there has inspired considerable research to determine its validity and reliability for prescribing exercise intensity. Research has shown that the TT is valid and a useful surrogate for both the ventilatory threshold (VT) and respiratory compensation threshold (RCT), not only in healthy individuals, but also in cardiac patients and athletes (Brawner et al., 2006; Foster et al., 2008; Foster et al., 2009; Gron Nielsen, 2014; Rodriguez-Marroyo et al., 2013; Voelker et al., 2002, Zanettini et al., 2013). The last positive (LP) stage of the TT is typically just below VT. At the EQ stage of the TT the individual is typically at or near their VT. When the individual reaches the NEG TT stage, they have passed the VT and are usually close to the RCT (Ballweg et al., Creemers et al., 2017; 2013; Dehart-Beverley et al., 2000; Goode, 1998; Goode, 2008; Jeans, Foster, Porcari, Gibson, and Doberstein, 2011; Quinn & Coons, 2011; Recalde et al., 2012; Rodriguez-Marroyo et al, 2013; Woltmann et al., 2015). Foster et al. (2008) tested the effect of a 6-week training program on VT and whether the TT would show a relationship between changes in VT and the EQ stage of the TT after training. The study found that VT increased significantly following training, and the subjects could last longer during the TT than they had prior to the training. The LP and EQ stages of the TT

also increased following the training program. Foster et al. (2008) also demonstrated that both the EQ stage of the TT and the VT decreased in parallel following blood donation (e.g. reduction of hemoglobin mass).

Training has been shown to shift the power vs. VO_2 curve to the right and improve fitness (Carazo-Vargas & Moncada-Jiménez, 2015; Favero & Jackson Stoll, 2016; Hama & Magied, 2014). However, there have not been any studies since Foster et al. (2008) assessing the relationship between both improvement and reduction in VO_2 and VT after a period of detraining or training using the TT. Given that replication of experimental results is a fundamental principle of scientific inquiry, the purpose of this study is to observe whether a change in a subjects VO_2 and VT can be tracked using the TT. This is a basic replication of the training data reported by Foster et al. (2008).

METHODS

Subjects

Fourteen healthy subjects were recruited from the University of Wisconsin-La Crosse community. All subjects completed the Physical Activity Readiness Questionnaire (2017 PARQ+) to determine contraindications to exercise or health concerns that could affect completion of the study. Prior to the study subjects were given both written and oral descriptions of the study and each subject provided written informed consent. The UWL Institutional Review Board for the Protection of Human Subjects reviewed and approved the protocol.

Subject were excluded from the study if they had a musculoskeletal injury, recent musculoskeletal injury that would conflict with max tests, cardiac or pulmonary

contraindications to exercise, and/or were pregnant. Out of the study's fourteen volunteers, thirteen completed the study. One subject dropped from the study during the final week after a sudden illness. Descriptive characteristics of those who completed the study are found in Table 1.

Table 1. Descriptive characteristics of subjects at beginning of study.

	Male (n=7)	Female (n=6)
Age (yrs)	21.7±1.89	19.6±0.98
Weight (kg)	79.0±20.76	75.6±25.10
Height (cm)	70.6±2.62	67.4±4.76

Values represent mean ± standard deviation.

Protocol

The subjects began by recording their exercise training program for two weeks to obtain baseline exercise information. They recorded the length of time and intensity of exercise using the Borg CR-10 scale (Borg, 1998). The training load was calculated using the session RPE method (Foster et al., 1995, 2001). After two weeks of logging their exercise, the subjects came to the laboratory to perform maximum tests. The tests were completed on four separate occasions on an electronically braked cycle ergometer (ExcaliburLode, Groningen, The Netherlands). Two tests were completed during week one and the other two tests during week six of training. Tests were separated by at least 48 hours. The first test was either the TT or an open-circuit spirometry test (AEI Technologies MOXIS Modular VO₂ System, Pittsburg, Pennsylvania), performed in

random order. Heart rate was recorded using radio telemetry (Polar Vantage XL, Kempele, Finland). Each subject started with a 3-minute warm up at 25 Watts, cycling at 80-100 rpm. The test continued with 3-minute stages with an increase of 25 Watts in each stage until a cadence of 80-100rpm could not be continued. During the last 15 seconds of each stage, HR and Rating of Perceived Exertion (RPE) using the Borg CR-10 (Borg, 1998) scale was recorded. During the TT protocol, the subject was asked, during the last 45 seconds of each stage, to recite a 101-word passage, the “rainbow passage,” supported by a cue-card. After reading the passage, the subject was asked if they “were able to speak comfortably”. They responded with “yes,” if they could speak comfortably, “yes, but,” if it was beginning to become difficult to speak, or “no,” if they could no longer speak comfortably. The same HR & RPE measurements were also recorded during the last 15 seconds of each stage.

At the completion of the second test the subject was asked to continue to record his/her physical activity for the next six weeks. The subjects used a modified TRIMP score using the Borg CR-10 RPE scale to record their exercise (Foster et al., 1995, 2001). Contact was done at least twice a week via email or text message to record training data. Following the 6-week session, each subject returned and repeated the first two tests. Ventilatory threshold was determined using the v-slope method and ventilatory equivalent methods (Foster & Cotter, 2005).

Between the test pairs the subjects were asked to modify (increase or decrease) their training. Details of training duration and intensity were recorded using the session RPE method (sRPE) (Foster et al., 1995, 2001). At the beginning of the study most of the

subjects were performing moderate training and were asked to increase the training load. A few of the subjects had busy schedules and chose to detrain.

STATISTICAL ANALYSIS

Data was analyzed using a two-way ANOVA with repeated measures to evaluate the hypothesis that changes in the power output at the LP and EQ stage of the TT would parallel changes in the power output at VT reflected by open circuit spirometry. Tukey's post-hoc analysis was used to detect within-group differences when justified by the ANOVA results. The level of significance was set at $p < .05$. Supportive analyses were made using linear regression.

RESULTS

Variables assessed between pre and post testing are represented in Table 2 and Figures 1-4b. It was found that there was also no significant difference from pre to post testing VO_2 max (L/min), VO_2 max (ml/kg/min). However, there was a significant change from pre to post testing in PPO (Watts), VO_2 at VT (Watts), PO at EQ TT (Watts), and PO at LP TT (Watts). Watts at VO_2 VT, Watts and EQ, and Watts and LP improved. The rate of increase in Watts at VT was significantly greater than the Watts at EQ TT and LP TT.

The pattern of changes in the Watts at VT and Watts at the LP and EQ TT stages were similar and achieved statistical significance (Figure 3). Parallel changes in individual values for changes in Watts at VT verses Watts at the LP stage of the TT (Figure 4a) and the EQ stage of the TT (Figure 4b).

Table 2. Changes in performance variables over the course of the study.

	Pre	Post	Change
PPO (Watts)			
TT	207±51.6	214±48.1	+7.0
VO ₂	202±49.8	212±50.9*	+10.0
HRMax (bpm)	189±6.0	188±4.2	-1.0
VO ₂ (L/min)	3.3±.87	3.4±.85	+0.1
VO ₂ (ml/kg/min)	43.0±9.04	44.0±9.52	+1.0
VT (Watts)	116±40.3	134±32.4*	+18.0**
LP TT (Watts)	100±40.8	110±29.8*	+10.0
EQ TT (Watts)	125±40.8	135±29.8*	+10.0

Values represent mean ± standard deviation.

*Significantly different than pre-test (p<.05).

** Significant change in pre-post values than LP TT and EQ TT (p<.05).

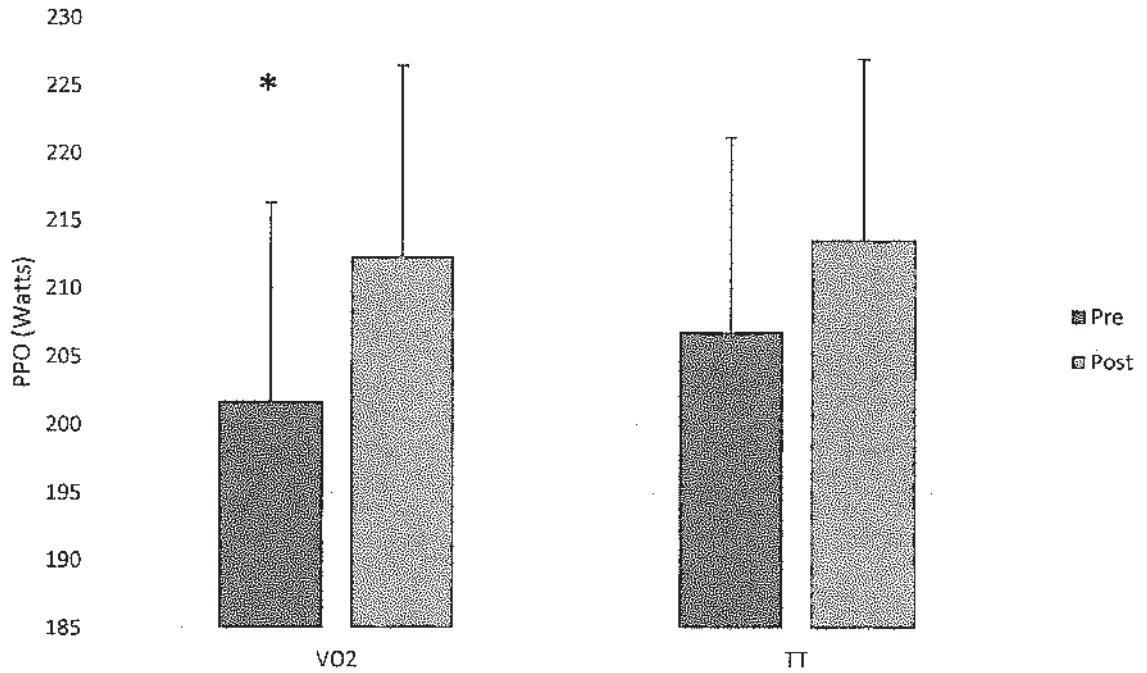


Figure 1: Changes in peak power output (Watts) from pre to post testing between VO₂ max test and Talk Test. Values represent mean ± standard error.

* Significantly different than pre test PPO.

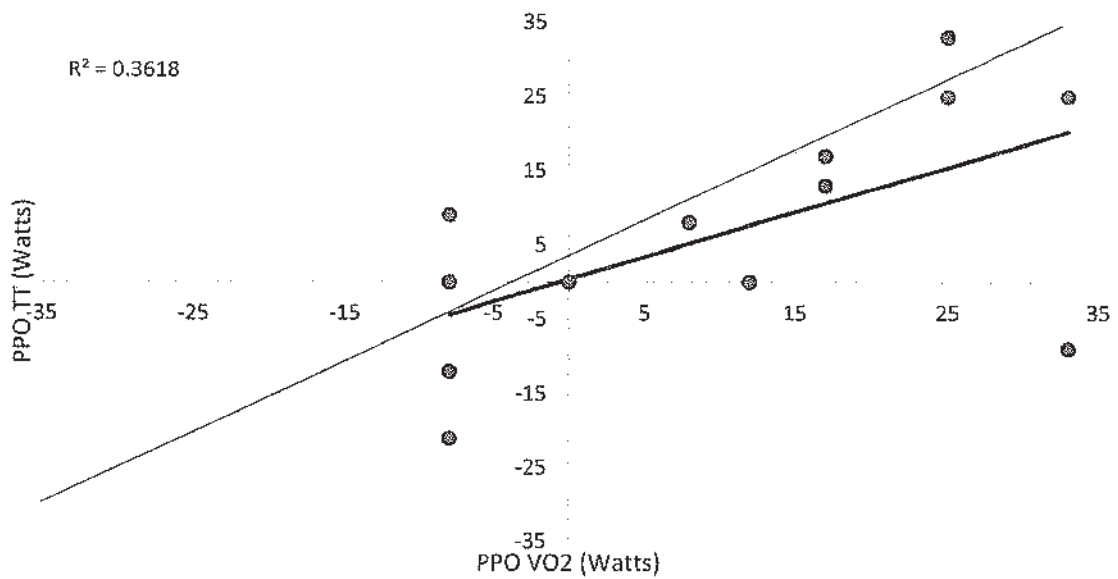


Figure 2: Scatterplot of post-pre PPO comparison of changes in TT and VO₂ max test.

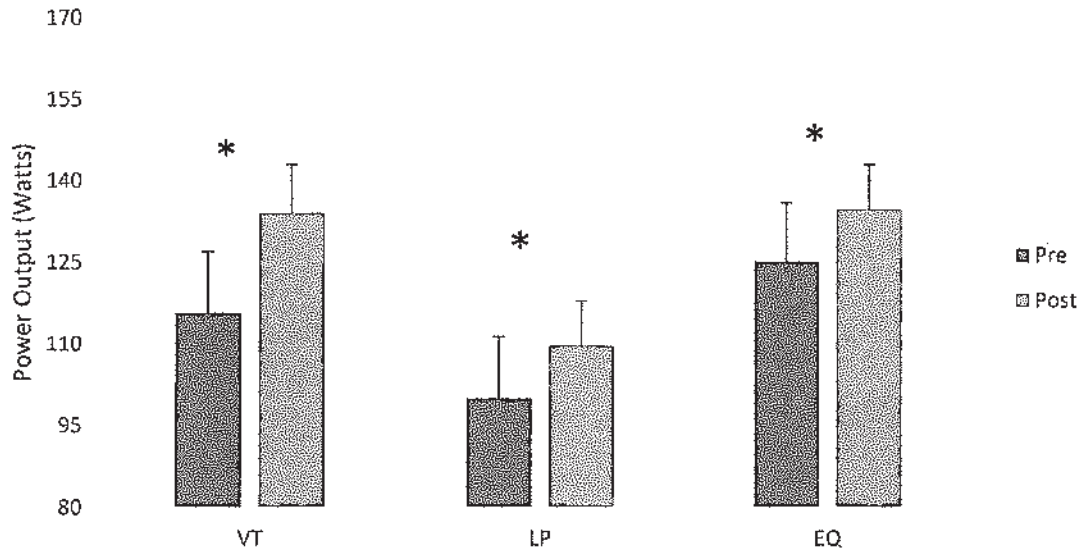


Figure 3: Changes from pre to post testing VT and EQ Watts. Values represent mean \pm standard error.

*Significantly different than pre-test PO.

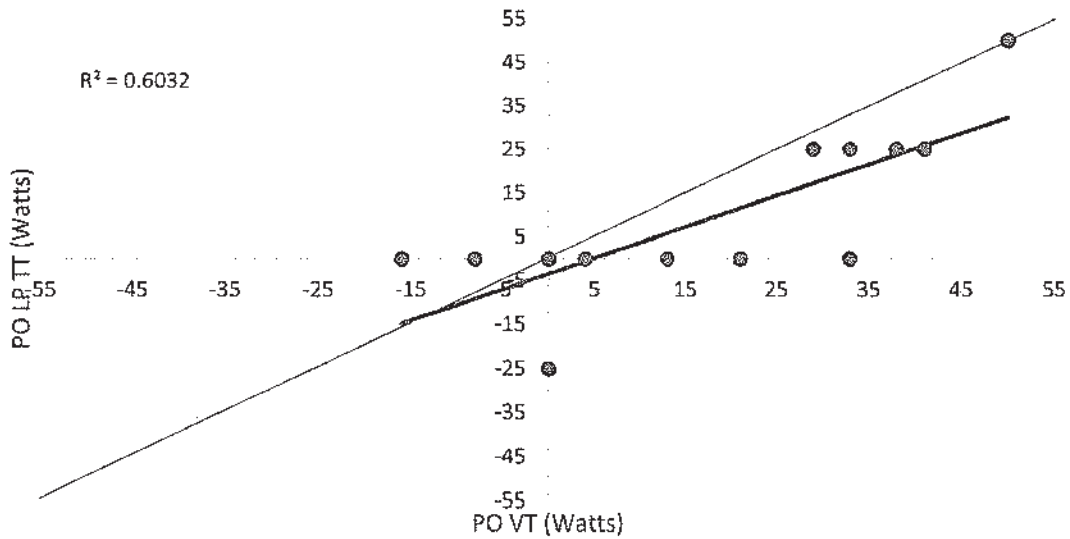


Figure 4a: Scatterplot of the pre-post PO comparison of changes in LP TT and VT.

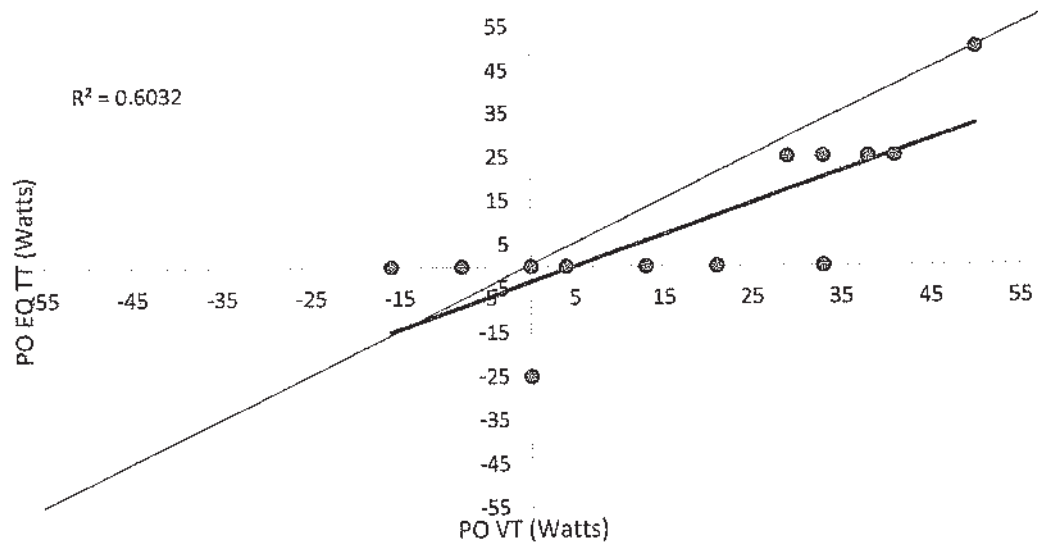


Figure 4b: Scatterplot of post-pre PO comparison of changes in EQ TT and VT.

Variables such as training load, RPE, and TRIMP increased at the start of the intervention period of the study but decreased in week four. Subject average weekly training data can be found in Table 3 and Figures 5-7. The decrease in exercise minutes, RPE, and TRIMP in week four was due to the Thanksgiving break and not having access to exercise equipment. The time spent exercising did not change significantly between the baseline and training portion of the study, however, RPE and TRIMP changed significantly.

It is worth noting that the baseline training loads were considerably in excess of the 150 min/week at moderate intensity (RPE=3) recommendation by ACSM (2017) for basic fitness, representing a TRIMP score of 450 AU per wee

Table 3: Subject Average Weekly Training Data

Week	Min	RPE	TRIMP
Baseline 1	146.9±135.97	4.5±1.35	681.8±723.62
Baseline 2	173.8±125.27	4.5±1.59	701.9±445.92
Week 1	211.3±169.79	5.9±1.24*	1161.5±836.42*
Week 2	231.2±164.87	5.8±1.25*	1316.1±954.33*
Week 3	248.7±140.24	5.8±1.19*	1471.6±915.45*
Week 4	154.1±64.30	6.1±1.55*	932.0±428.65*
Week 5	230.8±104.13	5.9±1.49*	1439.6±854.77*
Week 6	199.0±68.69	5.8±1.19*	1179.5±524.87*

Values represent mean ± standard deviation.

*Significantly different than baseline values.

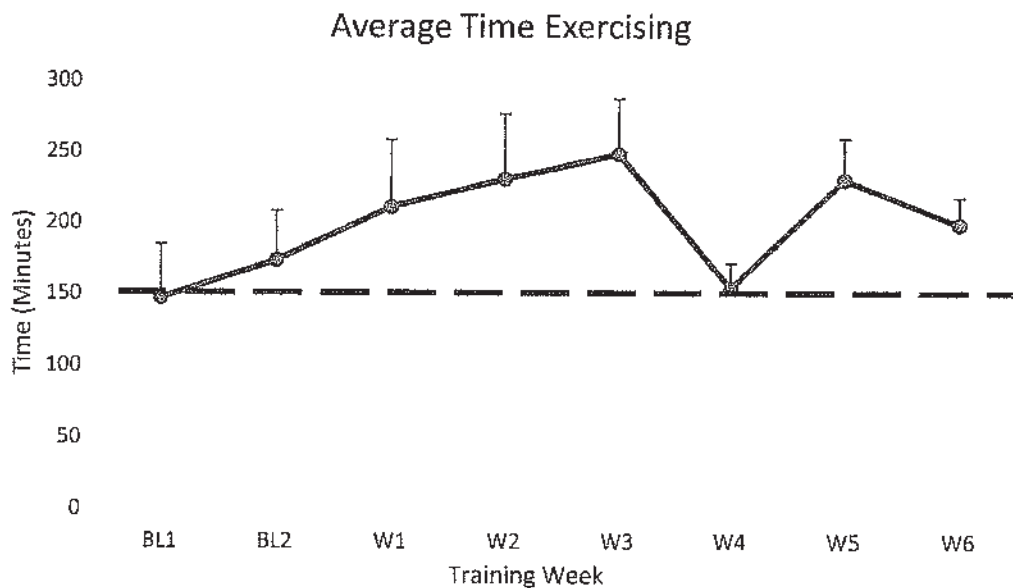


Figure 5: Average weekly exercise minutes. Values represent mean ± standard error.

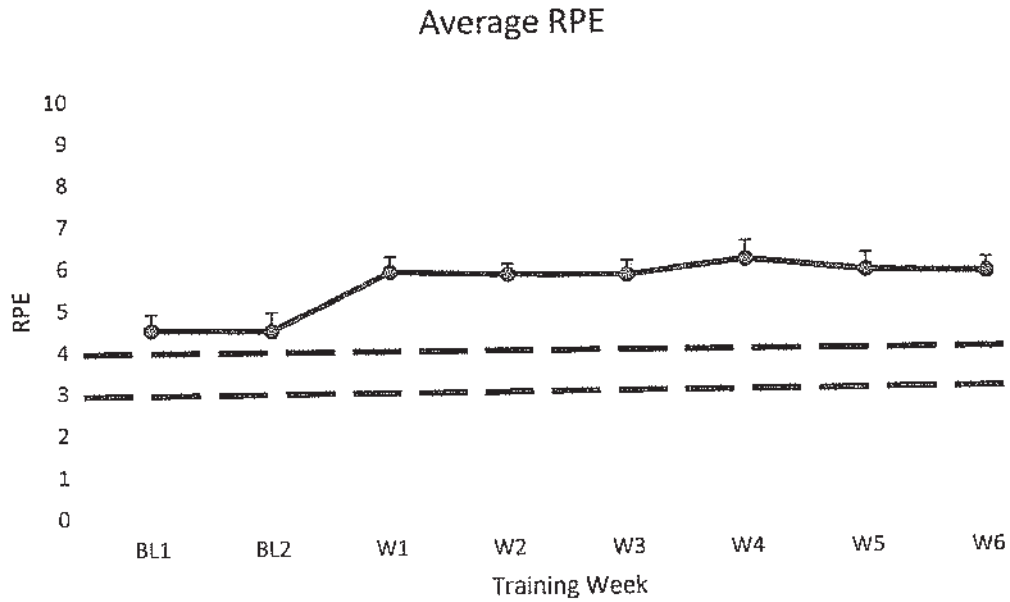


Figure 6: Average weekly training RPE. Values represent mean \pm standard error.

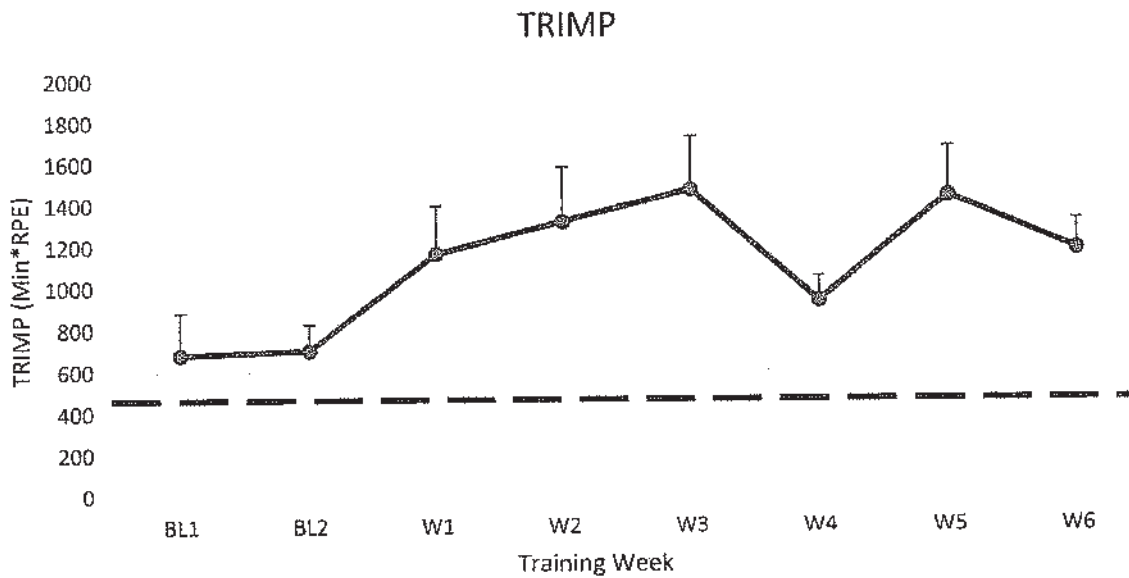


Figure 7: Average weekly TRIMP score. Values represent mean \pm error.

A plot of the average baseline TRIMP and the average TRIMP during the 6-week intervention shows that most subjects increased their training load (Figure 8).

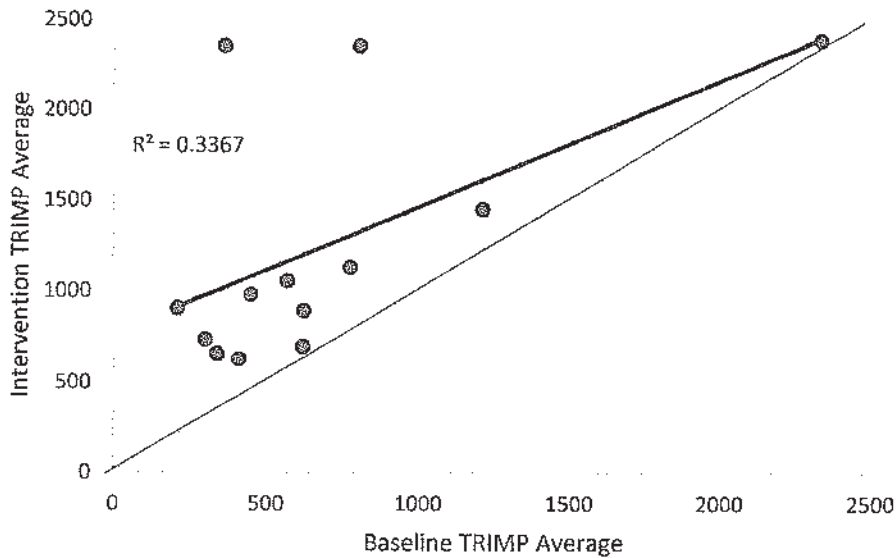


Figure 8: Scatterplot comparison of baseline TRIMP and intervention TRIMP averages.

DISCUSSION

The purpose of this study was to assess the ability of the TT to track changes in VT similar to those demonstrated by open circuit spirometry. Performance variables assessed were VO_2 PPO, TT PPO, VO_2 max (L/min), VO_2 max (ml/kg/min), TT LP Watts, TT EQ Watts, VT PO, and HR max. It was found that there was not a statistical difference between the pre or post VO_2 PPO and the TT PPO. There was however, a statistical difference between the change in VO_2 PPO and the change in TT PPO. As VT Watts increased or decreased the TT LP and EQ followed similarly. The Watts at VT change was greater than the change between pre-post LP TT and EQ TT. This is likely do to the jump in Watts per stage in the TT compared to using VO_2 data where VT can be found between stages. Our

study showed that the TT can track changes similarly to directly measured VT. If a subject increased their VT the response was reflected in the TT.

These data confirm the utility of the TT to track changes in VT, which was first reported by Foster et al. (2008). Foster et al. (2008) observed the effects of blood donation and training on a person's ability to perform a maximum test in both a VO_2 max and TT test. The study found that blood donation decreased VT and training increased the VT which was reflected in both the VO_2 and the TT. Figure 9 shows the data in Foster et al., 2008 compared to the present data.

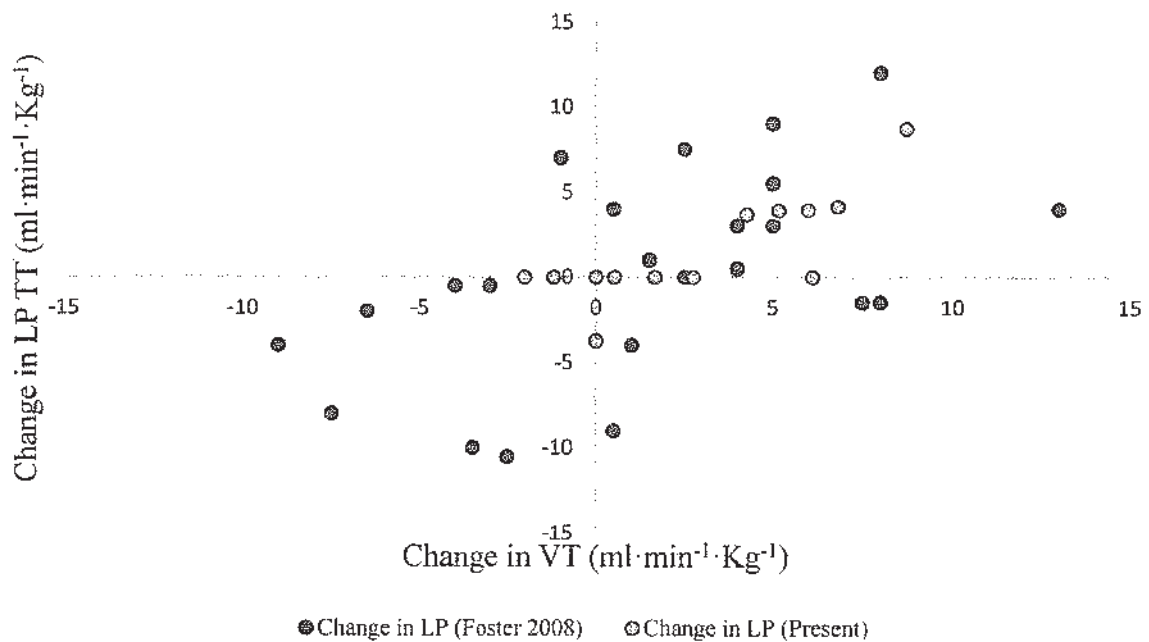


Figure 9: Comparison of post-pre percent change in VT (ml·min⁻¹·Kg⁻¹) and LP TT (ml·min⁻¹·Kg⁻¹) between Foster 2008 and present study.

This study along with many other studies (Brawner et al., 2006; Foster et al., 2008; Foster et al., 2009; Gron Nielsen, 2014; Rodriguez-Marroyo et al., 2013; Voelker et al., 2002, Zanettini et al., 2013) has shown that there was no difference between the VT Watts and TT

EQ Watts ($p < .05$). The LP stage was also shown to occur just below the VT, similarly to the Dehart-Beverly's study (Dehart-Beverly et al., 2000).

The TT has now been shown to be a reliable marker for exercise training as well. Porcari et al., (2018) showed that exercise capacity improved in both VO_2 and PO (Watts) whether the subject was guided by the %HRR method or by the TT during their training. Subjects in the TT group tended to exercise between 70-75% HRR which is in the recommended zone according to ACSM guidelines (2017).

There were several limitations to this study. The subjects did not go through a familiarization VO_2 max test or TT prior to the start of the study. Therefore, we cannot be sure that a true VO_2 max or TT was observed. This could have been a psychological bearer to perform their best and may alter the VO_2 max. Music was played during the max tests. This could have affected a subject if it was not a song that they liked or motivated them. We did our best to play stations that would motivate each subject individually. It has been shown that self-selected music can cause a reduction in RPE and influence individuals to higher intensities (Priebay, Foster, Gibson, Mikat, & Porcari, 2009). Despite being read the instruction for conducting the TT, some subjects reported that they were still able to talk comfortably when the investigator felt they could no longer talk. The investigator recorded when the investigator felt the subject was no longer able to talk comfortably. Lyon et al. (2014) found that subjects would report to the clinician that they were still able to speak even though the clinician had felt the subject had reached the EQ stage of the TT. In the case of intertester reliability in cardiac patients, Petersen, Maribo, Hjortdal, and Laustsen (2014) observed low reliability when two or more therapists administered the TT.

Another limitation is recorded RPE from the subjects during the training period. A RPE scale was sent to the subjects prior to beginning the study to be allow them to record their intensity in a baseline assessment or during the training period. There is no way of knowing if the subjects looked at the scale to determine their RPE or if the subjects guessed their intensity. The subject would have likely underestimated their exercise intensity unless the scale was visible (Loose et al., 2012; Reed & Pipe, 2014). However, as all subjects used the RPE scale during the pre-testing, it seems likely that they were habituated to the scale.

The results of this study suggest that determining exercise capacity can be done using the simpler method of the TT. In addition, VT was shown to occur at relatively the same PO as the EQ stage of the TT. This would allow an individual to conduct submaximal tests to determine if they are increasing, decreasing, or maintaining their current physical capacity without the need for expensive equipment or trained personnel. The TT is a very cheap and simple way of assessing one's own physical capacity and can be done as regularly as an individual would like rather than waiting for a laboratory appointment and paying a lot of money.

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APPENDIX A
INFORMED CONSENT

1. INFORMED CONSENT FOR "Use of the Talk Test to Track Changes in Oxygen Consumption, Ventilatory Threshold, and Respiratory Compensation Threshold."

Principle Investigator: Kristen Linzmeier

UW- La Crosse
221 Mitchell Hall
La Crosse, WI 54601
920 213 1095

2. I, _____, give my informed consent to participate in this study designed to assess the relationship between pre/post training plan values using the gold standard and the values obtained using a subjective Talk Test measurement. I have been informed that the study is under the direction of Kristen Linzmeier who is a graduate student at University of Wisconsin-La Crosse and is a student of Carl Foster, Ph.D., a Professor in the Department of Exercise and Sport Science at the University. I consent to the presentation, publication, and other release of summary data from the study which is not individually identifiable.

3. I have been informed that my participation in this study requires me to:

- a. Perform 4 exercise tests on two different occasions where I will work progressively harder until I am fatigued and no longer able to talk comfortably
- b. During each test, I will be asked how difficult I feel I am exerting myself.
- c. Wear a chest strap during all 4 tests that transmits my heart rate via radio waves to a specialized wrist watch.
- d. During two tests, I will breathe through to a scuba breathing valve to measure my metabolic rate.
- e. During two tests, I will recite a 101-word passage near the end of each stage and will be asked if I am able to talk comfortably. I am to respond either, "yes," "yes, but," or "no."
- f. After the first two tests, I will be given a 4 to 6-week training plan where I am to exercise 3-5 days per week at moderate to vigorous intensity.
- g. Email Kristen every day I exercise to keep a log.
- h. Return after 4 to 6 weeks and repeat the first two tests of my training to see if there are any changes.

4. I have been informed that there are minor risks associated with this study which include fatigue associated with heavy exercise, discomfort wearing a breathing valve, and possible injury partaking in exercise training program.

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

6. I have been informed that the investigator will answer questions regarding procedures throughout the course of the study.

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

8. Concerns about any aspects of this study may be referred to Dr. Foster at 608 785 8687. Questions about the protection of human subjects may be addressed to the Chair of the UW-L Institutional Review Board 608 785 6892.

Investigator: _____ Signature: _____ Date: _____
Participant: _____ Signature: _____ Date: _____

APPENDIX B

2017 PAR-Q+

2017 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition <input type="checkbox"/> OR high blood pressure <input type="checkbox"/> ?	<input type="checkbox"/>	<input type="checkbox"/>
2) Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?	<input type="checkbox"/>	<input type="checkbox"/>
3) Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).	<input type="checkbox"/>	<input type="checkbox"/>
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? PLEASE LIST CONDITION(S) HERE: _____	<input type="checkbox"/>	<input type="checkbox"/>
5) Are you currently taking prescribed medications for a chronic medical condition? PLEASE LIST CONDITION(S) AND MEDICATIONS HERE: _____	<input type="checkbox"/>	<input type="checkbox"/>
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer NO if you had a problem in the past, but it <i>does not limit your current ability</i> to be physically active. PLEASE LIST CONDITION(S) HERE: _____	<input type="checkbox"/>	<input type="checkbox"/>
7) Has your doctor ever said that you should only do medically supervised physical activity?	<input type="checkbox"/>	<input type="checkbox"/>

If you answered NO to all of the questions above, you are cleared for physical activity. Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

2017 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. **Do you have Arthritis, Osteoporosis, or Back Problems?**
If the above condition(s) is/are present, answer questions 1a-1c If **NO** go to question 2
- 1a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) YES NO
-
- 1b. Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)? YES NO
-
- 1c. Have you had steroid injections or taken steroid tablets regularly for more than 3 months? YES NO
-
2. **Do you currently have Cancer of any kind?**
If the above condition(s) is/are present, answer questions 2a-2b If **NO** go to question 3
- 2a. Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck? YES NO
-
- 2b. Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)? YES NO
-
3. **Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm**
If the above condition(s) is/are present, answer questions 3a-3d If **NO** go to question 4
- 3a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) YES NO
-
- 3b. Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction) YES NO
-
- 3c. Do you have chronic heart failure? YES NO
-
- 3d. Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months? YES NO
-
4. **Do you have High Blood Pressure?**
If the above condition(s) is/are present, answer questions 4a-4b If **NO** go to question 5
- 4a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) YES NO
-
- 4b. Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure) YES NO
-
5. **Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes**
If the above condition(s) is/are present, answer questions 5a-5e If **NO** go to question 6
- 5a. Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies? YES NO
-
- 5b. Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness. YES NO
-
- 5c. Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet? YES NO
-
- 5d. Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)? YES NO
-
- 5e. Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future? YES NO
-

2017 PAR-Q+

6. **Do you have any Mental Health Problems or Learning Difficulties?** *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome*
If the above condition(s) is/are present, answer questions 6a-6b If **NO** go to question 7
- 6a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? **YES** **NO**
(Answer **NO** if you are not currently taking medications or other treatments)
- 6b. Do you have Down Syndrome **AND** back problems affecting nerves or muscles? **YES** **NO**
-
7. **Do you have a Respiratory Disease?** *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*
If the above condition(s) is/are present, answer questions 7a-7d If **NO** go to question 8
- 7a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? **YES** **NO**
(Answer **NO** if you are not currently taking medications or other treatments)
- 7b. Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy? **YES** **NO**
- 7c. If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week? **YES** **NO**
- 7d. Has your doctor ever said you have high blood pressure in the blood vessels of your lungs? **YES** **NO**
-
8. **Do you have a Spinal Cord Injury?** *This includes Tetraplegia and Paraplegia*
If the above condition(s) is/are present, answer questions 8a-8c If **NO** go to question 9
- 8a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? **YES** **NO**
(Answer **NO** if you are not currently taking medications or other treatments)
- 8b. Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting? **YES** **NO**
- 8c. Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)? **YES** **NO**
-
9. **Have you had a Stroke?** *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*
If the above condition(s) is/are present, answer questions 9a-9c If **NO** go to question 10
- 9a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? **YES** **NO**
(Answer **NO** if you are not currently taking medications or other treatments)
- 9b. Do you have any impairment in walking or mobility? **YES** **NO**
- 9c. Have you experienced a stroke or impairment in nerves or muscles in the past 6 months? **YES** **NO**
-
10. **Do you have any other medical condition not listed above or do you have two or more medical conditions?**
If you have other medical conditions, answer questions 10a-10c If **NO** read the Page 4 recommendations
- 10a. Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months? **YES** **NO**
- 10b. Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)? **YES** **NO**
- 10c. Do you currently live with two or more medical conditions? **YES** **NO**

**PLEASE LIST YOUR MEDICAL CONDITION(S)
AND ANY RELATED MEDICATIONS HERE:** _____

**GO to Page 4 for recommendations about your current
medical condition(s) and sign the PARTICIPANT DECLARATION.**

2017 PAR-Q+

If you answered **NO** to all of the follow-up questions about your medical condition, you are ready to become more physically active - sign the **PARTICIPANT DECLARATION** below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more** of the follow-up questions about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+** at www.eparmedx.com and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

⚠ Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and **NO** changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that the Trustee maintains the privacy of the information and does not misuse or wrongfully disclose such information.

NAME _____

DATE _____

SIGNATURE _____

WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

For more information, please contact

www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+

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APPENDIX C

RATING OF PERCEIVED EXERTION

Borg's Rating of Perceived Exertion Scale 0-10.

0	No Effort (Standing, At Rest)
.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

RAINBOW PASSAGE

Rainbow Passage

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

APPENDIX E

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Introduction

Studies have shown that physical activity is beneficial for health. There is strong evidence that shows performing in the recommended volume of exercise will increase cardiorespiratory health, metabolic health, weight loss, joint and muscular health, and decrease depression and all-cause mortality (American College of Sports Medicine, 2017). Therefore, since exercise creates many positive benefits, the American College of Sports Medicine (ACSM) created guidelines to assist in prescribing exercise amongst various populations. The prescription is based on the FITT principle (frequency, intensity, time, and type). The recommendations for healthy adults is to exercise 3-5 days per week at a moderate (40-59% heart rate reserve [HRR]) to vigorous intensity (60-89% HRR) for 75 (vigorous) to 150 (moderate) minutes per week (ACSM, 2017). Following these guidelines will help to maximize health and fitness goals and reduce the risk of side effects (Loose et al., 2012). Intensity and time are the most influential variables in achieving physical fitness (PF) (ACSM, 2017; Truong, Niewenhuys, Beek, and Evers, 2015).

Objective Measurements

Gold Standard

The most accurate way to determine exercise capacity is through a maximal effort test. There are two common modes for obtaining this measurement; on the treadmill or an electronically braked cycle ergometer. For both tests, the subject will ideally have a mask

that is attached to an open-circuit spirometer to directly measure oxygen and carbon-dioxide that the subject is exhaling. During this same time, heart rate (HR) will be measured to obtain a maximal heart rate. The subject will exercise in increments until exhaustion. Once these measurements are obtained, an exercise intensity can be prescribed using the Karvonen heart rate reserve method (HRR). This value can be obtained by an individual calculating their HRR and multiplying it by the desired intensity. The equation is as follows:

$$\text{Max HR} - \text{Resting HR} = \text{HRR}$$

$$[\text{HRR} * \text{desired exercise percentage}] + \text{Resting HR} = \text{Target Heart Rate (ACSM, 2017)}$$

Karvonen “employed” %HRR as a way to measure exercise intensity and demonstrated that a minimum exercise intensity existed to cause training effects (Karvonen, Kentala, and Mustala, 1957). Karvonen found that participating in exercise that was 50% or greater of the range from rest to maximum HR resulted in a training effect. Therefore, using HR to determine exercise intensity has been considered the gold standard based on its linear relationship with VO_2 (Loose et al., 2012; Norman, Kracl, Parker and Richter, 2002).

In 2014, Engeseth and colleagues reported a 35-year follow-up study on the HRR method and its ability to predict cardiovascular (CV) death among physically unfit but otherwise healthy middle-aged men. Physical fitness (PF) is a significant indicator of CV health. Engeseth et al. (2014) also found that HRR and PF are correlated. This study observed 2,014 middle-aged men (40-59 years old) who were unfit but healthy. The end-point in the study was either cardiovascular disease (CVD) or CV death. The time to CV event was inversely associated with HRR and PF. Men with the lowest PF and HRR were

68% more likely to be diagnosed with or die due to CVD than those in the highest HRR and PF group (Engeseth et al, 2014). There was also an observed shorter duration time to CV death among the men in the lowest HRR group.

Problem with the Gold Standard

Despite the positives of the HRR method, there are some problems with the technique. To determine a true maximal HR, a VO₂ max test must be completed. This test requires expensive equipment, trained personnel, and therefore, can be quite costly. There are other methods to predict maximal HR; however, they are less accurate and do not consider those who have a higher or lower max HR. Subjective errors can occur as some individuals have a more difficult time finding their pulse and are not able to find an accurate HR to measure their intensity. This can be avoided by purchasing a HR monitor. These can, however, be expensive and may not be readily available for those just beginning exercise. Continually monitoring HR can create a negative effect and reduce enjoyment. This may be seen especially with those who are new to exercise and could possibly reduce long-term compliance to exercising. There also needs to be consideration that an individual may be on medication that can alter HR (β -blockers) and make it more difficult to train in the desired HR zones (Ballweg et al., 2013; Goode, Mertens, Shaiman, and Mertens, 1998; Loose et al., 2012; Norman et al., 2002; Quinn & Coons, 2011; Reed & Pipe, 2014; Rodriguez-Marroyo, Villa, Garcia-Lopez, and Foster, 2013; Schroeder, Foster, Porcari, and Mikat, 2017; Woltman et al., 2015). Katch, Weltman, Sady, and Freedson (1978) noted that using the %HRR training method may not stress individuals the same in relation to energy metabolism. Similarly, Scharhag-Rosenberger, Meyer,

Gäßler, Faude, Kunderman (2010) found that exercising at a standard VO₂ max for long periods of time leads to inhomogeneous metabolic strain and large variability even in groups of similar exercise capacity.

Subjective Measurements

Ratings of Perceived Exertion

In 1998, Gunnar Borg released his book on perceived exertion and pain scales which synthesized 25 years of experimental studies. Borg created two scales. One ranges from 6-20 and the CR-10 scale ranges from 0-10. Borg's 6-20 scale is used in many rehabilitation clinics and is the most common subjective form of defining exercise intensity (Borg, 1998). The ratings of perceived exertion (RPE) scales are widely accepted estimates of intensity which compares with methods that measure HR and lactate (Foster, Heimann, Esten, Brice, and Porcari, 2001b). However, for the subjective measurements to be accurate, the subject must be able to see the RPE scale. The subject will likely underestimate their exercise intensity unless the scale is visible (Loose et al., 2012; Reed & Pipe, 2014).

TRIMP

Training load is important for improving athletic performance and coaches create programs that vary in training load through periodization. Endurance athletes typically use training volume as an index for training. However, this method does not consider the importance of high intensity training bouts. In 1991, Eric Banister developed a method for quantifying exercise intensity known as training impulse (TRIMP). His method used

HR multiplied by duration and a relative weighting of intensity. This method was the first to consider different aspects in measuring exercise intensity to define a dose as a single term. Like the RPE method, there are limitations to this method. If an athlete forgot to wear their HR monitor or it malfunctioned, the data for that particular workout was gone. Heart rate does not evaluate high-intensity exercise and therefore, the TRIMP method does not translate high intensity exercise as well.

Foster et. al., (1995, 2001a) created a modified TRIMP score using RPE to measure the relative weighting of intensity instead of the zones that Banister implemented in his TRIMP method. During an exercise session, an athlete would multiply their exercise duration by the RPE for the entire workout. The score was taken 30 minutes after completion of the exercise so the end of the workout would not weigh heavily on the overall intensity of the workout. There was a strong relationship between session RPE and the summated HR zone for assessing exercise intensity. The RPE method may be a valid approach to assess exercise intensity and allow coaches to have a visual for athletes' improvement and periodization (Foster et al., 2001a).

Talk Test

History behind the Talk Test

The concept of the Talk Test (TT) began in the late 1950's when R. Goode was coaching at the University Settlement Aquatic Club. During that time, John Faulkner introduced Karvonen's method for measuring intensity for college swimmers. His training idea consisted of having collegiate swimmers swim four lengths of the pool at a HR of 170 bpm, rest until the HR returns to 150 bpm, and repeat 10 times. However, they

found that some athletes have very different maximum heart rates. There were some athletes whose HR (max) was in the 230's and others whose HR (max) was around 170. At the same time, Goode was observing sailors who were training. There was a large group of physically fit sailors running with two individuals falling behind the group breathing very heavily and struggling. Goode realized there needed to be a way to gauge exercise intensity that was relevant to everyone's needs and intensities. One afternoon, John Grayson was in Goode's office biking, and he told Goode of a time when he used to hike in the mountains. They were told to climb no faster than they could talk to reduce anaerobic metabolism. This is where the TT was created (Goode, 2008).

Protocol of the Talk Test

The protocol for the TT is quite simple and there are multiple ways in which one can complete this test. The first way is the most common form of the TT which is to recite a passage from a cue card. The individual will be asked to read a card at various points during their exercise program. After reading the passage aloud, the individual will be asked if they can speak comfortably. If they reply "yes," the test continues. This is considered a positive TT response. At some point the test will begin to become more difficult, and the individual might respond with "yes, but," signifying that it is becoming more challenging. This stage is known as the equivalent stage (EQ) of the TT. The previous stage would be considered the last positive (LP) since it was the last time the person could speak comfortably. The test continues until the individual responds with "no." This point is called a negative response (NEG). Many studies have used the pledge of allegiance (POA) as the passage to be recited. Shroeder, Foster, Porcari, and Mikat

(2017) found that the length of the passage affects the ability to predict ventilatory threshold (VT) and respiratory compensation threshold (RCT) during the TT. Their study found that a passage of 93 words created the most reliable results for VT at EQ TT and RCT at NEG TT where the PO was within one Watt.

A second option to complete the TT is using a cassette player with pre-recorded responses. An individual will exercise and respond to questions that are being asked on a cassette tape. This version simulates what it would be like to have a conversation with someone while exercising. The cassette version is less common as it requires a tape and cassette to be carried. The public is less likely to use this route as it requires the tape player to be with them while they exercise.

The final option for the TT is the counting Talk Test (CTT). An individual simply counts as high as they can through a normal exhale (without holding one's breath) at a steady pace, one one-thousand, two one-thousand, three one-thousand, etc. Norman, Kracl, Parker and Richter (2002) studied the comparison of the CTT to the HRR method for estimating exercise intensity in healthy adults. Their purpose was to see if the simplicity of the CTT could be translated to the fitness industry to prescribe exercise intensity for lower intensity exercises as well as moderate and vigorous. The results showed that exercising at 30-55% of the resting CTT value was consistent with ACSM recommendations for light to moderate activity (Norman et al., 2002; Norman, Hopkins, Crapo, 2008). The CTT translated throughout the ranges of exercise intensity unlike the other TT versions that are useful in determining higher intensity exercises. There are no scales, cassettes, or cue cards needed for understanding the intensity. There is a flaw to the study, however, as they used $220 - \text{age}$ for determining max HR in the HRR

comparison. This method is not very accurate as maximum HR varies depending upon the individual.

Loose et al. (2012) did a similar study that tested multiple exercise methods (run, walk, elliptical, bike, and stair stepper). Loose used the $220 - (0.7 * \text{age})$ method to determine max HR which is a more accurate and accepted avenue for determining maximum HR. Their study showed that the CTT was consistent among all areas of exercise.

Mechanism of the Talk Test

The TT works because of the body's natural physiological mechanisms. At rest, speech production causes a reduction in ventilation. This holds true even during exercise (Rostein, Meckel, and Inbar, 2004). When a person is exercising their body has an increase in H⁺ ions, norepinephrine, and epinephrine in their blood (Goode, 2008). Increases in these hormones cause more frequent and deeper inhalations. When intensity increases it causes more H⁺ ions to be released and creates the need to inhale more and interrupt speech. With high intensity exercise the voluntary respiratory control system takes over and disrupts a person's ability to speak to increase O₂ levels in the blood and body. A decrease in minute ventilation (V_E) during speech causes a reduction in O₂ consumption and an increase in blood lactate. Doust and Patrick (1981) found that there was a reduction in V_E from 78 breaths per minute to 38 breaths per minute. The respiratory frequency was reduced, but tidal volume was not. Immediately following the reading of the passage, V_E overshoot by 14% and then returned to normal within 30 seconds of completing the stage (Doust & Patrick, 1981). Creemers et al. (2017) studied

the effect of speech on breathing rate and blood CO₂ levels. Their study, along with Meckel et al., (2001) showed that VO₂, VCO₂, and V_E significantly decreased during speech and increased immediately after speech was completed. Since speech requires a suppression of breathing frequency and words are only produced during exhalation, breathing frequency also decreased. However, at this same time end-tidal CO₂ pressure, a marker of arterial CO₂, increased during speech. This information supported their hypothesis that speech causes a retention of CO₂ and likely to cause more CO₂ to be present in the arterial blood. This is thought to make speech feel less comfortable.

A decrease in blood O₂ causes lactate to build up in the blood since it is not able to be cleared as quickly as it would if there was O₂ present. The maximal lactate steady state (MLSS) is the level at which lactate can be cleared at the same rate that it is being formed. The point at which the blood lactate (BLa) begins to accumulate in the blood is called the lactate threshold (LT) (Reed & Pipe, 2014). Lactate threshold and VT have been shown to occur at similar points during an exercise test and are considered a cause and effect rather than occurring together.

Relation to Ventilatory Threshold and Respiratory Compensation Threshold

To understand the relation of VT and RCT there needs to first be an understanding of what those values represent. The VT is the point at which ventilation begins to increase at a quicker rate than VO₂. The over compensation of breathing is caused by a rise in CO₂ production. Ventilatory threshold is associated with BLa accumulation in the blood which is buffered very quickly, producing CO₂ and H₂O. The increase in BLa causes a person to breath more in an attempt to get rid of the excess CO₂.

When the lactate level begins to increase ($>4\text{mmol}\cdot\text{L}^{-1}$) rapidly, it challenges pH regulation and causes hyperventilation. This response is called RCT. The TT is related to these two measurements in relation to ability to speak. When an individual reaches the EQ stage of the TT, they are close to the VT and are beginning to have difficulty speaking. The individual has reached the point where H^+ ions are being buffered and causes increased levels of CO_2 . This shift requires them to breath more frequently which interrupts speech (Goode, 2008). When an individual reaches the NEG stage, they are no longer able to talk comfortably and are breathing quite heavily to try to get O_2 to the blood and body in order to compensate for the falling pH.

Reliability of the Talk Test

In 2000, Dehart-Beverly and colleagues tested the relationship between the TT and VT. The study found that the last time a person can pass the TT (LP stage) is just short of the VT. At the EQ TT stage, the point at which the person is not sure if they can speak comfortably, is approximately when VT occurs. When the person is definitely no longer able to talk (NEG TT stage), they fail the test because they are consistently over the value of VT and close to RCT (Ballweg et al., 2013; Creemers et al., 2017; Goode, 1998; Goode, 2008; Jeans, Foster, Porcari, Gibson, and Doberstein, 2011; Quinn & Coons, 2011; Recalde et al., 2012; Rodriquez-Marroyo et al, 2013; Woltmann et al., 2015). These results have been shown to be accurate in healthy individuals, athletes, and cardiac patients (Brawner et al., 2006; Foster et al., 2008; Foster et al., 2009; Gron Nielsen, 2014; Rodriquez-Marroyo et al., 2013; Voelker et al., 2002, Zanettini et al., 2013). The TT is not only comparable to the VT and RCT values, but it also correlates

with the ACSM standards for recommended exercise intensity. The LP stage of the TT has been shown to be consistent with the standards set for exercise intensity (Persinger, Foster, Gibson, Fater, and Porcari, 2004). Reed & Pipe's (2014) study, however, showed that LT was more reflective of the measurements at LP and EQ rather than VT. Furthermore, Gillespie, McCormick, Mermier, and Gibson (2015) tested the TT on competitive male cyclists and their results differed from those above. They found that the VT did not occur at the EQ stage of the TT; however, they noted that their participants had very high VO_2 max levels ($65.9 \pm 6.9 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). Gillespie and colleagues believe that their results are still accurate considering the differences in aerobic capacity between high level athletes and fit individuals.

Application to athletes

A coach creates a very detailed periodization plan for each season, but athletes and coaches are not always on the same page when it comes to expectation of each workout. When sessions are intended to be relatively easy, athletes tend to workout at a greater training load than the coach intended (Foster et al., 2001b). Likewise, when an athlete's workout is intended to be very difficult the athlete tends to exercise below the intensity at which the coach desired the athlete to exercise at. Athletes are likely to execute a training plan differently than what was designed. The TT can be used to help subjectify one's training paces. In a study assessing the TT in trained cyclists, they found that the TT was very similar to a VO_2 max test in determining VT and RCT (Rodríguez-Marroyo et al., 2013). The TT has also been shown to track improvement in VO_2 max following a 4-6-week training plan (Foster et al., 2008).

Application to healthy individuals

Exercise testing for endurance exercise is very demanding and the approaches to prescription vary depending upon the type of exercise the individual is participating in. Jeans et al. (2011) tested the TT on steady-state exercise on healthy well-trained individuals. Their study found that there is a needed down-regulation of exercise intensity when doing steady-state exercise verses interval training. A majority of individuals trained at the LP stage or less for background training in light of higher intensity workouts. There was a physiological drift that occurred during sustained submaximal exercise of roughly 10% (Foster et al., 2009; Jeans et al., 2011). It is recommended to train at LP-1 stage of the TT for steady-state exercise.

In society, it has become very popular to donate blood to a blood bank for extra cash. However, people are told to not partake in exercise following the donation. Foster et al. (2008) looked at the effects of donating blood on VT and responses to exercise using the TT. In their study, participants completed two exercise tests; one to determine VO_2 max and the other using the TT as a marker of exercise intensity. Following the two tests, participants donated 500 ml of blood and returned to complete the two tests after 48 hours of recovery. The experimental blood loss created a significant reduction in hematocrit and VO_2 peak. The markers of exercise intensity were both reduced similarly by the blood loss. Therefore, their study shows that even 48 hours past blood donation an individual's ability to exercise at a high intensity is reduced due to a lack in red blood cells to transfer O_2 to the body.

Application to patients

Patients needed another avenue to be prescribed exercise intensity because of the effect their medications had on HR. The TT is not just for healthy individuals or athletes as it has also been shown to be accurate and apply to patients as well. For patients with exertional ischemia, the protocol typically is to exercise at a HR 10 bpm lower than the level which causes exertional ischemia. This protocol again, looks at HR which can be challenging for people to take or requires equipment to be bought. Cannon et al., (2004) studied whether the TT could be used to prescribe exercise intensity in those who have exertional ischemia. Their study found that when a patient began to have exertional ischemia, the patient was above their VT. When a patient reached the LP stage of the TT, the patient's HR corresponded to 10 bpm below the first sign of electrocardiographic ischemia. The LP stage was also within the ACSM's recommendation for producing minimal training effect.

Zanettini et al. (2012) studied the TT on individuals who had a myocardial revascularization (coronary artery bypass graft or percutaneous coronary intervention). Their study found that there was good reliability between the three thresholds (LP, EQ, and NEG). When the subjects could still talk comfortably during exercise the individuals were training at an intensity below their anaerobic threshold. The LP stage was found to be at 88% of the patient's optimal training zone. These results aligned with several other studies that assessed the reliability of the TT (Dehart-Beverly et al., 2000; Voelker et al., 2002).

Zanettini and colleagues (2012) also observed intertester reliability in recording the LP, EQ, and NEG stages of the TT. They found that there was no difference in results

between operators. These results differ from Petersen, Maribo, Hjortdal, and Lausten (2014) and Lyon et al. (2014) who found that the stage at which a patient reaches LP, EQ, and NEG are different and operator-dependent. The reliability was weak when prescribing exercise intensity in cardiac patients who had 2 or more physiotherapists administer the TT. Therefore, when assessing a patient's cardiovascular strength, the TT should be conducted similarly to case-managing (each clinician is assigned a patient to work with throughout the rehabilitation period).

Lyon et al. (2014) studied the TT in response to steady-state exercise training intensity in cardiac patients. This study took into consideration that HR may be appropriate during the first few minutes of exercise, but it will drift to a higher value as exercise continues for long periods of time. They found that a reduction from LP stage TT to LP-1 stage TT created a 12% reduction in workload that was appropriate for patients or healthy individuals at the lowest exercise capacity (Lyon et al., 2014). It is ideal for cardiac patients to exercise at LP-1 or LP-2 stages of the TT and to frequently check their ability to talk especially in a cardiac rehabilitation setting.

Training Plans

As an individual or athlete spends more time in aerobic/anaerobic training they increase in their fitness capabilities and cardiorespiratory fitness. It has also been shown to increase VO_2 in adolescents and athletes (Carazo-Vargas & Moncada-Jiménez, 2015; Favero & Jackson Stoll, 2016; Hama & Magied, 2014). However, the only study that related to the TT and the use of a training plan was Foster's study in 2008. The 2008 study sought to see if the VT and TT had a relationship with each other and if both would

show changes in improvement in training. Foster et al. (2008) found that training resulted in an increase in time to LP stage and the VO_2 at the LP stage of the TT. The VT increased significantly as well along with the overall time to completion of the maximum test. To my knowledge, there have not been any other studies that relate the TT to a training plan to see if both objective and subjective measurements would demonstrate changes in fitness level.

Summary

The TT has been shown to be a reliable marker for prescribing exercise intensity across various populations and has even been a reliable marker in those who have exertional ischemia (Brawner et al., 2006; Foster et al., 2008; Foster et al., 2009; Gron Nielsen, 2014; Rodriguez-Marroyo et al., 2013; Voelker et al., 2002, Zanettini et al., 2013). This relatively new subjective form of prescribing exercise intensity is highly correlated to the gold standard of exercise prescription. With the strong correlation to HRR and VO_2 max, the TT can assist those who are not able to afford an objective test and can assist those who are beginning to start a healthy lifestyle. It has been shown that a training program can increase one's VO_2 in adolescents and athletes of various sports (Carazo-Vargas & Moncada-Jiménez, 2015; Favero & Jackson Stoll, 2016; Hama & Magied, 2014). However, besides the study done by Foster et al. (2008), there has been little research done on the ability of the TT to track changes in the VO_2 , VT, or RCT. Therefore, the purpose of my study is to see if the TT can be used to see changes in an individual's VO_2 , VT, and RCT among relatively unfit but healthy individuals.

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