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HEART RATE RESERVE VERSUS TALK TEST: IS THERE A SIMILAR TRAINING EFFECT?

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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HEART RATE RESERVE VERSUS TALK TEST: IS THERE A SIMILAR TRAINING EFFECT?

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

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ABSTRACT

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The Talk Test (TT) is a submaximal, incremental exercise test that is useful in prescribing exercise based on an individual's ability to speak comfortably during exercise. This study compared the training effects of two different 10-week training intensities on endurance adaptions in sedentary, young adults. Forty-four adults ventilatory threshold (VT) 1.59±0.39 L.min-1 were randomized to two training groups. The training program was 10 weeks in duration (3 times weekly for 40 minutes per session). The Talk Test group (n=20) performed all 30 training sessions solely using the TT as the intensity control. Subjects rated their speech comfort every 5-minute stage after reciting a standardized paragraph. Speech comfort, heart rate (HR), and Rating of Perceived Exertion (RPE) were recorded every 5 min. The Heart Rate Reserve (HRR) group (n=24) performed at %HRR ranges 40-59% in week 1-4, 50-69% in week 5-8, and 60-79% in week 9-10. Heart rate and RPE were recorded every 5 min. Pre and post intervention, subjects were tested for maximal oxygen consumption (VO_2max) and VT. The results concluded that both groups improved from pre to post intervention ($P<.05$), but no significant differences were evident between groups ($P>0.05$). The TT may be used a simple and non-invasive method to prescribe exercise intensity compared to HRR. Given that maximal exercise tests to detect maximal heart rate (HRmax) are not widely available, the equivalent responses to training is available using the simpler TT method. The TT is an effective and attractive alternative to the %HRR method which has been the gold standard for exercise prescription.

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INTRODUCTION

Sedentary behavior is a worldwide epidemic. Research has shown that sedentary behavior is linked to obesity, which impacts the development of cardiovascular diseases, dyslipidemia, diabetes, hypertension, and hypercholesterolemia (Pescatello, 2014). The American Heart Association (AHA) and the American College of Sports Medicine (ACSM) released physical activity (PA) guidelines in 2007 for healthy adults aged 18-65 years old intended to combat such health issues (Haskell et al., 2007). The PA guidelines recommend a minimum accumulation of 30 minutes of moderate intensity exercise, 5 days per week; or at least 20 minutes of high intensity exercise 3 days per week (ACSM, 2013). In addition, resistance training activities designed to increase muscular strength and endurance are recommended at least 2 times per week to promote cardiovascular fitness and metabolic health (Pescatello, 2014). These PA guidelines are prescribed based on the FITT-VP principle of frequency (how often), intensity (how hard), time (how long), type (what kind), volume (how much), and progression (increase over time). The FITT-VP variables are generally easy to interpret and apply, with the exception of exercise intensity.

Exercise intensity is the most difficult variable to prescribe in the FITT-VP principle, because most guidelines depend on maximal exercise test results. The current ACSM recommendation for moderate exercise intensity is 40%-60% of heart rate reserve (HRR) or maximal oxygen consumption (VO_2max), and 60%-90% HRR or VO_2max for vigorous exercise intensity (ACSM, 2013). The HRR is derived from a maximal exercise test, taking into account both resting heart rate (HRrest) and maximum heart rate (HRmax). Although a maximal exercise test is required for this method, it may not be a practical option. Maximal exercise tests are rarely performed before the start of training programs in healthy individuals or even patients referred for a rehabilitation program. Thus, effective, subjective tools are needed to measure exercise intensity.

There is a rich literature concerning objective measures of exercise intensity as a basis for exercise prescription. Guidelines and position stands published by ACSM (2013) have evaluated longitudinal changes in exercise capacity based on subjective methods of exercise prescription. Parfitt, Evans, & Eston (2012) examined the effect of using the rating of perceived exertion (RPE) scale to control training intensity and demonstrated that a normal training response occurs when RPE is "clamped" at 13. Limited research exists to determine the effectiveness of other subjective intensity measures.

The Talk Test (TT) is simple, subjective measurement for prescribing exercise intensity. The TT is effective at identifying intensities below the ventilatory threshold (VT) which may be the ideal index for prescribing training intensity (Mezzani et al., 2012). The relationship between the TT and VT has been seen across various populations including healthy students (Dehart-Beverley, Foster, Porcari, Fater, & Mikat, 2000), sedentary individuals (Foster et al., 2009; Engen, 2015), well trained adults (Recalde et al., 2002; Woltmann et al., 2015), well-trained cyclists (Rodriquez-Marroyo, Villa, Garcia-Lopez, & Foster, 2013), patients with coronary artery disease (Brawner et al., 2006; Voelker et al., 2001), patients with a recent myocardial revascularization

(Zanettini et al., 2013), and patients in cardiac rehabilitation programs (Lyon et al., 2014; Doro, 2015).

The validity and reproducibility (Ballweg et al., 2013) of the TT has been established. Foster et al. (2008) investigated how changes in VT would affect the TT. Four independent studies were conducted to decrease VT (via 500 mL whole blood donation), increase VT (via six week aerobic training program), or exercise intensity changes above and below VT (via two interval exercise training sessions on a cycle ergometer or a treadmill). All four studies showed that the VT and the TT are "robustly related" and support the concept that the TT is a valid surrogate of VT (Foster et al., 2008). The TT may be a more suitable, alternative method for prescribing exercise intensity compared to the HHR method because it is not evaluation dependent. However, intervention data is lacking.

Studies have traditionally used VO_2max as an outcome measure (ACSM, 2013). However, VT is potentially a better marker at sustainable exercise capacity (Mezzani et al., 2012; Foster & Cotter, 2005). The VT differs among people in relation to their age, gender, physical fitness, and health, which makes training at VT individualized. The VT is variable among individuals, because it takes into account specific level of metabolic stress better than VO_2max or HR (Fabre, Massé-Biron, Ahmaidi, Adam & Préfaut, 1997). The breakpoint in ventilation is marked by VT, which is at the same workload at the dyspnea threshold (Quantin, Jolimoy-Boileau, & PreTaut, 1996). Thus, individualized training programs based on VT may lead to a greater training responses than standardized training program.

The purpose of this study is to determine if a training effect will occur causing increases in VT using both the TT and HRR as a basis for intensity prescription. It is hypothesized that the training response of VT will be similar in both HRR vs TT groups. This study is part of a larger study which examines changes in VO_2max, HR, TT, RPE, and enjoyability between TT and HRR training groups.

METHODS

Subjects

Fifty-four healthy, previously inactive, young adults were recruited from the University of Wisconsin-La Crosse community. All subjects completed the Physical Activity Readiness Questionnaire (PAR-Q) and an Exercise History Questionnaire to determine if any contradictions or physical limitations affecting their ability to participate in the study were present. Prior to testing, all subjects were given both oral and written versions at the research protocol, purpose, and potential risks and benefits were explained before they provided written informed consent. The UWL Institutional Review Board for the Protection of Human Subjects reviewed and approved the protocol.

Subjects achieving a relative VO_2max over 50 ml/kg/min or 43 ml/kg/min for males and females, respectively, were excluded from the study. Eight subjects were excluded from the study because of their advanced aerobic capacity; thus, 46 subjects initially participated in the study. However, of the original 46 subjects, only 44 completed the training program. Data analysis was based on the subjects who completed the study (Table 1).

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

Variable	Talk Test (n=20)	Heart Rate Reserve (n=24)
Age (yrs)		
Males (17)	21.2 ± 2.82	21.0 ± 5.90
Females (27)	20.5 ± 1.97	19.5 ± 1.26
Height (cm)		
Males	179.5 ± 7.27	176.9 ± 3.97
Females	165.0 ± 9.84	166.0 ± 7.74
Weight (kg)		
Males	83.9 ± 10.63	77.0 ± 14.55
Females	67.6 ± 10.72	65.5 ± 11.80

Values presented represent mean ± standard deviation.

Protocol

Each subject performed pre and post training incremental maximal exercise tests on an electrically-braked cycle ergometer (Lode Excallibur, Groningen, The Netherlands). The workload began at 25 W and increased by 25 W every 2 minutes (min) up to maximal exertion. Subjects wore a scuba type mask to allow analysis of respiratory gas exchange using open-circuit spirometry (Moxus Metabolic Cart System, AEI Technologies, Pittsburgh, Pennsylvania). Calibration was conducted using reference gases (16% O_2, 5% CO_2) and room air. The pneumotach was calibrated with a 3-liter syringe. VO_2max was defined as the highest continuous 30s VO_2 during the test. Ventilatory threshold was identified using a combination of the v-slope and ventilatory equivalent methods (Foster & Cotter, 2005). Heart rate was measured continuously using radiotelemetry (Polar Vantage XL, Polar USA, Lake Success, New York), and RPE was assessed using the 6-20 category ratio scale of Borg (Borg, 1970) at the end of each stage. Following the completion of the initial exercise tests, subjects were stratified by VO_2max within each gender and then randomly assigned to either the TT or HRR training groups.

The training program was 10 weeks in duration (3 times weekly for 40 minutes per session). All training sessions were performed on a mechanically-braked cycle ergometer (Monarch, Stockholm, Sweden). The pedaling rate was fixed at 60 rpm (reinforced by music with a dominant beat frequency of 120 counts per minute). Thus, the power output (PO) was effectively regulated by changing the resistance on the pedals. All subjects wore a HR monitor (Polar Vantage XL, Polar USA, Lake Success, New York) during training.

Talk Test Group

The TT group trained solely using the TT as the intensity measure. All training sessions began with a 5-min warmup at ~30 W. For the first exercise session, the initial workload was set at a PO corresponding to 90% of VT. After 5 min, subjects recited the 'Rainbow Passage' and speech comfort was assessed. If the subject was able to speak comfortably, PO was increased by ~30 W. If comfortable speech was either equivocal or definitely not comfortable, PO was reduced by ~30 W. Although not used to determine training PO, HRR and RPE 6-20 scale were recorded at 5-min intervals. A 5-min cool down at ~30 W followed the 30 min training session. Session RPE (0-10 scale) (Foster, Schrager, & Snyder, 1995) was recorded at the conclusion of the session. For all subsequent exercise sessions, PO for the initial 5 min after the warmup was set at the same PO where the subject could speak comfortably during the previous workout.

Heart Rate Reserve Group

The HRR group trained solely using HR as the intensity measure. All training sessions began with a 5-min warmup at ~30 W. For the next 30-min, training intensity was set using %HRR ranges calculated from their pre testing maximal exercise test. The prescribed %HRR ranges were 40-59% for weeks 1-4, 50-69% for weeks 5-8, and 60-79% for weeks 9-10. Every 5-min during the workout HR was assessed. If HR was below the target %HRR range, PO was increased ~30W. If HR was within the target %HRR range, PO remained the same. If HR was above the target %HRR range, PO was reduced by ~30 W. A 5-min cool down at ~30W followed the 30-min training session. Although not used to determine training intensity, RPE (6-20 scale) was recorded at 5-min intervals and sRPE (0-10 scale) was recorded at the conclusion of the session.

Exercise enjoyment was assessed during 1 session each week. Enjoyment was assessed using the Exercise Enjoyment Scale (Stanley & Cumming, 2010). This was given to the subjects before exercise, 15 min into the exercise bout, and at the conclusion of the 5-min cool down.

STATISTICAL ANALYSIS

Standard descriptive statistics were used to describe subject population and to summarize differences from pre and post testing: Independent t-tests were used to compare pre-testing scores between the HRR and TT groups. If there was no significant difference in pre-testing scores between groups, changes from pre to post testing were compared using two-way ANOVA with repeated measures. If the pre-testing scores were significantly different between the HRR and TT groups, changes from pre to post testing were compared using analysis of covariance. If there was a significant F ratio, Tukey's post-hoc tests were used to isolate pairwise differences. Alpha was set at .05 to achieve statistical significance.

RESULTS

Data relative to training intensity for the TT and HRR groups are presented in Figure 1. The vertical dashed lines at weeks four and eight indicate a change in prescribed exercise intensity in the HRR group. When looking at exercise intensity, the TT group exercised at a higher %HRR than the HRR group for weeks 1-8. For both RPE and session RPE (sRPE), the TT group worked significantly harder than the HRR group for weeks 1-4. For PO, the TT group worked at significantly higher workloads for weeks 1-5.

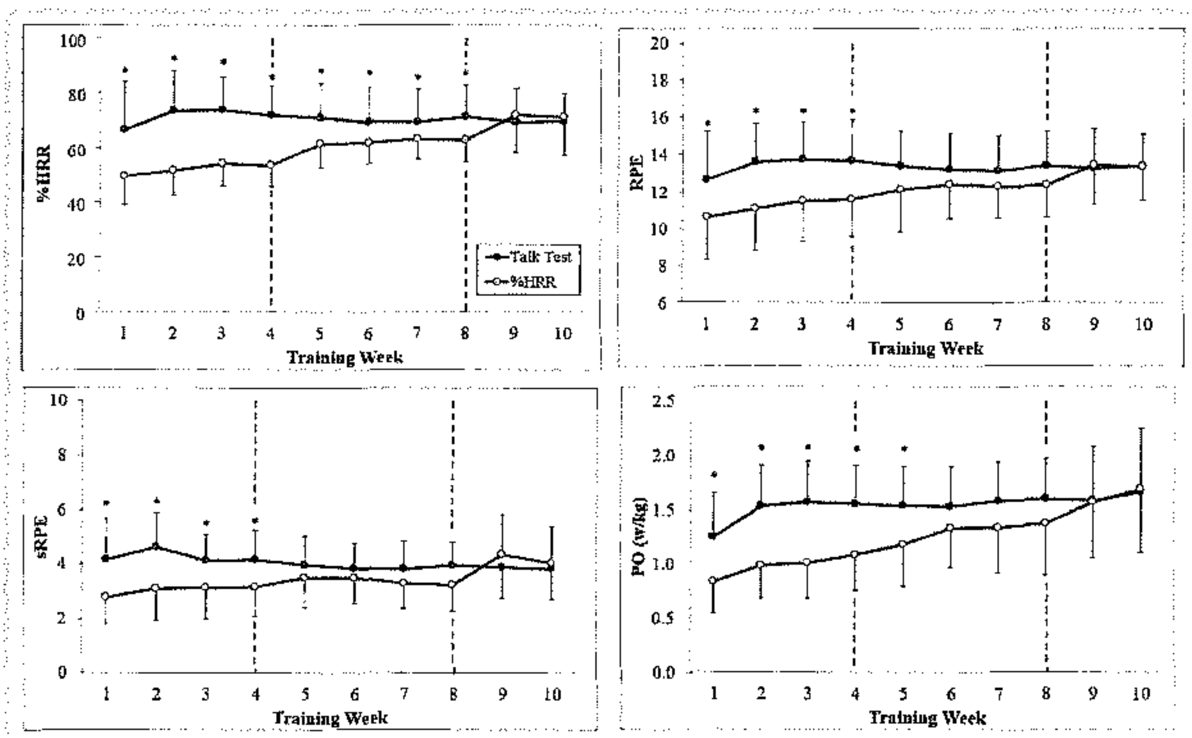

Figure 1. Comparison of training between the Talk Test and the HRR groups measuring heart rate, RPE, sRPE, and PO across weeks of training in relation to method of controlling training. Accepted ACSM ranges are shaded.
*Significant difference between groups (p<0.05).

The week by week responses of HRR in relation to the HRR at VT from the pre to post incremental tests are presented in Figure 2. Because the workload was regulated entirely by the TT response, the HRR tracked significantly higher in the TT group than the HRR group in weeks 1-8, where HRR was controlled at the low ranges recommended by ACSM (Pescatello et al., 2014) during the early weeks ($p<0.05$). During the last two weeks of training, with the HRR group controlled at the higher 60-80% of HRR recommended by ACSM, there was no differences in the HRR during training between the TT and HRR groups. There was a small increase in the HRR at the VT during incremental exercise in both training groups. Vertical dashed lines at week four and eight indicate a change in %HRR ranges the HRR group trained within.

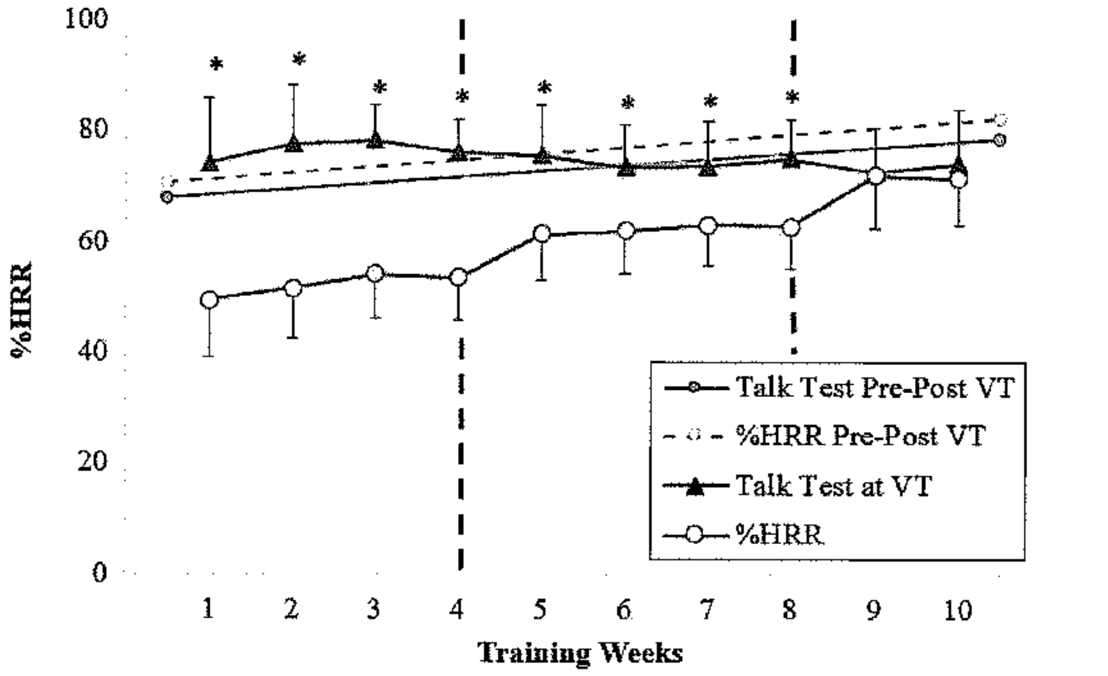

Figure 2. Comparison of training heart rates between the Talk Test at +/-, or EQ, and HRR group across weeks of training. Accepted ACSM range for %HRR are shaded.
*Significant difference between groups ($p<0.05$).

The week by week responses of PO in relation to pre and post incremental tests are presented in Figure 3. The PO values at the EQ, a surrogate of VT, within the TT group are significantly higher than those PO averages by week within the HRR group in weeks 1-5, and eight. Within week to week averages, both the TT group at VT and the HRR group train below values compared to the pre and posttests. Vertical dashed lines at week four and eight indicate a change in %HRR ranges the HRR group trained within.

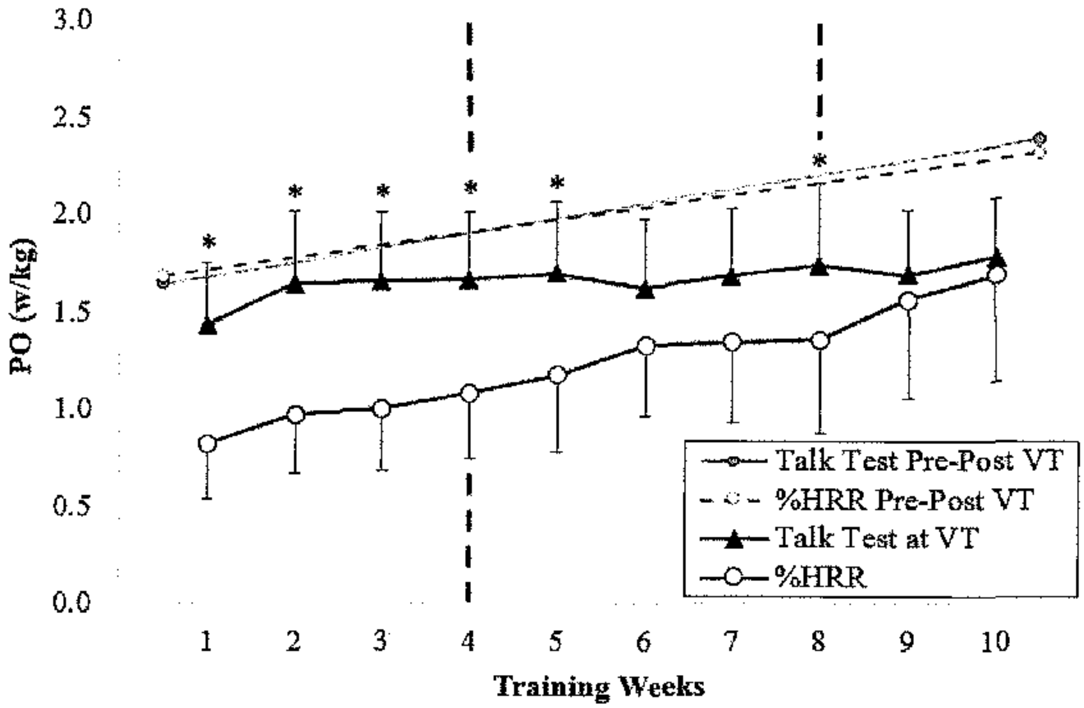

Figure 3. Comparison of PO values between the Talk Test at +/-, or EQ, and %HRR group across weeks of training.
*Significant difference between groups (p<0.05).

Figure 4 and Figure 5 illustrate the relationship between the average weekly TT scores at +/-, the surrogate of VT, compared to the average weekly TT training scores. Figure 4 demonstrates that generally, the %HRR of the TT group during training, trained just below the VT. The shaded window represents that regardless if at pre HRR at VT, weekly HRR average, average HRR at VT, or post HRR at VT, all averages remained within the ACSM guidelines. Figure 5 illustrates pre and post PO in W per kilogram remain higher than averages during training. Similarly, the average TT training PO remains just under those PO values within the TT group at VT.

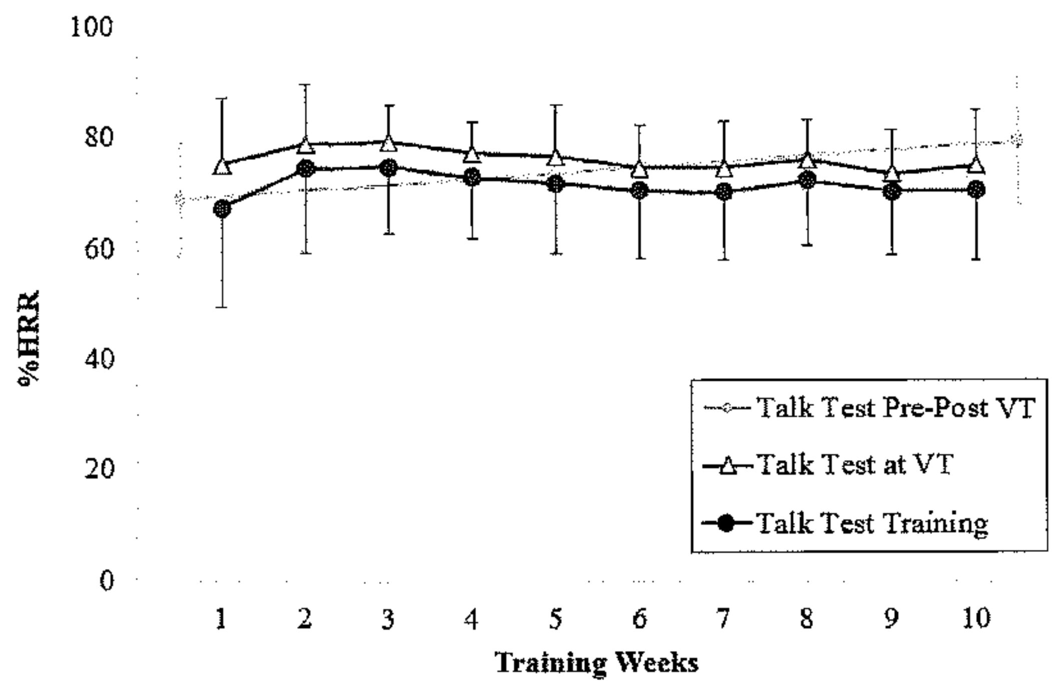

Figure 4. Comparison of heart rates between the Talk Test group during Training and the Talk Test group at +/-, or EQ, across weeks of training. Accepted ACSM range for %HRR are shaded.

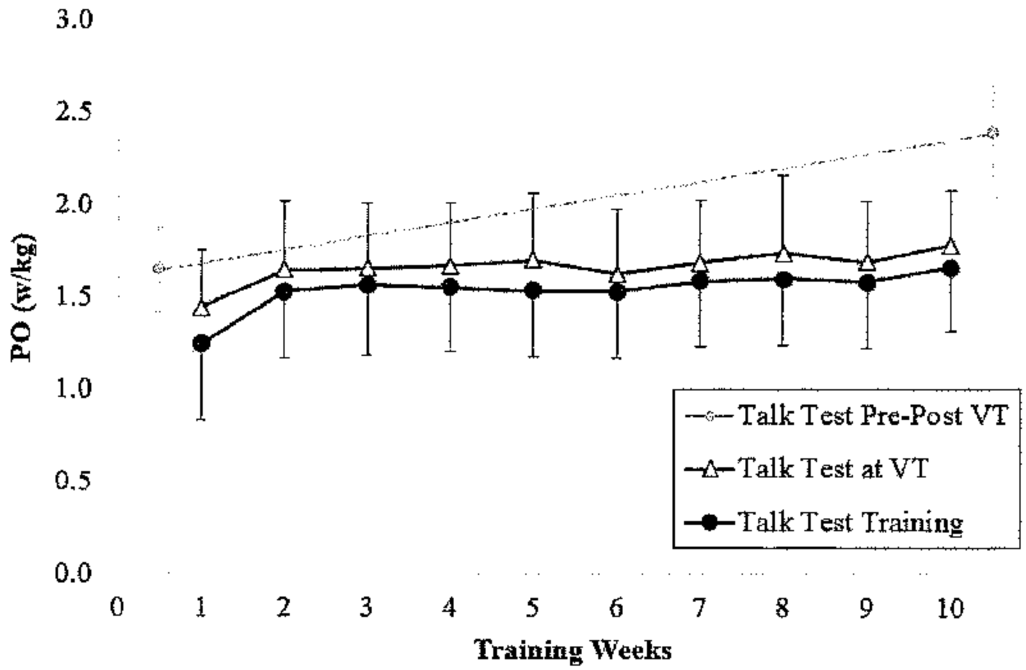

Figure 5. Comparison of PO between the Talk Test during Training and the Talk Test group at +/-, or EQ, across weeks of training.

Mean values for VO_2 at VT, PO at VT (expressed both in Watts and Watts/kg), HR at VT, and RPE at VT are presented in Table 2.

Table 2. Changes in performance variables over the course of the training period in the HRR and TT training groups.

Variable	Pre	Post	Change	% Change
VO_2 @ VT (L/min)				
HRR	1.38 ± 0.323	2.18 ± 0.512*	+0.80	58.0
TT	1.84 ± 0.464	2.41 ± 0.454*	+0.57	31.0
VO_2 @ VT (mL/kg/min)				
HRR	20.2 ± 4.73	31.7 ± 5.18*	+11.5	56.9
TT	24.5 ± 3.99	32.5 ± 4.78*	+8.0	32.7
PO at VT (Watts)				
HRR	114 ± 23.3	158 ± 36.6*	+44	38.6
TT	123 ± 24.2	176 ± 30.9*	+53	43.1
PO at VT (Watts/kg)				
HRR	1.68 ± 0.400	2.31 ± 0.388*	+0.63	37.5
TT	1.65 ± 0.234	2.38 ± 0.340*	+0.73	44.2
HR at VT (bpm)				
HRR	157 ± 17.8	172 ± 16.7*	+15	9.6
TT	154 ± 14.3	168 ± 16.8*	+14	9.1
RPE at VT				
HRR	13.1 ± 2.09	13.4 ± 1.70	+0.3	2.3
TT	13.2 ± 2.01	13.9 ± 1.89	+0.7	5.3

Values presented represent mean ± standard deviation.
*Significantly different than pre-test ($p<0.05$).
#Change significantly different than HRR group ($p<0.05$).

Both gross VO_2 at VT (L/min) and body weight normalized VO_2 at VT (mL/kg/min) were significantly higher ($p<0.05$) in the TT group than in the HRR group (1.84 ± 0.464 vs 1.38 ± 0.323 L/min, $p < 0.001$) and (24.5 ± 3.99 vs 20.2 ± 4.73 mL/kg/min, $p < 0.002$) at the beginning of the study (Figure 6). There was no significant interaction for the changes in either gross or body weight normalized between TT and HRR groups in VO_2 at VT over the course of the study (2.18 ± 0.512 vs 2.41 ± 0.454) ($p=0.892$) and (31.7 ± 5.18 vs 32.5 ± 4.78) ($p=0.963$). However, both the TT and HRR groups demonstrated a significant increase (change = +0.57 vs +0.80 L/min and change = +8.0 vs +11.5 mL/kg/min) in VO_2 at VT from pre to post-testing.

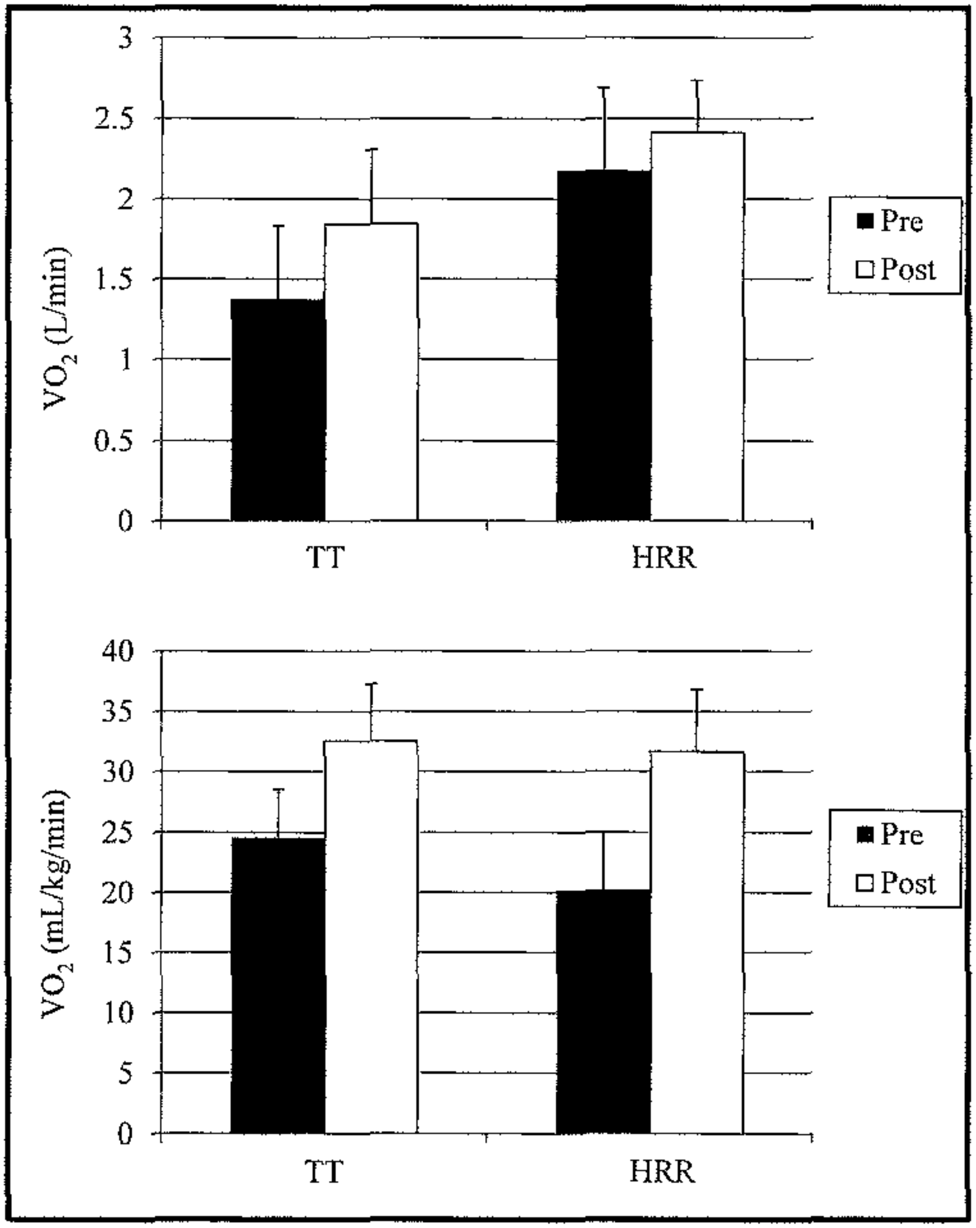

Figure 6. Mean Values (±SD) for VO_2 @ VT expressed both as L/min and mL/kg/min. Both groups improved significantly with training. However, there was no groups x trials interaction for changes in VO_2 @ VT.

Figure 7 shows the relationship between PO at VT (expressed as both Watts and Watts/kg). There was no significant difference in pre-test scores between the TT and HRR groups (123 ± 24.20 vs 114 ± 23.29 Watts) and (1.65 ± 0.23 vs 1.68 ± 0.40 Watts/kg). No significant interaction ($p = 0.296$ and 0.303) was evident between TT and %HRR groups in PO at VT (Watts and Watts/kg) in response to training (176 ± 30.86 vs 158 ± 36.61) and (2.38 ± 0.34 vs 2.31 ± 0.39). However, both TT and HRR had a significant increase (change = +44 vs +53 Watts and change = +0.73 vs +0.63 Watts/kg) in PO from pre to post-testing.

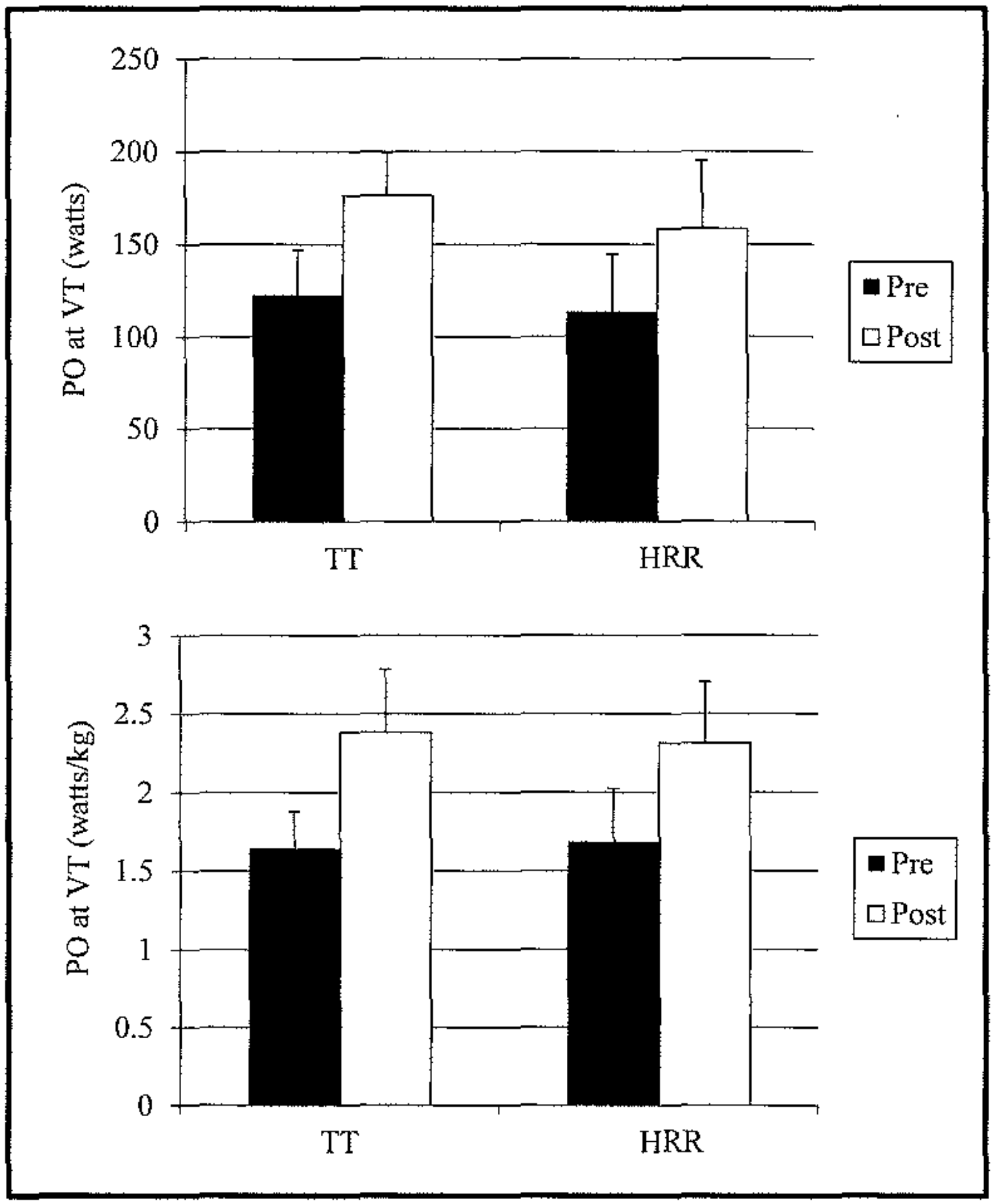

Figure 7. Mean Values (±SD) for PO @ VT expressed both as Watts and Watts/kg. Both groups improved significantly with training, but there was no groups x trials interaction.

Heart Rate and RPE at VT are compared between the TT and HRR groups in Figure 8. There was no significant difference in pre-test scores between the TT and HRR groups (154 ± 14.3 vs 157 ± 17.8 bpm) and (13.2 ± 2.01 vs 13.1 ± 2.09). No significant interaction ($p = .921$ and 0.594) was evident between TT and HRR groups in HR and RPE in response to training (168 ± 16.81 vs 172 ± 16.74 bpm) and (13.9 ± 1.89 vs 13.4 ± 1.70). However, both the TT and HRR groups had a significant increase (change = +14 vs +15 and change = +0.7 vs +0.03) in HR at VT from pre to post-testing.

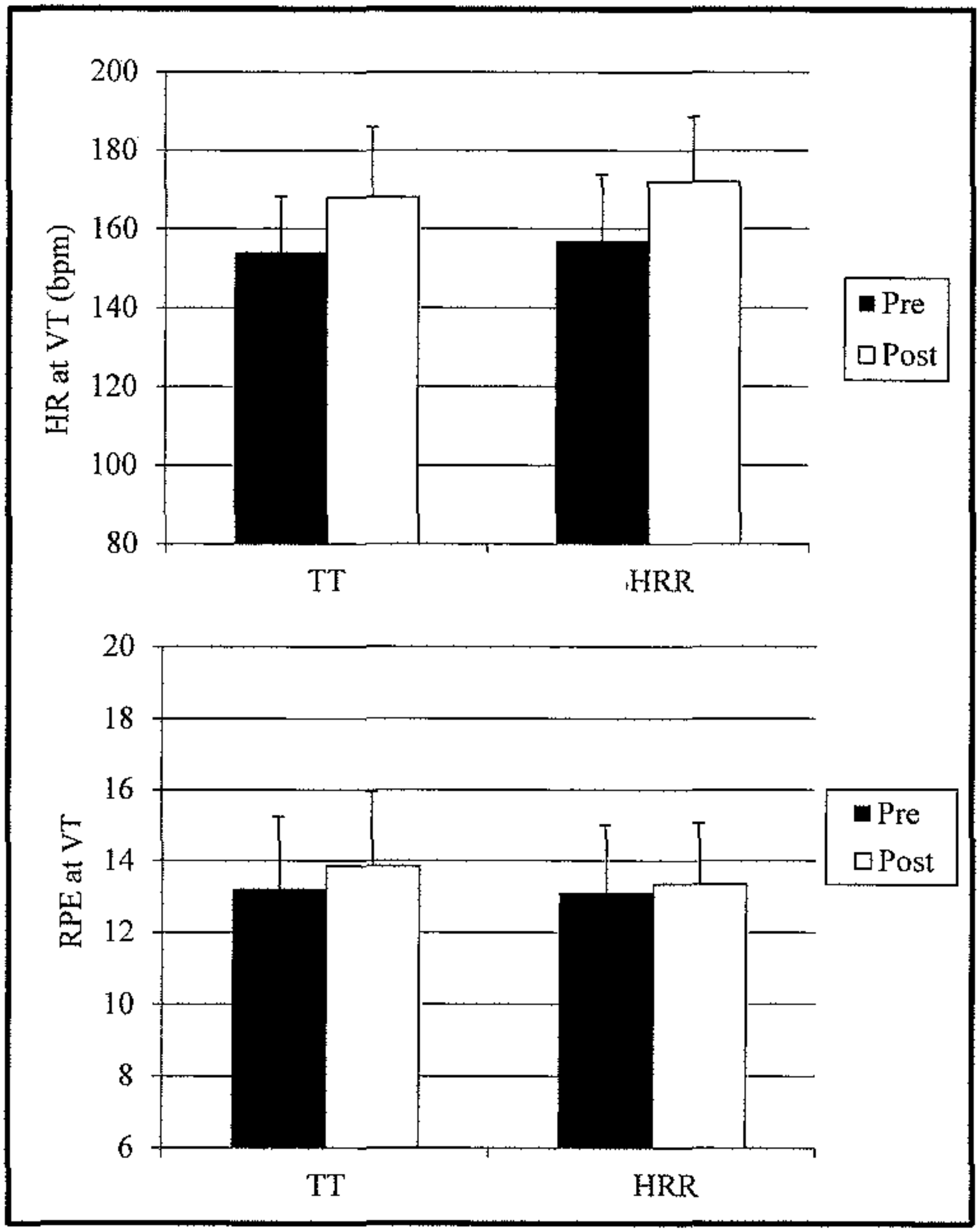

Figure 8. Mean Values (±SD) for HR @ VT and RPE @ VT. There was a significant increase in HR @ VT in both groups, but there was no groups x trials interaction.

DISCUSSION

The purpose of this study was to determine if changes in VO_2 and PO at VT occurred to a comparable degree in response to training guided by using either the TT or %HRR, as intensity measures, in young sedentary adults. The results support the hypothesis that the training response is similar in VT between the HRR and TT groups.

The variables of HR, PO, and RPE were the similar in both the %HRR and TT groups at the beginning of the training intervention. However, the TT group worked significantly harder during the first 8 weeks of the intervention. The training intensity was readjusted in the HRR group at week 4 and 8 from 40-59% to 50-69% and 60-79%, respectively; per the normal progression scheme with this method (ACSM, 2013). The ACSM (2013) recommends an overall range of training intensities from 40-90% HRR, but communicates the importance of starting sedentary subjects at 40-59% HRR. Throughout the training intervention, the subjects in both groups were exercising within ACSM exercise intensity guidelines for %VO2max, %HRmax, and RPE (Pescatello, 2014). The design intervention was reflected on VT in both groups. The magnitude of improvement was similar between the TT and %HRR groups.

The present data are consistent with prior studies which demonstrate that the TT is well correlated to VT. The last time an individual can speak comfortably (last positive TT) suggests an intensity below VT. When speaking becomes labored or an individual is uncertain whether or not speaking is equivocal, exercise intensity is approximately equivalent to VT (Dehart-Beverley et al., 2000; Persinger et al., 2004; Recalde et al., 2002; Voelker et al., 2002). Likewise, if speech is not comfortable (negative), exercise intensity is consistently associated with an intensity above VT.

Limited literature exists on the training effect on HR at VT. In agreement with the current study, Paulson et al. (2007) demonstrated that fitness can be improved with training utilizing the TT in tracking changes at the VT during a 6-week training study as he found the HR at VT increased pre to post intervention of 5.4 bpm. The present study's training intervention was 10 weeks in duration which correlates with increased training effects and larger increases in HR at VT.

Our findings disagree with Lucía, Hoyos, Pérez, & Chicharro (2000). These authors found that HR at VT remained stable in professional cyclists during the course of a training year despite the significant shifts in PO at VT. Foster, Fitzgerald, & Spatz (1999) also demonstrated stable HR values corresponded to VT, despite increases in PO at VT in competitive speed skaters. Thus, the HR at VT appears quite stable across the period of heavy training in elite athletes. These two studies suggest that high level athletes can regulate the intensity of their training sessions using HR data.

There were technical issues which might have influenced the present results. First, the study's protocol used 2-min stages during the maximal exercise tests. The VT is best determined in shorter than 2-min stages (Foster, Schrager & Snyder, 1995) although the TT is optimally measured with longer stages (Xiong, 2015). Second, the study used sedentary individuals from the University community. These subjects may not have been completely untrained for the sense that sedentary individuals are untrained, and there was no preliminary training prior to intervention. In order to control for training status, researchers took steps to exclude subjects with elevated values for VO_2max (50 ml/kg/min or 43 ml/kg/min for males and females, respectively). The methodology required two maximal incremental tests to obtain information regarding VO_2 max, VT, and HRmax as well as the TT. These two maximal tests were performed pre and post exercise training.

In conclusion, the present study has investigated if a training effect exists in VT comparing the TT and HRR groups. The results support the hypothesis, the training response of VT was between the TT versus HRR groups in response to training. The study results show substantial improvement in VT within both TT and HRR groups. With equivalent results, the present data identified that the TT may be used as a simple and non-invasive method to prescribe exercise intensity. Given that maximal exercise tests to detect HRmax are not widely available, the equivalent responses to training using the much simpler TT suggest that is an effective and attractive alternative to the HRR method which has been the gold standard for exercise prescription (ACSM, 2013).

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APPENDIX A

INFORMED CONSENT

UNIVERSITY *of* WISCONSIN
LA CROSSE

Informed Consent Form

Title of Investigation: *Training Effect on Talk Test vs Heart Rate Reserve*

Names of Principal Investigators: Kate Falck, Sam Suckow, Jillian Turek, or Anna Wargowsky

This document is to certify that I, ______________________________, hereby freely agree to participate as a subject in a research study as an authorized part of the educational and research program of the University of Wisconsin-La Crosse under the supervision of Dr. Carl Foster, Ph.D and Dr. John Porcari, Ph.D.

- The research project has been fully explained to me by Kate Falck, Sam Suckow, Jillian Turek, or Anna Wargowsky, and I understand this explanation, including what I will be asked to do. A copy of the procedures of this investigation and a description of any risks, discomforts and benefits associated with my participation has been provided and discussed in detail with me.
- I have been given an opportunity to ask questions, and all such questions and inquiries have been answered to my satisfaction as well as I am free to decline to answer any specific items or questions in interviews or questionnaires.
- I understand that, in the event of physical injury resulting from this investigation, neither financial compensation nor free medical treatment is provided for such physical injury.
- I certify that to the best of my knowledge, I have no physical or mental illness or weakness that would increase the risk during participation in this investigation.
- I understand that participation in this research project is voluntary and not a requirement or a condition for being the recipient of benefits or services from the University of Wisconsin-La Crosse or any other organization sponsoring the research project.
- I understand that the approximate length of time required for participation in this research project is 22 hours.
- I understand that if I have any questions concerning the purposes or the procedures associated with this research project, I may call or write to the principal investigator(s) or to the Institutional Review Board for the Protection of Human Subjects.
- I understand that it will not be necessary to reveal my name in order to obtain additional information about this research project from the principal investigator(s).

____ ____________

Signature of Subject Date

____ ____________

Signature of Investigator Date

APPENDIX B

PAR-Q

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

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		
☐	☐	1.	**Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	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?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of <u>any other reason</u> 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. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to <u>all</u> PAR-Q questions, 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 basic fitness so that you can plan 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 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING 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 or may be pregnant – talk to your doctor before you start becoming more active.

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

<u>Informed Use of the PAR-Q</u>: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

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 being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section 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 ______________________

SIGNATURE ______________________ DATE ______________________

SIGNATURE OF PARENT ______________________ WITNESS ______________________
or GUARDIAN (for participants under the age of majority)

Note: 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.

CSEP | SCPE

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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)
0.5	Very, Very Easy
1	Very Easy
2	Easy
3	Moderate
4	Somewhat Hard
5	Hard
6	
7	Very Hard
8	
9	Very, Very Hard (Nearly Maximal)
10	Maximal Effort

Borg's Rating of Perceived Exertion Scale 6-20

6	
7	Very, Very Light
8	
9	Very Light
10	
11	Fairly Light
12	
13	Somewhat Hard
14	
15	Hard
16	
17	Very Hard
18	
19	Very, Very Hard
20	

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 light into many beautiful colors. These take the shape of a long round arch, with its path high above and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow."

APPENDIX E

EXERCISE HISTORY QUESTIONAIRRE

UNIVERSITY *of* WISCONSIN
LA CROSSE

Exercise History Questionnaire

1. Are you currently involved in regular endurance (cardiovascular) exercise? If so, how many minutes/days a week do you engage in this activity?

   Yes ☐ No ☐ If Yes, _____ Days/Week for ______Minutes/Session

2. Do you currently play a sport or other recreational activities (besides HPR 105 Lab)? If yes, what types of sports/physical activity?

   Yes ☐ No ☐ If Yes, explain ________________________________

3. Does your job involve physical labor?

   Yes ☐ No ☐

4. In the past 6-8 weeks, explain what you have done for physical activity?

   ____

   ____

   ____

   ____

   ____

APPENDIX F

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Introduction

Sedentary behavior is a worldwide epidemic. Research has shown sedentary behavior is linked to obesity which impacts the development of cardiovascular diseases, dyslipidemia, diabetes, hypertension, and hypercholesterolemia (Pescatello, 2014). The American Heart Association (AHA) and the American College of Sports Medicine (ACSM) revised physical activity (PA) guidelines in 2007 for healthy adults aged 18-65 years old to combat such health issues (Haskell et al., 2007).

The new PA guidelines recommend of the minimum accumulation of 30 minutes of moderate intensity exercise 5 days per week; or a minimum of 20 minutes of high intensity exercise 3 days per week (ACSM, 2013). In addition, resistance training activities are recommended at least 2 times per week to increase muscular strength and endurance to promote cardiovascular fitness and metabolic health (Pescatello, 2014). These PA guidelines are prescribed based on the FITT-VP principle of frequency (how often), intensity (how hard), time (how long), type (what kind), volume (how much), and progression (increase over time). The FITT-VP variables are generally easy to interpret and apply, with the exception of exercise intensity.

Exercise intensity is the most difficult variable in the FITT-VP principle to prescribe, because of its dependency on a maximal exercise test results. The current ACSM recommendation for moderate exercise intensity is 40%-60% heart rate reserve

(HRR) or maximal oxygen consumption (VO_2max) and 60%-90% HRR or VO_2max for vigorous exercise intensity (ACSM, 2013). The HRR is derived from a maximal exercise test, taking resting heart rate (HRrest) from maximum heart rate (HRmax) to calculate HRR. Although a maximal exercise test is the preferred method to gauge exercise intensity, it may not be a practical option for the general population.

Maximum Oxygen Intake

Maximal oxygen intake is the most widely accepted measurement of cardiorespiratory fitness in the field of exercise physiology (Shepard et al., 1968). The term "maximal oxygen intake", originated from Hill and Lupton (1923), is described as the point at the end of a progressive exercise intensity test where oxygen consumption (VO_2) plateaus despite increases in exercise workload (Mitchell, Sproule, & Chapman, 1958). Research has supported the concept of the VO_2 plateau with progressive work rates (Taylor, Buskirk & Henschel, 1955; Mitchell et al., 1958).

The classic study of Taylor et al. (1955) was to obtain VO_2max with a motor driven treadmill in a laboratory setting. Further research discovered VO_2max can accurately be measured in three modalities: stepping, cycling, and treadmill running (Shepard et al., 1968). With various modalities, VO_2max tests can be used in a range of applications such as determining athletic ability (Saltin & Astrand, 1967; Jacobs et al., 2011) and assessing cardiovascular health and mortality risk (Myers et al., 2002). Maximal oxygen uptake can measure cardiovascular function and fitness through the integration of performance in the respiratory, circulatory, and muscular systems (Shepard et al., 1968; Mitchell & Blomqvist, 1971; Arena & Sietsema, 2011).

While maximal oxygen intake may be the "gold standard" of the cardiovascular system (Rowell, 1974), it is not suitable for the general population. Maximal exercise tests are time-consuming, require trained professional administration, pose technological demands, and are not without risk. Therefore, the need for effective, subjective methods for exercise intensity prescription is evident.

Rating of Perceived Exertion

Gunner Borg (1970) developed the Rating of Perceived Exertion Scale (RPE) as a subjective form of prescribing exercise intensity. The Borg (1982) 6-20 Category Scale is used as a simple and easy way to measure perception of exertion at a certain point during exercise. Each individual has a unique physiology that formulates a RPE driven by psychological factors (cognition, memory, past experiences, understanding of task) and situational factors (knowledge of the end point, duration, chronological characteristics of the task) (Eston, 2012). Physical environmental factors such as temperature (Crewe, Tucker, & Noakes, 2008), altitude (Johnson et al., 2009), and external distractions such as music and/or visual stimuli (Eklund & Tenenbaum, 2014) also influence changes in RPE. The use of the RPE scale in sport, exercise, and rehabilitation has established a strong relationship with exercise intensity (Eston, 2012).

Given the robust relationship between RPE and exercise intensity, the RPE scale became the most common subjective method used in the field of exercise physiology (Birk & Birk, 1987). Parfitt, Evans, & Eston (2012) was the first study to use RPE training. They demonstrated that a normal training response occurs when RPE is "clamped" at 13. They stated that a self-regulated exertion of 13 suggests an individual is exercising at a "somewhat hard" level which is widely recommended for improved fitness and cardiovascular health. Additional studies suggest patients who self-select an RPE range of 10-14 show positive affective responses (Ekkekakis, 2004). A RPE range of 12-15 is appropriate when prescribing exercise intensity (Birk & Birk, 1987). It correlates with 50-85% VO_2max, which ACSM recommends for a training effect. Self-reported subjective methods can be used to guide exercise intensity as an adjunct to objective methods (Brawner et al., 2006).

In 1982, Borg constructed a category (C) ratio (R) scale known as the Borg CR10 Scale (CR10). Although the Borg 6-20 Category Scale is still widely used, CR10 was developed to enhance the association of verbal expressions with numbers (Borg, 1982). The Borg CR10 scale is useful in the clinical diagnosis of breathlessness and dyspnea, chest pain, angina, and musculo-skeletal pain (Gappmaier, 2012). Thus, CR10 is best suited when there is pain arising from a specific area in the body. Using the CR10 scale as a basis, session RPE was created to quantify an average RPE of a whole exercise session (Foster & Cotter, 1995). Session RPE became a popular method of assessing acute and chronic training load (Foster et al., 2001), and can be calculated by multiplying relative session RPE (scale of 0 to 10) by exercise duration (minutes) or number of repetitions for resistance training (Eston, 2012).

The ACSM's position statement explains there is insufficient evidence to support using the RPE as a primary method of exercise training (Garber et al., 2011). Research has shown individuals need to visually see the Borg scale for accurate RPE ratings (Abadie, 1996). The use of RPE is underestimated while exercising at a moderate to high intensity level when an RPE scale was not present (Abadie, 1996). Therefore, as the RPE scale has been a popular method for subjective measurement, the requirement for scale availability makes RPE impractical for measuring exercise intensity during activities of daily living.

Talk Test

Another subjective method of gauging intensity is the Talk Test (TT). The TT is based on the physiology of speech. In order to create speech, air needs to be expelled from the lungs to initiate vocal cord vibrations. Professor Henry Joseph Grayson originally developed the concept of the TT in 1939 when he instructed British mountaineers to "climb no faster than you can speak." The TT interested researchers and evolved from a measure of speech ventilation (V_E) to exercise intensity and exercise testing (Doust & Patrick, 1981; Meyer et al., 1995; Foster et al., 2009). In 1991, ACSM instituted the TT into the Guidelines for Exercise and Training, but without research and support, it has been withdrawn.

Goode et al. (1998) continued to study the TT using the "breath sound check" during controlled exercise. Exercising at a workload where subjects could "hear their breathing" is at or close to the ventilatory threshold (VT). Mertens et al. (2001) determined that when subjects can "hear your breathing" using the Breath Sound check, the intensity was within 15% of the VT. This intensity correlates well with the ACSM recommended %HRR range for health benefits, suggesting that the breath sound check and the Talk Test are appropriate methods to determine exercise intensity (Goode et al., 1998).

The TT protocol is performed in conjunction with an incremental exercise test with stages two or three minutes in duration. A speech provoking stimulus is presented about 30 seconds before the end of each stage. The Pledge of Allegiance (POA) and the

Rainbow Passage (RP) are two of the most commonly used passages for initiating speech production. After reciting the speech provoking stimulus, the subject is asked, "can you speak comfortably?" The possible responses are "yes", "yes, but", or "no". A positive TT is achieved when the subject can speak the speech provoking stimulus clearly and comfortably. The hardest stage at which this is possible is considered the Last Positive (LP). The stage before is the last positive (LP-1). The Equivocal stage (EQ) is the first time that the subject is unsure if they can speak comfortably. The first stage in the TT protocol where comfortable speech is impossible is called the negative stage (NEG). Typically the EQ stage of the TT is associated with the ventilator threshold (VT) (Dehart-Beverly et al., 2000), and the NEG stage is associated with the respiratory compensation threshold (RCT) (Recalde et al., 2002).

The TT has been validated in numerous populations: sedentary individuals (Foster et al., 2009; Eugen, 2015), well-trained adults (Recalde et al., 2002; Woltmann et al., 2015), well-trained cyclists (Rodriquez-Marroyo, Villa, Garcia-Lopez, & Foster, 2013), patients with coronary artery disease (Brawner et al., 2006; Voelker et al., 2001), patients with a recent myocardial revascularization (Zanettini et al., 2013), and patients in cardiac rehabilitation programs (Lyon et al., 2014; Doro, 2015). Furthermore, the TT has been validated among different modalities (treadmill and cycle ergometer) (Persinger, Foster, Gibson, Fater, & Porcari, 2004). Track walking was later validated as another modality for the TT protocol (Brawner et al., 2006). With the abundance of recent literature on diverse populations, the TT may prove to be a suitable primary method to determine exercise intensity across the spectrum of athletes to clinical populations.

Recent literature has documented that TT results measured during submaximal, incremental exercise can be used to prescribe steady-state exercise (Woltmann et al., 2015; Lyon et al., 2014; Doro, 2015). Foster et al. (2009) and Jeans et al. (2011) demonstrated that incremental tests can be used to define steady-state training intervals by choosing the stage before the LP (LP-1) for sedentary individuals, the LP for active subjects, or the LP-1 or LP-2 stage for patients with cardiovascular disease (Lyon, et al., 2014). Lyon et al. (2014) demonstrated that cardiac patients could complete steady-state exercise at the LP-1 and LP-2 stages, well below the VT. Woltmann et al. (2015) further explored this concept by examining the physiological impact of "clamping" or adjusting the TT at certain intensity levels. The idea of clamping the TT is an effective tool for prescribing exercise for sedentary adults to improve cardiovascular fitness (Woltmann et al., 2015). Doro (2015) validated the concept of clamping the TT with cardiac patients using only the TT to self-monitor intensity levels and appropriate ranges. She found that cardiac patients can maintain steady state exercise at appropriate intensity ranges using only the TT to monitor exertion during a 30 minute exercise session. Thus, the TT can function as a sole marker of exercise training intensity (Engen, 2015). The next step in the evolution and application of the TT is to determine if a training response can be reliably be produced.

Ventilatory Threshold

The correlation between ventilation and speech during exercise stimulated the development of the VT. Quantin, Jolimoy, & PreTaut (1996) concluded the VT occurred at the same load level as the dyspnea threshold. The VT is the point when V_E increases disproportionately to VO_2 in response to non-metabolic CO_2 production. At this point, the increase in VCO_2 is greater than the increase in VO_2 attributable to buffering at lactic acidosis. The purpose of the VT is to determine aerobic fitness level and anaerobic threshold.

A graded exercise test is normally used to determine VT through the V-slope method using 2 or 3 minute intervals for gas exchange analysis (Schneider, Phillips, & Stoffolano, 1993). In the V-slope method, there is a moment of sudden increases in CO_2 which is associated with the VT (Beaver, Wasserman, & Whipp, 1986; Hansen, Stevens, Eijnde, & Dendale, 2012). Mertens et al. (2002) demonstrated that ventilation is related to VT. Since speech production requires a suppression of breathing frequency, the natural increase in breathing frequency at the VT makes speech less comfortable (Foss, 2015). Similarly, speech is less comfortable at the VT and in the EQ stage following the TT. Dehart-Beverly et al. (2000) demonstrated that speaking comfortably during exercise correlated with being below the VT. Inversely, if reciting the speech provoking stimulus was uncomfortable, exercise intensity was above the VT. If a subject was unsure if speaking was comfortable or uncomfortable, the intensity level was at or near the VT (Dehart-Beverly et al., 2000).

The VT is an alternative index of sustainable exercise capacity that may be superior to the traditionally used VO_2max (Foster & Cotter, 1995). Mezzani et al. (2013) demonstrated that the VT is a superior method of prescribing exercise to traditional HRR. The TT is effective at identifying intensities below the VT when comfortable speech production is evident. The relationship between the TT and VT has been studied across various populations including sedentary individuals, well-trained individuals, and patients with cardiac disease (Foster et al., 2009; Eugen, 2015; Rodriguez-Marroyo et al., 2013;

Recalde et al., 2002; Woltmann et al., 2015; Brawner et al., 2006; Voelker et al., 2001; Zanettini et al., 2013; Lyon et al., 2014; Doro, 2015).

The TT may be a suitable method to determine exercise intensity below the VT (Mezzani et al., 2012). The need for further research is evident in determining what the effects are if VT was manipulated. Foster et al. (2008) investigated how changes in VT would affect the TT. Four independent studies were conducted to increase VT (via 500 mL whole blood donation), decrease VT (via six week aerobic training program), or inferred above and below VT. All four studies showed VT and the TT are "robustly related", and that the TT is a reliable marker of VT. The TT may be a suitable, alternative method for prescribing exercise intensity rather than using the %HHR method or the RPE method (Eston, 2012; Parfitt et al., 2012).

Research has concluded the TT can also be used as a sole marker of exercise training intensity among normal (Engen, 2015) and clinical (Doro, 2015) populations. Furthermore, experimental VT manipulation has demonstrated that the TT is a reliable marker of VT. Although the TT continues to be used as a simple and cost-effective method of prescribing exercise intensity, more research needs to be completed in determining if a training response exists.

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