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CAN THE TALK TEST IDENTIFY MAXIMAL LACTATE STEADY STATE?

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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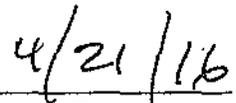
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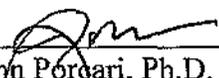
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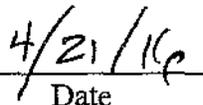
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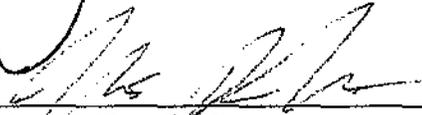
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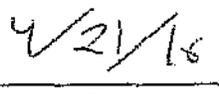
  
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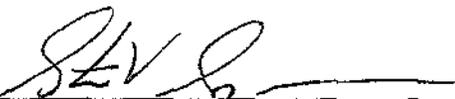
  
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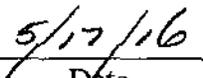
  
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## ABSTRACT

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**Introduction:** The Talk Test (TT) has been shown to be an effective surrogate of standard methods of prescribing exercise training intensity. This study was designed to evaluate if the talk test can identify MLSS. **Methods:** Apparently healthy triathletes (N=12) volunteered and served as subjects. Each subject performed two incremental exercise tests on a cycle ergometer to measure VT, RCT, and VO<sub>2max</sub> and to identify stages of the TT (LP-1, LP, EQ, NEG). Subsequently, subjects performed 30 minute steady rides at a constant power output to determine MLSS. In all of the tests and trials, HR and RPE (Borg 0-10 scale) were collected. During the MLSS trials, blood lactate was measured. **Results:** The PO measurements indicated that the NEG TT stage occurred at a PO that was significantly greater than the MLSS PO. The LP-1 TT occurred at a PO that was significantly lower than the MLSS PO, while the PO at the LP TT was not significantly different than the PO of the MLSS. **Conclusion:** The combined observations suggest if the TT is clamped at the NEG, the exercise intensity will be higher than the MLSS, which occurs close to the intensity of the LP TT during incremental exercise.

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## INTRODUCTION

Historically, the main paradigm for prescribing exercise training intensity has been the use of relative physiological variables, such as relative percentage of power output (PO), oxygen consumption ( $VO_{2max}$ ), heart rate (HR), blood lactate ([HLa]), ventilatory threshold (VT), lactate threshold (LT), respiratory compensation threshold (RCT), and maximal lactate steady state (MLSS). All are derived from maximal exercise tests. Though these variables allow for accurate measurements of physiologic thresholds, they can be potentially dangerous for older or vulnerable populations (Katch et al., 1978; Goode et al., 1998; Scharhag-Rosenberger et al., 2009), require sophisticated technology and appropriate personnel to run the equipment. Therefore the need of finding additional means of prescribing exercise intensity is clear.

The lack of availability of maximal exercise testing has led to the popularization of subjective methods of exercise prescription. The Rating of Perceived Exertion (RPE) (Borg, 1998) is the most widely accepted subjective method in the exercise physiology community (Eston, 2012). Another subjective method that has gained popularity, but has remained less well accepted, is the Talk Test (TT). Though both are convenient and can be used to guide exercise prescription, there remains a degree of uncertainty when using submaximal exercise testing in prescribing exercise intensity.

In order to find an alternative method, much research has been conducted to validate findings from speech production during exercise and its correlation with physiologic markers of exercise intensity. Meckel, Rotstien, & Inbar, (2002) examined

the cardiopulmonary and metabolic responses to speech during exercise of varying intensities and found that to allow adequate speech production, one must adapt their breathing pattern. Simply, speech production is correlated with an increase in oxygen cost, a decrease in oxygen consumption, and therefore a decrease in ventilatory efficiency. More specifically, the decrease in  $\text{VO}_2$  during speech while exercising was accompanied by a significant drop in ventilation as well as an increase in blood lactate concentration [HLA].

Considering that the breathing frequency normally increases markedly at the intensity of the ventilatory threshold (VT), it is commonly understood that during exercise at higher intensities, speech production, which requires suppressing breathing frequency, becomes more difficult. Previous research has demonstrated that the TT is effective at identifying intensities below the VT if the subjects are able to speak comfortably. If subjects were unable to speak comfortably they are typically at or above VT (Dehart-Beverly, Foster, Porcari, Fater, & Mikat, 2000). Similar relationships between the TT and the VT seen in several populations including well-trained cyclists (Rodríguez-Marroyo, Villa, García-López, & Foster, 2012), well-trained adults (Recalde et al., 2002), patients with coronary artery disease (Brawner et al., 2006; Voelker, 2002), patients with exertional ischemia (Cannon et al., 2004), sedentary individuals (Foster et al., 2009), patients with a recent myocardial revascularization (Zanettini et al., 2012) and healthy students (Dehart-Beverly et al., 2000).

Given that the TT is considered to be a valid measure of measuring exercise intensity in various populations, research is lacking in terms of whether it could be translated to an exercise prescription across modes of exercise or if the VT was

manipulated. Persinger et al. (2004) evaluated the consistency of the TT by measuring the relationship between the TT the VT on the treadmill and cycle ergometer. In both modes of exercise, the data supported the hypothesis that the TT was a consistent measure of exercise intensity across different modes of exercise. In a similar study, Foster et al. (2008) showed that even with experimental manipulations of the VT, the TT was a reliable marker of VT and could be applied to exercise prescription.

In 2009, Foster et al. examined what happened to exercise intensity when the TT responses during incremental exercise were “translated” to steady-state exercise training. This followed earlier studies demonstrating that absolute training intensity could be “translated” based on HR responses during incremental and steady state responses to exercise (Foster et al., 1986). Results showed that workloads must be reduced when applying a desired workload to a steady-state bout. To replicate these results using the TT, other research studies tested steady-state workloads in well-trained individuals (Jeans et al., 2011), sedentary individuals (Foster et al., 2009), competitive runners (Foster et al., 2012; Woltmann et al. 2015), and cardiac patients (Lyon et al., 2014). These studies evaluated how much of a reduction in absolute exercise intensity was needed to produce adequate speech in both populations. The data from these studies supported the idea that different reductions from incremental exercise intensities are required between various populations in order to meet suitable exercise guidelines. In general, in well-trained individuals can sustain exercise at the last positive (LP) workload, sedentary individuals can sustain exercise at the stage prior to the last positive stage (LP-1) workload, and cardiac patients can sustain exercise at the LP-1 or LP-2 workload.

In addition to the TT being robustly related to the VT, Quinn and Coons (2011) showed that the TT was highly related to the lactate threshold (LT). The results revealed that during the positive (POS) stage of the TT, subjects were below their LT. During the equivocal (EQ) and negative (NEG) stages of the TT, subjects were above their LT. By identifying that in response to the TT, VT and LT produce comparable effects during the POS, EQ and NEG stages. This study reinforced the concept that the TT is a valid surrogate of both physiological makers.

The concept that the TT is suitable method for determining LT and VT led to the idea that the TT may predict MLSS, critical power (CP) and second ventilatory threshold (VT<sub>2</sub>). Studies by Woltmann et al. (2015), Pringle and Jones (2002), and Jones et al. (2008) are particularly significant because they all demonstrated that these physiological variables may be correlated in terms of intensity. Woltmann et al. (2015) identified physiological effects during steady-state conditions, but was unable to establish the MLSS because only a few of subjects were able to complete the NEG TT stage. Pringle and Jones (2002) found that if subjects worked slightly below the CP, they were near the MLSS. Therefore, the current study aimed to find if the exercise intensity was held constant, defined by the TT, exercise intensity would be controlled below the MLSS. However, accurately prescribing exercise remains problematic due to the variability of subjective responses in different populations and protocols (Foxdal et al., 1994; Sjödín & Jacobs, 1981; Amann et al., 2006). The current study hypothesized if the TT is negative, the exercise intensity would be approximately at the MLSS intensity. With these results, others can begin designing training programs at specific work intensities and measure their effect on aerobic and anaerobic performance. Coaches and athletes might therefore

adhere to these advances and construct training intensities based upon the determinants of exercise tolerance.

## **METHODS**

### **Subjects**

Apparently healthy and well-trained student volunteers from the University of Wisconsin-La Crosse Triathlon Team (N=12), aged 18-64, volunteered and served as subjects (Table 1.). The Physical Activity Readiness Questionnaire (PAR-Q) was given to all subjects to identify health problems that might contraindicate participation. A detailed protocol, describing the purpose and risks of the study was provided and each subject provided written informed consent. Approval from the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects was obtained prior to the study.

Table 1. Descriptive characteristics of the subjects (N=12).

Variable	Male (n=7)	Female (n=5)
Age (years)	32.2 ± 17.87	26.4 ± 12.82
Mass (kg)	76.3 ± 3.82*	64.1 ± 6.51
Height (cm)	71.5 ± 1.72*	65.5 ± 2.78

\*Significant difference between genders ( $p < 0.05$ ).  
Data are reported as mean ± standard deviation.

#### Testing Procedure

Each subject performed two maximal incremental exercise tests on a cycle ergometer (*Lode, Netherlands*): 1) with respiratory gas exchange to measure VT, RCT, and VO<sub>2max</sub> and 2) a TT protocol. In both of the tests, HR (*Polar Vantage XL, Polar Instruments, Port Washington, NY*) and RPE (Borg 0-10 scale) were measured while the subjects performed the same incremental test. Subjects began at a PO of 25 Watts. At the end of every 2-minute stage, power output (PO) was increased by 25 Watts. During the TT protocol, during the last 30-seconds of each 2-minute stage, the subjects recited a standard paragraph, the Rainbow Passage (101 words). After every recitation, the subject was asked, “Can you speak comfortably?” The subject responded in one of three ways: 1) “yes,” indicating a positive response (POS), 2) “yes, but,” indicating an EQ response, or 3) “no,” indicating a NEG response. The TT continued until the subject quit due to fatigue.

On separate days, each subject completed a series of constant PO tests on the cycle ergometer. Based on the results of each subject's maximal increment tests, the PO at the MLSS was likely to be achieved was predicted. Fingertip blood lactate [HLa] (*Unistik 2 Normal, Owen Mumford Inc., Marietta, GA*), HR, RPE, and TT responses were recorded during the steady-state rides (0, 10, 20, and 30 minutes); or at exhaustion if the subject did not complete 30-minutes. Prior to each 30 minute steady-state ride, the subject performed a standard five-minute warm-up. The goal the steady-state rides was to establish the highest PO that caused an increase in [HLa] of  $\leq 1$  mmol/L during the last 20 minutes of the 30-minute ride (Pringle and Jones, 2002; Beneke, Leithäuser, & Ochentel, 2011). During the last minute of each ten-minute segment, the subject recited the Rainbow Passage (101 Words). After the subject read the passage, the researcher asked the subject, "Can you speak comfortably?" The subject responded in one of three ways: 1) "yes," indicating a positive (POS) response, 2) "yes, but not sure," indicating an equivocal (EQ) response, or 3) "no," indicating a negative (NEG) response. Individual PO values for MLSS were selected based on [HLa] responses.

## STATISTICAL ANALYSIS

Standard descriptive statistics, using the SPSS statistical software package (Version 23.0), were used to characterize the subject population (*SPSS Inc., Chicago, IL*). Differences between the means were compared using an Independent T-Test and are presented as means  $\pm$  SD.

The effect size for this analysis ( $d = 2.24$ ) was found to exceed Cohen's (1988) convention for a large effect ( $d = .80$ ). Approximately 9 subjects would be needed to obtain statistical power at the recommended .80 level. The alpha was set at .05.

A two-way ANOVA with repeated measures was used to analyze the data. There was no significant interaction between genders ( $p > .05$ ). Differences between methods of measuring intensity (PO) were compared using a one-way ANOVA with repeated measures. Significant differences between methods were identified when ( $p < 0.05$ ). Tukey's post-hoc tests were used to detect differences between the methods when justified by ANOVA.

## RESULTS

The descriptive physiological characteristics of the 12 subjects are presented in Table 2. The results of the steady-state ride at the MLSS exercise intensity are presented in Figure 1. All subjects were able to complete the ride, and measured values for HR, RPE, and [HLA] remained relatively constant across the 30 minute time trial. The shaded areas of the HR graph represent American College of Sports Medicine (ACSM)'s recommendations for %HRR during exercise for healthy adults (60-80%), which were achieved throughout the entire 30 minute exercise bout (ACSM, 2014). The RPE response during the MLSS trial, increased slightly across the 30 minute ride, but remained in the “hard” (RPE ~5) range throughout the exercise bout. Blood [HLA] showed the same pattern as HR, remaining constant across the 30 minute ride. The ability to speak fluctuated across time during the MLSS ride. At the end of the ride (2/12 subjects) were able to speak comfortably, (9/12 subjects) were equivocal about speech production and (1/12 subjects) were definitely unable to speak comfortably.

In the study, it was hypothesized that if the TT was negative, the exercise intensity (PO) would approximate the MLSS intensity. In Figure 2, it is evident that the PO at the NEG TT stage during the incremental test occurred at a PO that was significantly greater than the PO at the MLSS. The LP-1 TT occurred at a PO that was significantly lower than the PO at MLSS, while the PO at the LP TT was not significantly different than the PO of the MLSS. The combined observations tell us that if the TT is clamped at the NEG PO, the exercise intensity will be higher than the MLSS.

Alternatively, selecting the PO at the LP TT during the incremental test will produce exercise responses during sustained exercise consistent with the MLSS.

Table 2. Descriptive physiological characteristics of the subjects (N=12).

<b>Variable</b>	<b>Male (n=7)</b>	<b>Female (n=5)</b>
VO <sub>2</sub> (ml/kg/min)	63.1 ± 6.84*	51.1 ± 7.08
MaxHR (bpm)	178.5 ± 10.95	182.0 ± 9.46
MaxWatts	325.6 ± 25.71*	230.0 ± 41.08
VT (Watts)	235.4 ± 27.04*	184.0 ± 46.55
RCT (Watts)	297.4 ± 31.98	252.6 ± 62.29
POSTT (Watts)	175.0 ± 50.00*	110.0 ± 22.36
LP-1 TT (Watts)	200.0 ± 50.00*	135.0 ± 22.36
LPTT (Watts)	225.0 ± 50.00*	160.0 ± 22.36
EQTT (Watts)	250.0 ± 50.00*	185.0 ± 22.36
NEGTT (Watts)	278.5 ± 48.79*	210.0 ± 22.36
MLSS (Watts)	231.4 ± 28.55*	159.4 ± 35.47

\*Significant difference between genders ( $p < 0.05$ ).  
Data are reported as mean ± standard deviation.

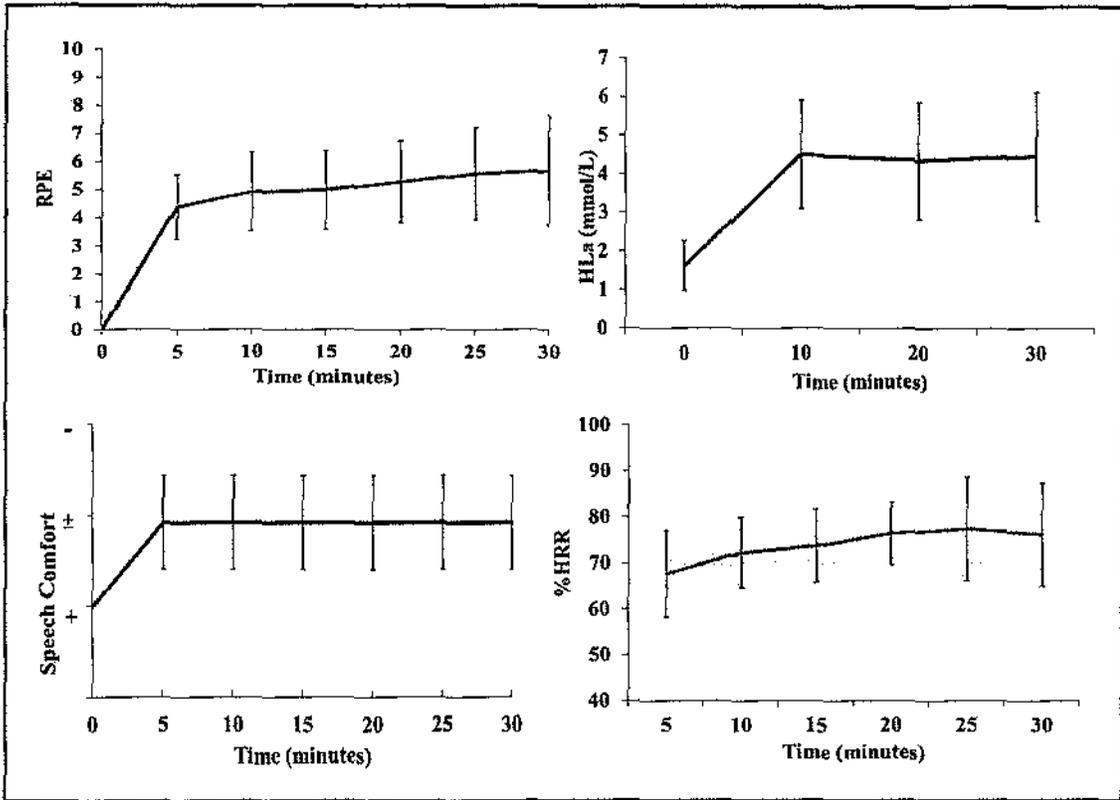


Figure 1. RPE, blood lactate, speech comfort, and %HRR during the MLSS ride. Results are mean  $\pm$  standard deviation.

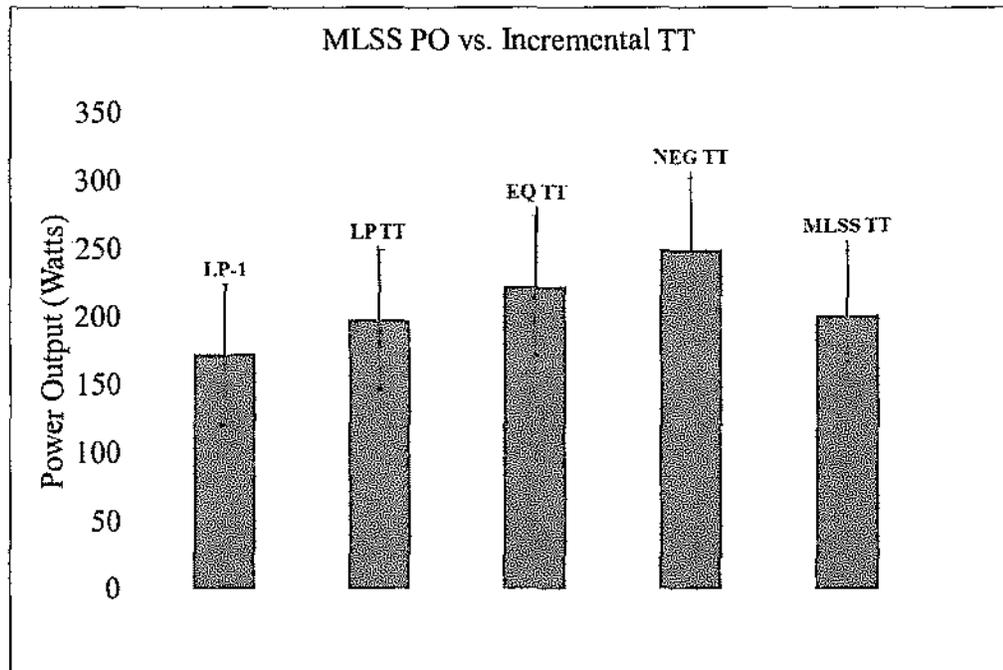


Figure 2. MLSS PO vs. Incremental TT PO.

\*Indicates significant difference to the MLSS PO (Tukey's Post-Hoc Analysis).

## DISCUSSION

Generally speaking, clamping the TT response at the highest intensity which allowed comfortable speech was associated with fully steady-state exercise responses. These data support the implications from the previous correlative studies relating the TT to physiologic responses. There has been a considerable amount of interest in the value of high intensity training during the last several years, the best evidence suggests that endurance athletes do the majority (70-90%) of their training at intensities below the VT/LT (Esteve-Lanao, Foster, Seiler, & Lucia, 2007; Seiler, 2010). The present data supports that the ability to speak comfortably (LP-1) is associated with this training intensity zone without the normally required HR or [HLA], but with being defined solely through TT responses. The incremental exercise intensity at the LP seems to be associated with the MLSS intensity, representing the lower border at the same exercise intensity.

Woltmann, et al. (2015) provided evidence on aerobic interval prescription by looking at HR, RPE, and [HLA] responses at the LP, EQ and NEG intensities. Not all of the subjects were able to complete the two heavier 30 minute exercise bouts successfully. This study indicated runs at the NEG TT, were likely above the intensity of the maximal lactate steady state (MLSS), which suggests that athletes are training at an intensity greater than the critical power (CP) (Jones, Vanhatalo, Burnley, Morton, & Poole, 2010). Thus Woltmann, et al. (2015) suggested that the NEG TT intensity represents an intensity between the respiratory compensation threshold (RCT)/MLSS/CP and  $VO_{2max}$ , which is

widely accepted as appropriate for “aerobic intervals” (Daniels, 2014; Seiler, 2010) and serves as the basis for much of the interval training accomplished by endurance athletes.

According to Daniels, (2014); Esteve-Lanao, Foster, Seiler, & Lucia, (2007); and Seiler, (2010), athletes must do at least some of their training at intensities  $\geq$  MLSS, in the so-called “severe” intensity domain (Jones, Vanhatalo, Burnley, Morton, & Poole, 2010) where metabolic disturbances may be profound, but which may lead to large and specific training responses. Thus having a very simple marker of exercise intensity (NEG) presents a simple and practical option for those athletes unable to measure HR or [HLA]. Likewise, the value of “threshold runs” is widely appreciated by athletics coaches as a device for improving running performance (Daniels, 2014), which should be performed at about the LP intensity for incremental exercise.

The TT has been shown to work more or less the same with both running and cycling (Persinger, Foster, Gibson, Fater, & Porcari, 2004), thus it seems reasonable to suggest that it is a very robust measurement, not requiring retesting or [HLA] to define unique training HR zones.

## **CONCLUSION**

The data suggest that the TT is a valid technique for prescribing exercise intensity. Specifically, the TT responses (POS, EQ, NEG) accurately correlate with exercise intensities below, at/near, and above the VT and LT during incremental exercise. These data also indicate that if the LP TT intensity is clamped, the exercise intensity should be approximately equal to the MLSS. Thus predictable levels of exercise intensity can be achieved for exercise training in both healthy individuals and athletes.

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APPENDIX A

PAR-Q

# PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

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

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

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

YES	NO	
<input type="checkbox"/>	<input type="checkbox"/>	1. Has your doctor ever said that you have a heart condition AND that you should only do physical activity recommended by a doctor?
<input type="checkbox"/>	<input type="checkbox"/>	2. Do you feel pain in your chest when you do physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	3. In the past month, have you had chest pain when you were not doing physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
<input type="checkbox"/>	<input type="checkbox"/>	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
<input type="checkbox"/>	<input type="checkbox"/>	7. Do you know of any other reasons why you should not do physical activity?

If  
you  
answered

**YES to one or more questions**

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want as long as you start slowly and build up gradually. Do you may need to repeat your activities in ways which are safe for you. Talk with your doctor about the kinds of activities you wish to participate and follow their advice.
- Find out which community programs are safe and helpful for you.

**NO to all questions**

If you answered NO to every PAR-Q question, you can be reasonably sure that you can:

- start becoming much more physically active - begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal - this is an excellent way to determine your level of fitness so that you can take the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 140/90, talk with your doctor before you start becoming much more physically active.

**DELAY RECOMMENDS MUCH MORE ACTIVE:**

- If you are not feeling well because of a temporary illness such as a cold or a fever - wait until you feel better, or
- If you are on any drug program - talk to your doctor before you start becoming much more active.

**PLEASE MEDIATE:** If your health changes so that you then answer YES to any of the seven questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Information from the PAR-Q: The Canadian Society for Exercise Physiology (CSEP) and their agents assume no liability for persons who undertake physical activity, and if it is found after completing this questionnaire, consult your doctor prior to physical activity.

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

NOTE: If the PAR-Q is done prior to a program before or after you return to a physical activity program or a fitness appraisal, the results may be used for legal or administrative purposes. I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

NAME \_\_\_\_\_

ADDRESS \_\_\_\_\_ CITY \_\_\_\_\_

PROVINCE/STATE \_\_\_\_\_

or District (for mail orders only) \_\_\_\_\_

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

FIGURE 2.1. Physical Activity Readiness (PAR-Q) Form. (Source: Physical Activity Readiness Questionnaire [PAR-Q]. Public Health Agency of Canada and the Canadian Society

## CHAPTER 2 Preparticipation Health Screening and Risk Stratification

### Assess your health status by marking all true statements

#### History

You have had:

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

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

#### Symptoms

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

#### Other health issues

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

#### Cardiovascular risk factors

- You are a man older than 45 years
- You are a woman older than 55 years, have had a hysterectomy, or are postmenopausal
- You smoke, or quit smoking within the previous 6 months
- Your blood pressure is  $>140/90$  mm Hg
- You do not know your blood pressure
- You take blood pressure medication
- Your blood cholesterol level is  $>200$  mg/dL
- You do not know your cholesterol level
- You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister)
- You are physically inactive (i.e., you get  $<30$  minutes of physical activity on at least 3 days per week)
- You are  $>20$  pounds overweight

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

None of the above

*You should be able to exercise safely without consulting your physician or other appropriate health care provider in a self-directed manner in a facility that meets the*

APPENDIX B  
INFORMED CONSENT

**Informed Consent**  
**Comparative Intensity Effectiveness on the Talk Test and Respiratory  
Compensation Threshold and Maximal Lactate Steady State**

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*Purpose and Procedure*

This study is designed to evaluate the comparative effects of the Talk Test (TT) and the Respiratory Compensation Threshold (RCT) and Maximal Lactate Steady State (MLSS) in athletes in order to design a protocol that can be utilized in athletic populations to prescribe adequate exercise intensities for training purposes

My participation will involve two pre-test incremental maximal cycle ergometer tests (same protocol, each requiring <60 minutes per test), and 3-5 post-test aerobic steady state tests (<45 minutes/per test). The testing may be very fatiguing.

Testing will take place in the Human Performance Laboratory, Mitchell hall 225.

During Pre-Test I, I will wear a snorkel-like device to analyze my breathing and, in order to measure my heart rate, I will have a heart rate monitor strapped to my chest. In Pre-Test II, I will wear a heart rate monitor and be asked to recite a phrase that is given to me repeatedly. I recognize that I will be donating small blood samples, from my finger-tip, during the post-testing procedure. Throughout all of these testing procedures (pre and post) I will provide honest perceived exertion on how I am feeling when asked at each incremental stage, and will give my best effort.

I acknowledge participating in this study is voluntary and I have the right to quit at any time. If I have questions about this consent form or any of the procedures, I will not hesitate to ask questions.

*Potential Risk*

Similar to any form of exercise, I acknowledge I may get tired and my muscles may get sore. As a result, I understand this may change my training outside of the laboratory. Individuals trained in CPR, Advanced Cardiac Life Support and First Aid will be in the laboratory, and the test will be terminated if complications occur. The risk of serious or life-threatening complications, for healthy individuals, like myself, is near zero.

*Rights and Confidentiality*

My participation is voluntary. I can withdraw or refuse to answer any questions without consequences at any time.

I can withdraw from this study at any time, for any reason, without penalty.

The results of this study may be published in the scientific literature or presented at professional meetings using grouped data only.

All information will be kept confidential through the use of number codes. My data will not be linked with personally identifiable information.

*Possible Benefits*

The primary benefit of this study is to the exercise community, and to the ability of exercise professionals to better serve their clients and athletes. By participating in a research project, I may find that my academic experience at UWL is richer and I may know more about my physical fitness level.

Questions regarding study procedure may be directed to Sarah Smith (906) 290-2170 smith.sarah3@uwlax.edu, Danielle Kolman (608) 604-0057 kolman.daniell@uwlax.edu, or their advisor (Dr. Carl Foster, 608-785-8687). Questions regarding the protected human subjects may be addressed to the UW-La Crosse Institutional Review Board for the Protection of Human Subjects (608-785-8124).

By signing below, I agree to these terms and wholly understand my rights as a subject.

**\*You will not be penalized or treated differently for not participating in this study.**

Participant \_\_\_\_\_ Date \_\_\_\_\_

Researcher \_\_\_\_\_ Date \_\_\_\_\_

APPENDIX C  
REVIEW OF LITERATURE

## INTRODUCTION

Historically, the main paradigm for prescribing exercise training intensity has been the use of physiological variables and relative percentages such as power output (PO), oxygen consumption ( $VO_{2max}$ ), heart rate (HR), blood lactate ([HLa]), ventilatory threshold (VT), lactate threshold (LT), respiratory compensation threshold (RCT), and maximal lactate steady state (MLSS) by conducting maximal exercise tests. Though these variables and percentages allow for accurate measurements of physiologic thresholds, it can be potentially dangerous and impractical for older or vulnerable populations. Another hindrance of a max test is the need for sophisticated gas exchange equipment and the appropriate personnel to run the equipment. Therefore the need of finding another form of prescribing exercise intensity is evident.

Katch, Weltman, Sady, & Fresson (1978) and Scharhag-Rosenberger et al. (2009) demonstrated that prescribing exercise intensity based on relative percentages or Relative Percent Concept produces huge errors. Katch et al. had subjects exercise at the same relative percent heart rate (HR), while Scharhag-Rosenberger had subjects exercise at 4 different percentages of their ( $VO_{2max}$ ). Subjects from both studies concluded their relative percent values were extremely inaccurate when it came to measuring anaerobic threshold and [HLa]. Therefore, using the Relative Percent Concept to prescribe training is an inaccurate way of monitoring exercise intensity and this led to the recognition of using subjective methods as a measure of exercise intensity (Goode, Mertens, Shaiman, & Mertens, (1998).

The Rating of Perceived Exercise Scale (RPE) (Borg, 1998) is the main subjective method that has been widely accepted in exercise physiology; particularly in cardiac rehab programs (Eston et al., 2012). Another subjective method that has gained popularity, but has remained less well accepted, is the Talk Test (TT).

The origin of the TT began in 1937 when Professor Henry Joseph Grayson gave advice to British mountaineers to “climb no faster than you can speak” (Goode, Mertens, Shairiman, & Mertens, 1998). Later, Goode et al. conducted a study suggesting if you can hear yourself breathing during exercise, you are exercising at appropriate levels. Subjects participated in three, separate tests on a cycle ergometer. As soon as the subject could “hear their breathing,” they were instructed to keep pedaling with no change in resistance for 5-minutes. Heart rate was monitored and recorded. Days later, they repeated the same procedure on the same subjects, but with a running modality. Both tests resulted in the same findings. Heart rate corresponded with intensities appropriate for training effects 60-90% of maximal heart rate ( $HR_{max}$ ). Little did Goode et al. know, Grayson’s simple recommendation had set the foundation for what may be a superior subjective method for measuring exercise intensity.

The standard TT protocol is simple and easy to follow. A subject performs an incremental exercise, with stages lasting 2-3 minutes. Near the completion of each stage, the subject recites a standard speech-provoking stimulus and is asked, “Can you speak comfortably?” Only three responses can be achieved; speech is still comfortable (a positive TT), speech is possible but not entirely comfortable (an equivocal TT (EQ)), and when comfortable speech is definitely not possible, a negative TT (NEG). To achieve a positive TT, the subject must be able to speak comfortably while exercising. If the subject

is hesitant about speaking comfortably, this results in an EQ TT. If the subject cannot speak comfortably, this results in a NEG TT. Different protocols have been used in studies conducting the TT, but the two most common are: 1) having the subject read a standard paragraph during the last thirty seconds of the stage, the Pledge of Allegiance (POA) or the Rainbow Passage, or 2) having the subject listen to a previously recorded interview and respond to the questions out loud.

The TT has also been shown to be well correlated with the principles of speech production. Meckel, Rotstein, & Inbar, (2002) examined the cardiopulmonary and metabolic responses to speech during exercise of varying intensities in healthy, young men. They found that to allow adequate speech production, one must adapt their breathing pattern to one that allows them to take in the required amount of oxygen. The results from this study concluded that speech production is correlated with an increase in oxygen cost, a decrease in oxygen consumption, and therefore a decrease in ventilator efficiency. More specifically, the decrease in  $VO_2$  during speech while exercising was accompanied by a significant drop in ventilation as well as an increase in [HLa] concentration. However, only the lowest intensity exercise bout produced such changes in [HLa] and it remains unclear to why the increases in the other two (more difficult) exercise bouts were smaller and not significant.

This concept led researchers to believe the TT may be related to the VT. Previous research has demonstrated that the TT is effective at identifying intensities below the VT if the subjects are able to speak comfortably. Likewise, if subjects were unable to speak comfortably they are typically at or above their VT (Dehart-Beverly, Foster, Porcari, Fater, & Mikat, 2000). Similar relationships between the TT and the VT was seen in

several populations including well-trained cyclists (Rodríguez-Marroyo, Villa, García-Lopez, & Foster, 2012), well-trained adults (Recalde et al. 2002), patients with coronary artery disease (Brawner et al., 2006; Voelker, 2002), patients with exertional ischemia (Cannon et al., 2004), sedentary individuals (Foster et al., 2009), patients with a recent myocardial revascularization and healthy students (Zanettini et al., 2012; Dehart-Beverly et al., 2000).

Given that the TT was considered to be a valid measure of measuring exercise intensity in various populations, research was lacking in terms of whether it could be translated to an exercise prescription across modes of exercise or if the VT was manipulated. Persinger et al., (2004) evaluated the consistency of the TT by measuring the relationship between the TT the VT on the treadmill and cycle ergometer (Foster et al., 1986). In both modes of exercise, the data supported the hypothesis that the TT was a consistent measure of exercise intensity across different modes of exercise. In a similar study, Foster et al. (2008) showed that even with four experimental manipulations of the VT, the TT was a reliable marker of VT and be applied to exercise prescription.

In 2009, Foster et al. examined what happened to exercise intensity when the TT responses during incremental exercise were “translated” to steady-state exercise training. They showed that workloads must be reduced when applying a desired workload to a steady-state bout. To replicate these results, other research studies tested steady-state workloads in well-trained individuals (Jeans et al., 2011), sedentary individuals (Foster et al., 2009), competitive runners (Foster et al., 2012; Woltmann et al., 2015), and cardiac patients (Lyon et al., 2014). These studies evaluated how much of a reduction in absolute exercise intensity was needed to produce adequate speech in both populations. The data

from these studies supported the idea that different reductions from incremental exercise intensities are required between various populations in order to meet suitable exercise guidelines. In general, in well-trained individuals can sustain exercise at the last positive (LP) workload, sedentary individuals can sustain exercise at the stage prior to the last positive stage (LP-1) workload, and cardiac patients can sustain exercise at the LP-1 or LP-2 workload.

In addition to the TT being robustly related to the VT, Quinn and Coons (2011) showed it was highly related to the lactate threshold (LT). The results revealed during the positive (POS) stage of the TT, subjects were below their LT and during the EQ and NEG stages of TT, subjects were at or above their LT. Quinn and Coons also observed two other important findings. First, the physiological and perceptual values during the LP stage of the TT were significantly lower than physiological and perceptual values recorded at the LT. Secondly, the physiological and perceptual values during the EQ and NEG TT stages were significantly higher than the physiological and perceptual values at the LT. This study concluded that in response to the TT, VT and LT produce similar effects during the POS, EQ and NEG stages. Therefore, this study reinforced the concept that the TT is a valid surrogate of both physiological markers.

The concept that the TT is suitable method for determining LT and VT led to the idea that the TT may predict MLSS, critical power (CP) and second ventilatory threshold (VT<sub>2</sub>). Woltmann et al. (2015), Pringle and Jones (2002), and Jones et al. (2008) studies are particularly significant because they all demonstrated that these physiological variables may be correlated in terms of intensity. Woltmann et al. (2015) identified physiological effects during steady-state conditions, but was unable to establish the

MLSS because only a few of subjects were able to complete the NEG TT stage. Pringle and Jones (2002) found that if subjects worked slightly below the CP, they were near the MLSS. Therefore, we aimed to find if the exercise intensity was held constant, defined by the TT, it may be able to control exercise intensity below the MLSS. However, accurately prescribing exercise remains problematic due to the variability of subjective responses in different athletic populations and protocols (Foxdal et al., 1994; Sjödín & Jacobs, 1981; Amann et al., 2006).

However, according to Foxdal et al. (1994) accurately prescribing exercise remains problematic due to the variability of subjective responses in different athletic populations and protocols. So far, blood lactate accumulation has been studied within elite marathon runners (Sjödín & Jacobs, 1981), professional rowers (Beneke, 1995), and male cyclists (Amann et al., 2006), but no conclusive criterion has been replicated. Therefore, we plan to reproduce Woltmann's et al. (2015) study, by introducing more steady-state conditions and observe if the talk test can identify MLSS.

In our study, we hypothesized if the TT is negative, the exercise intensity would be at the MLSS intensity. With our results, we can begin designing training programs at specific work intensities and measure their effect on aerobic and anaerobic performance. Coaches and athletes might therefore adhere to these advances and construct training intensities based upon the determinants of exercise tolerance.

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