UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

THE EFFECT OF PROGRESSIVE FATIGUE ON SESSION RPE

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

William Sustercich

College of Science and Health
Clinical Exercise Physiology

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THE EFFECT OF PROGRESSIVE FATIGUE ON SESSION RPE

By William Sustercich

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

The candidate has completed the oral defense of the thesis.

Carl Foster, Ph. D.
Thesis Committee Chairperson

Date: 5/12/17

Richard Mikat, Ph. D.
Thesis Committee

Date: 5/12/17

Matthew Andre, Ph.D.
Thesis Committee

Date: 5/12/2017

Thesis accepted

Steven Simpson, Ph.D.
Graduate Studies Director

Date: 8/4/17

ABSTRACT

Sustercich, W. The effect of progressive fatigue on session RPE. MS in Clinical Exercise Physiology, May 2017, 40pp. (C. Foster)

Introduction: The purpose of this study was to examine the effect of progressive fatigue from continuous workouts on Session Rating of Perceived Exertion (sRPE). Methods: Twelve moderately fit college age students who were active for the past three months for at least three times a week for 30-minutes or more were recruited. Subjects performed a maximal incremental cycling test to determine max power output (MPO). Subjects completed workouts on the bike at varying percentages of their MPO to test the hypothesis that sRPE for a given exercise bout would change with progressive fatigue. The workouts were Monday through Thursday for two weeks. The first week was three 30-minute sessions followed by a 1-hour session. The second week was three 1-hour sessions followed by a 30-minute session. Blood lactate was measured periodically throughout each workout. sRPE was measured 30 minutes after each session. Results: The 30-minute sessions had a sRPE that was significantly less than the 1-hour sessions ($p = .006$). The analysis of HLa during the hard sessions showed significant differences between sessions ($p = .002$). The analysis of the RPE/HLa ratio showed significant differences between sessions ($p = .003$). Discussion: The results of this study supported our hypothesis. During the prolonged exercise bouts, there was a significant decrease in HLa and a progressive increase in sRPE.

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INTRODUCTION

Monitoring training intensity is a necessary aspect of exercise and sport. Gunnar Borg created the 6-10 scale rating of RPE scale to help monitor psychophisological responses to exercise. Borg (1990) states that, "The scale was designed to grow linearly with exercise intensity and heart rate for work on the bicycle ergometer." Using perceived exertion integrates a variety of information from the exerciser such as signals elicited from the working muscles and joints, the nervous system, and central cardiovascular and respiratory functions when examining the exercisers perception of the training session (Borg 1982). To make the RPE scale easier to use for the lay population and not restricted to those familiar with mathematical or technical terminology Borg modified the 6-20 RPE scale and created the category-ratio 10 (CR-10) scale (Borg 1982).

Foster et al. (1995) created the sRPE, which modifies Borg's 0-10 RPE scale as a global measurement of an entire training session. Previous research has shown that sRPE is a reliable measurement tool for predicting exercise intensity in relation to more technological and physiological measurements such as heart rate (HR) and blood lactate (HLa) (Foster et al., 2012; Green, McIntosh, Hornsby, Timme, Gover, & Mayes 2009; Herman, Foster, Maher, Mikat, & Porcari 2006; Day, McGuigan, Brice, & Foster, 2004; Foster, Helmann, Esten, Brice, & Porcari, 2001; Foster et al., 2001; Foster, Snyder, & Welsh, 1999; Foster 1998; Foster et al., 1995). Using the sRPE rating and multiplying by the training session duration allows calculation of a training impulse score, which represents the intensity-duration product of that training session, the training load (Foster 1998; Foster et al., 1995). sRPE and training load are useful tools to measure the actual load of a training session for an athlete or exerciser compared to less accessible and technologically demanding, measurement tools. In addition, having a reliable tool to measure the actual training load of a workout can help improve the effectiveness of the training plan.

Coaches and therapists have an intensity in mind for the workouts in the training plans they create. However, athletes tend to rate the intensity of training sessions differently than coaches intend (Rodrigues-Marroyo, Medina, Garcia-Lopez, Garcia-Tormo & Foster, 2014; Foster et al., 2006; Foster et al., 2001). sRPE has been shown in previous research to reveal discrepancies between coach and athlete (Foster et al., 2001). One of the issues with training, especially in athletes, is overreaching. Blood lactate (HLa) is a byproduct of the breakdown of muscle glycogen for ATP. HLa concentrations will be high during steady state exercise however, during prolonged exercise muscle glycogen stores will be depleted leading to progressive reductions in HLa. One of the plausible causes of overreaching is the depletion of muscle glycogen; without proper recovery time in order to restore the depleted glycogen stores (Snyder 1998; Snyder, Kuipers, Cheng, Servais, & Fransen, 1995; Costil et al., 1988). With this discrepancy present, the possibility of overreaching in during successive prolonged bouts of exercise, and the difficulty of using training intensity measurements, more evidence is needed on the effects of prolonged fatigue on sRPE.

To further test the validity of sRPE, this two-part study examined the relationship between lactate responses and sRPE during (1.) steady state and (2.) prolonged exercise bouts on the cycle ergometer. Blood lactate measurements will be used as a surrogate to estimate the effect of changing muscle glycogen concentration on sRPE. This will help evaluate any relationships between muscle fatigue and sRPE during steady state and prolonged exercise bouts. Thus, the purpose of this study is to examine the relationship between sRPE and HLa concentrations during prolonged exercise. It is hypothesized that during the second week, with more prolonged exercise than usual, sRPE will progressively increase, while there will be decreases in HLa, despite performing the same absolute intensity of training.

METHODS

The subjects recruited for this study were 12 moderately fit college-age exercisers (6 males and 6 females). All subjects were healthy, based on the completion of the physical activity readiness questionnaire (PAR-Q) prior to participation in the study. Written informed consent was also obtained from each participant prior to beginning the study. The protocol was approved by the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects. Descriptive statistics for the subjects are provided in Table 1.

Table 1. Descriptive Statistics

	Males n=6	Females n=6
Age (years)	21.2 ± 2.92	21.2 ± 2.99
Height (cm)	176.1 ± 4.14	171 ± 8.6
Weight (kg)	76.8 ± 5.75	67.5 ± 8.81
VO_2max (mL/kg/min)	51.8 ± 6.15*	46.8 ± 2.63
Power Output max (watts)	258.5 ± 31.07	190.5 ± 24.66

Each subject completed a maximal incremental test to find individual max power output (MPO). Before the test the subjects' age, height, and weight were recorded along with room temperature, barometric pressure, and humidity. Additionally, each subject performed four exercise tests Monday through Thursday, two weeks in a row. Each training session was completed on an electrically braked cycle ergometer (Lode Excalibur, Gronnigen, Netherlands). The first week there were 30-minute continuous intermittent training sessions with the fourth day being a 1-hour session, (which was the 30-minute session back to back). Each session started with a 5-minute warm-up at 25% of their MPO followed by 5-minutes at 50% of MPO. They then rode at 25% of MPO for 2-minutes. They then cycled at 75% of MPO for 5-minutes. Again, they rode at 25% of MPO for 2-minutes followed by riding at 100% of MPO for 2-minutes. Then they again rode at 25% for two minutes and then rode at 50% of MPO for 7-minutes, which finished their 30-minute training session. The schematic PO is shown in Figure 1.

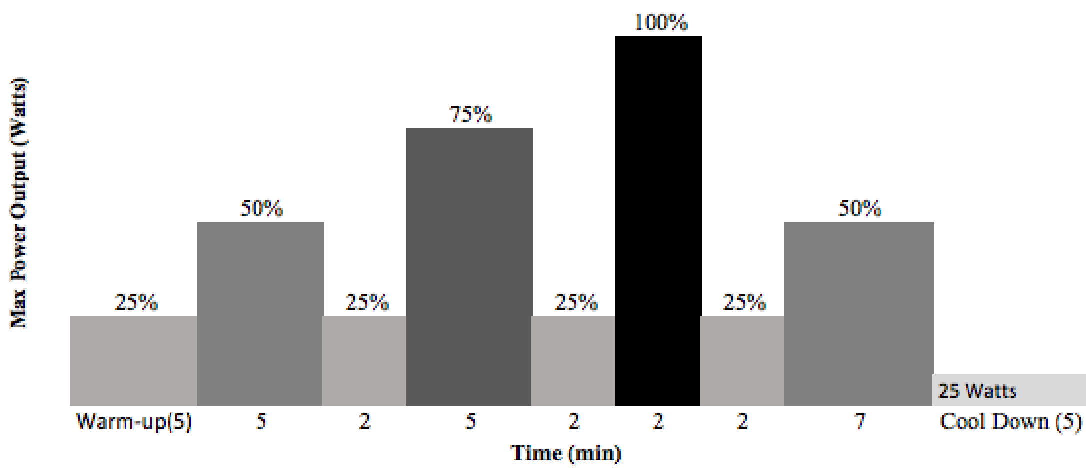

Figure 1. Individualized Training Session Percentages of Max Power Output.

The fourth day of the first week was double workout where the first 30-minutes was followed by a repeat of the first 30-minutes immediately after the first 30 minutes was completed. The second week consisted of three double workout days with the last day being the original 30-minute workout. During each training session HR and RPE were measured at rest and at the end of each minute. HR was measured using radiotelemetry (Polar Electo-Oy, Finland). HLa was measured at rest and at the 5, 10, 17, 21, and 30-

minute markers using a lactate meter (Lactate Plus, Massachusetts, USA). Thirty minutes after each training session sRPE was measured. For both RPE and sRPE Borg's CR-10 scale was used (Figure 3).

Table 1. The Borg CR10 scale (1982) modifiied by Foster et al. (2001).

Classification	Descriptor
0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	-
7	Very hard
8	-
9	-
10	Maximum

Figure 2. Borg's CR-10 Rating of Perceived Exertion Scale.

ANALYSIS

To analyze the data collected for this study three separate repeated measures ANOVA were used to compare sRPE, HLa, and RPE/HLa during the steady state and prolonged exercise bouts. Fisher's testing was used for pairwise comparisons. Statistical significance was accepted when $p<0.05$.

RESULTS

Session Rating of Perceived Exertion between sessions, HLa of both hard and easy sessions, and RPE/HLa ratio were all compared using a repeated measures ANOVA. The 30-minute sessions, (n=4) had a sRPE rating that was significantly less than the 1-hour sessions, ($p = .006$; $df = 77$; $F = 10.327$). Sessions 4 and 8 were both significantly different than session 10 suggesting prolonged fatigue during the 60-minute workout ($p = .006$; $df = 77$; $F = 10.327$). Sessions 4, 8, and 9 were not significantly different from each other ($p = .006$; $df = 77$; $F = 10.327$). These differences can be seen in Figure 3 and Table 2. Comparisons of the significantly different sessions can be seen in Figure 4. The analysis of HLa during the hard sessions showed a progressive decline across sessions consistant with progressive fatigue ($p = .002$; $df = 33$; $F = 5.89$). The differences are shown in Figure 5 and Table 3. The analysis of HLa during the easy sessions showed a small but significant decrease across sessions as well ($p = .002$; $df = 33$; $F = 6.419$). The differences are shown in Figure 5 and Table 4. The analysis of the RPE/HLa ratio for each session showed significant differences between sessions ($p = .003$; $df = 11$; $F = 14.319$). These differences can be seen in Figure 6 and Table 5

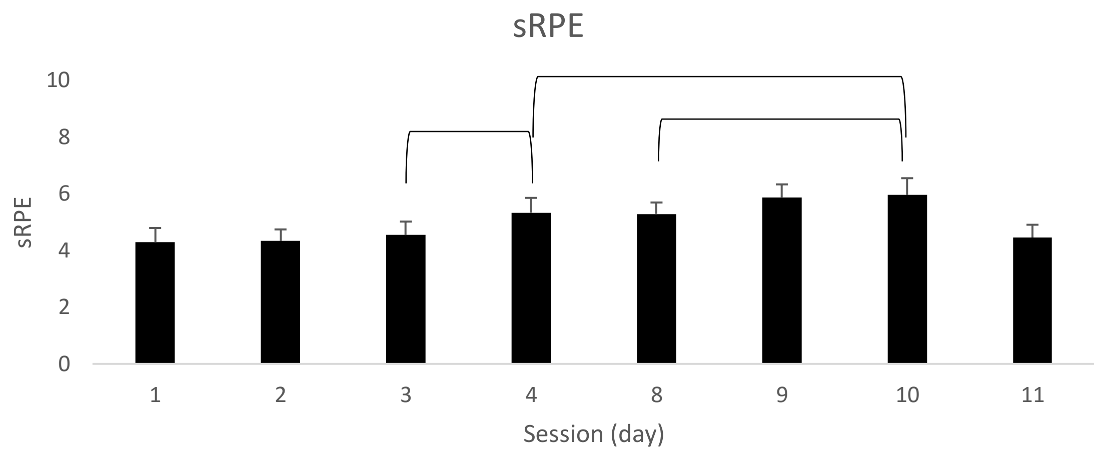

Figure 3. Session Rating of Perceived Exertion averages across sessions. Significant pairwise differences are indicated by the brackets.

Table 2. Session Rating of Perceived Exertion averages across sessions

	n=12
Day 1	4.3±1.7
Day 2	4.3±1.4
Day 3	4.5±1.7
Day4	5.3±1.8*!
Day 8	5.3±1.4!
Day 9	5.9±1.6
Day 10	6.0±2.1
Day 11	4.5±1.6

*denotes significant difference from Day 3
!denotes significant difference from Day 10

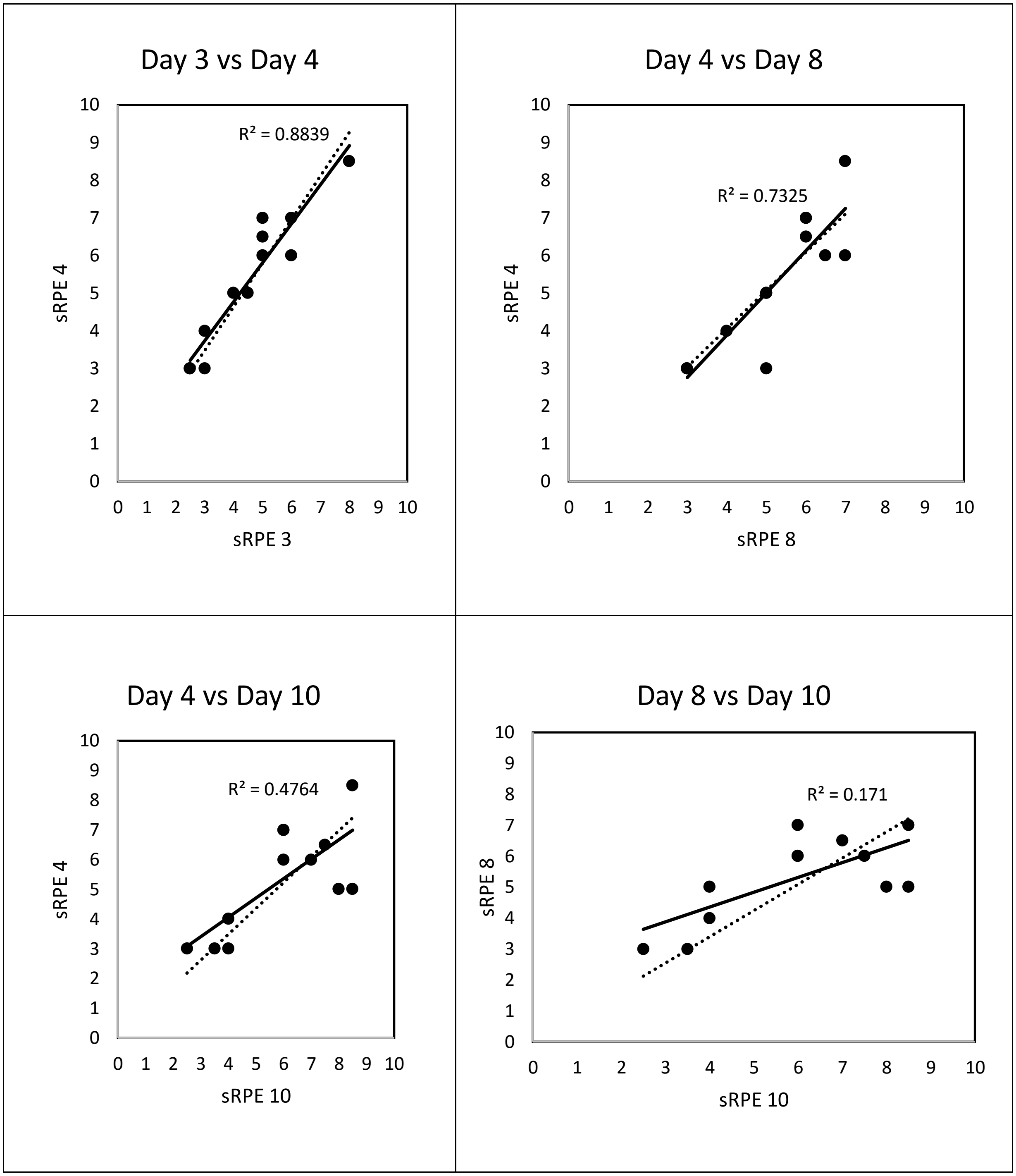

Figure 4. sRPE average comparison between sessions 3 and 4, 4 and 8, 4 and 10, and 8 and 10.

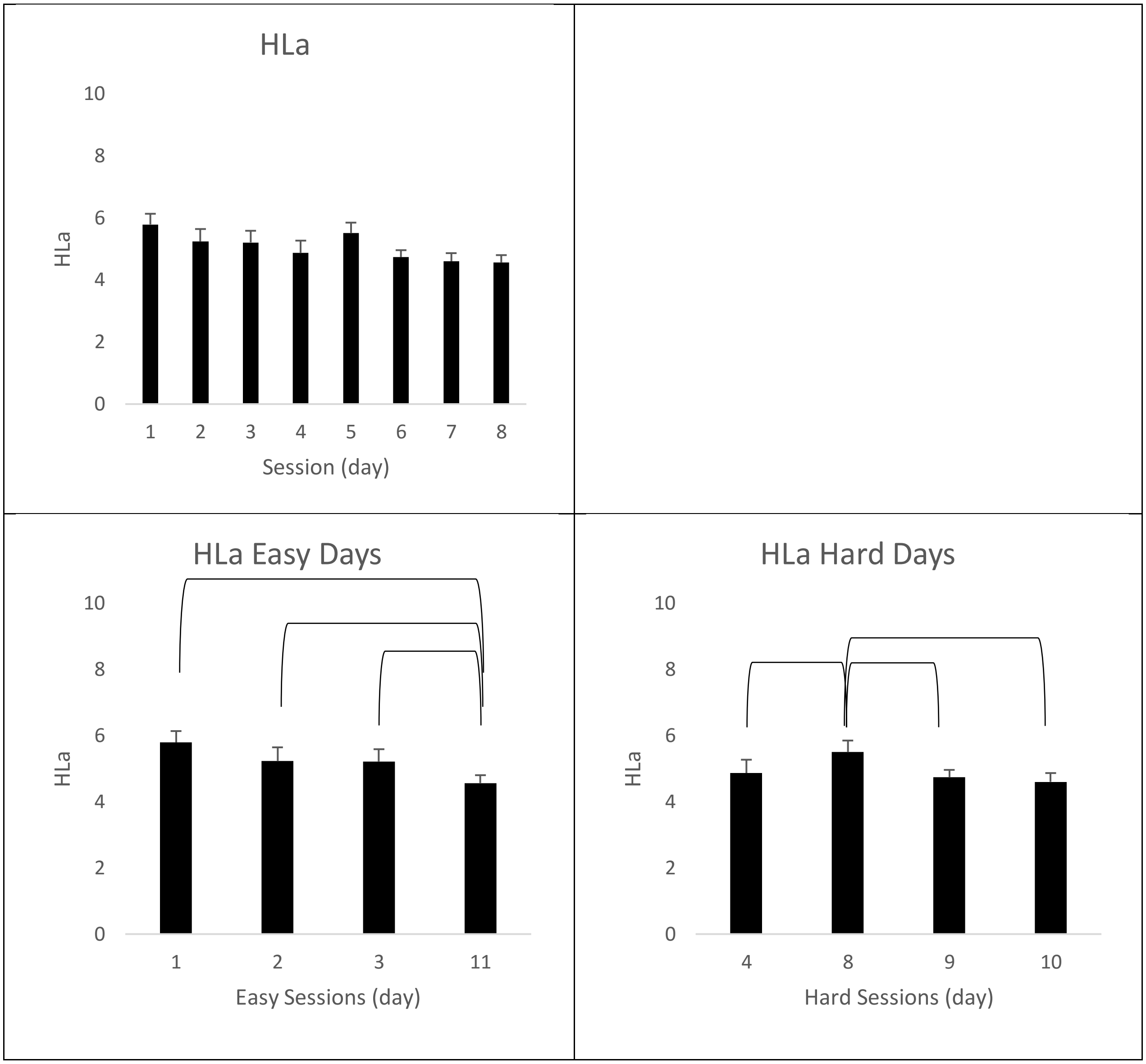

Figure 5. HLa averages of every session. HLa averages of easy days. HLa averages of hard days. Significant pairwise differences are indicated by the brackets.

Table 3. Blood Lactate averages across the hard sessions

Session	Session Rating	n=4
HLa Average Day 4	4.5±1.3	
HLa Average Day 8	5.1±1.1*	
HLa Average Day 9	4.4±0.7#	
HLa Average Day 10	4.3±0.9#	

*denotes significant difference from HLa Average 4
#denotes significant difference from HLa Average 8

Table 4. Blood Lactate averages across the easy sessions

Session	Session Rating	n=4
HLa Average Day 1	5.0±1.0*	
Hla Average Day 2	4.4±1.2*	
Hla Average Day 3	4.5±1.1*	
Hla Average Day 11	3.9±0.7	

*denotes significant difference from Hla Average 11

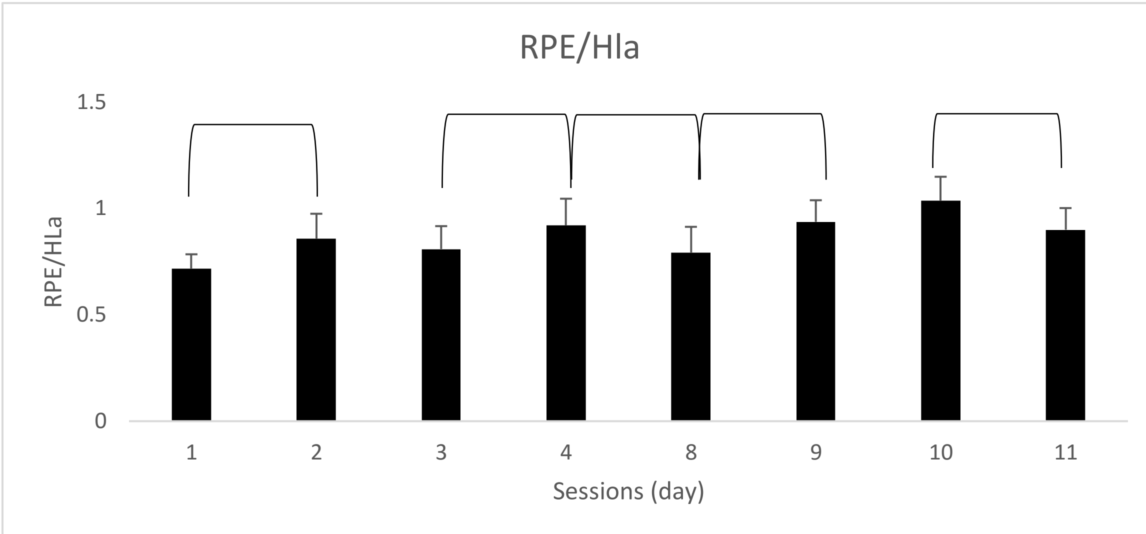

Figure 6. RPE/Blood Lactate ratio across the sessions. Significant pairwise differences are indicated by the brackets.

Table 5. RPE/Blood Lactate ratio across the sessions

Session	Session Rating	n=12
RPE/Hla 1	0.7±0.2	
RPE/Hla 2	0.9±0.4	
RPE/Hla 3	0.8±0.4	
RPE/Hla 4	0.9±0.4#!	
RPE/Hla 8	0.8±0.4	
RPE/Hla 9	0.9±0.4!	
RPE/Hla 10	1.0±0.4!	
RPE/Hla 11	0.9±0.4*	

*denotes significant difference from RPE/Hla 1
#denotes significant difference from RPE/Hla 3
!denotes significant difference from RPE/Hla 8

DISCUSSION

The present data supports the hypothesis that the sRPE would increase significantly as longer than usual sessions progressed. The hard sessions also showed a significantly higher sRPE than the easy sessions. Herman et. al. (2006) also showed that sRPE increases significantly after progressive fatigue from continuous bouts of exercise. These data support the concept that sRPE reflects information beyond the intensity of exercise and whether acutely, (during a 60-minute or 30-minute ride), or a sub-acutely, (during 3 consecutive days of higher than usual training), reflect accumulating fatigue, in addition to exercise intensity.

Blood lactate during of the very last workout, an easy session, was significantly lower than the easy days of the first week. The HLa during the hard sessions showed a progressive decrease as the sessions progressed. A study from 1971 showed similar decreases in blood lactate after successive days of prolonged exertion which, paralleled progressive decreases in muscle glycogen (Costil, Bowers, Branam, & Sparks, 1971). The workouts were formatted in such a fashion that strained the subjects enough during the 1-hour long sessions to elicit a decrease in HLa and an increase in sRPE. Another study reported a similar HLa-RPE response to continuous bouts of exercise (Weltman, Weltman, Kanaley, Rogol, Veldhuis, & Hartman, 1998). The decrease in HLa paired with an increase in sRPE are a potential indicator that the subjects were unable to replenish their muscle glycogen stores adequately in between the hard workouts.

Limitations of this study were that some of the exercisers were stronger cyclists than others even though they all met the physical requirements. The subject's diets were not controlled in any way. There were several subjects who remained consistent in their sRPE ratings after the hard sessions. This could be because they were more experienced cyclists and had a better recovery method and diet than the other subjects. However, Weltman (1998) reported that HLa-RPE relationship is altered throughout repeated bouts of exercise independent of recovery. It would be beneficial to complete another study with the subjects put on a specific diet as well as a specific recovery routine. Another limitation in this study is that we were limited to using HLa samples as a surrogate measurement for muscle glycogen concentrations. To get a more accurate depiction of physiological fatigue it would be beneficial to repeat this study in a setting that allowed for direct measurement of muscle glycogen.

In conclusion, the results of this study supported our hypothesis. During the prolonged exercise bouts, there was a significant increase in sRPE paired with a significant decrease in HLa concentrations. If the hard sessions would have been extended to five or six days the data would likely have more clearly supported our hypothesis. Even so, this study provides significant evidence that the sRPE provides information that is more complex than just a marker of exercise intensity.

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APPENDIX A

INFORMED CONSENT

Informed Consent

Protocol Title: Stability of Session RPE and the Effect of Progressive Fatigue on Session RPE

Principal Investigators:

Keegan Edgerton & William Sustercich 730 24th St. N. Street La Crosse, WI 54601 (320) 293-2087 or (720) 384-5798

Emergency Contacts:

Keegan Edgerton & William Sustercich (320) 293-2087 or (720) 384-5798

Purpose and Procedures

- The purpose of this study is to evaluate both the validity and reliability of Session RPE method in comparison to objective physiological measures of exercise intensity (Heart Rate & Blood Lactate) during constant and progressive intermittent exercise.

- My participation will involve one maximal exercise test which will be very fatiguing. For the test I will wear a snorkel-like device to analyze by breathing.

- I will be completing 8 training sessions for an approximate 10 hours total of time. The training sessions include exercising on a cycle ergometer with power output increasing which will cause fatigue.

- During all tests, I will wear a heart monitor, strapped around my chest, to monitor my heart rate.

- Blood will be taken from my fingertip every few minutes during testing to measure blood lactate.

- Testing will take place in room 225 Mitchell Hall, UW-L.

Requirements

- Must be a moderately fit individual with a regular workout routine of at least 3 days a week of cycling for 30 minutes or more for the last 3 months.
- Must be able to complete two consecutive weeks of testing, four days each week Monday through Thursday.
- Testing will consist of a VO_{2max} test to determine max power output on the bike.
- The first week of tests will be 30 minutes long with a 1-hour long session on Thursday.
- The second week of tests will be 1-hour long with a 30-minute session on Thursday.

Potential Risks

- I may experience finger and muscle soreness and substantial fatigue.
- 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 & Confidentiality

- My participation is voluntary. I can withdraw or refuse to answer any question without consequences at any time.
- I can withdraw from the study at any time for any reason without penalty.
- The results of this study may be published in scientific literature or presented at professional meetings using grouped data only.
- All information will be kept confidential using number codes. My data will not be linked with personally identifiable information.

Possible benefits (for use if there are any direct benefits to the participants)

• I and other exercisers or athletes may benefit by understanding how to implement easier and less costly methods to administer exercise intensities.

I have read the information provide on this consent form. I have been informed of the purpose of this test, the procedures, and expectations of myself as well as the testers, and of the potential risks and benefits that may be associated with volunteering in this study. I have asked any and all questions that concerned me and received clear answers so as to fully understand all aspects of this study.

Questions regarding study procedures may be directed to Keegan Edgerton (320-293-2087) or William Sustercich (720-384-5798), the principal investigator, or the study advisor Dr. Carl Foster, Department of Exercise and Sport Science, UW-L (608-785-8687). Questions regarding the protection of human subjects may be addressed to the UW-La Informed Consent Crosse Institutional Review Board for the Protection of Human Subjects, (608- 785-8124 or irb@uwlax.edu).

Participant________________________________ Date________________
Researcher________________________________ Date________________

APPENDIX B

Review of Literature

INTRODUCTION

Exercise prescription, whether it be for athletes or exercisers, involves four basic factors: 1.) mode or type of exercise, 2.) frequency of participation, 3.) duration of each exercise bout, 4.) intensity of the exercise bout (Kenny, Wilmore, & Costil 2012). According to Kenny et al. (2012) of the four basic factors, exercise intensity, how hard one pushes themselves during a training session, appears to be the most important factor in exercise prescription. In the field of exercise and sport science the search for a valid and reliable means of measuring the intensity of training sessions, for athletes and exercisers alike, has been a very important research topic. According to Allen et al. (2014) in the ACSM's guidelines for exercise testing and prescription: Ninth edition states, "the overload principle in exercise training states that individuals must exercise above a certain intensity to challenge the body sufficiently to result in changes in physiologic parameters". Challenge individuals' intensity threshold is key in improving performance and must be kept in mind when creating training plans. Thus it is necessary to measure exercise intensity so that individuals may achieve appropriate intensity thresholds.

Traditional approaches to prescribing exercise intensity uses percentages of maximal heart rate (HR_{max}), or HR reserve (%HR) and maximal oxygen uptake (VO_{2max}) as well as blood lactate (HLa). Using these methods to prescribe exercise intensity has been shown to be reliable. However, laboratory equipment is necessary to identify individualized percentages of VO_{2max}, HR and HLa. For the average exerciser and athletes, it would be desirable to find a less time consuming, less technologically demanding and less expensive way to measure exercise intensity. Foster (2016) describes how “coaches need several things to guide athletes…” including “…a way to assess athletes that is minimally disruptive”. Two methods have been shown to be useful replacements to the traditional methods of measuring exercise intensity, Rating of Perceived Exertions (RPE) and Session Rating of Perceived Exertion (sRPE) (Herman, Foster, Maher, Mikat, & Porcari 2006; Day, McGuigan, Brice, & Foster 2004; Foster et al, 2001a; Foster et al., 1995; Borg. 1990; Borg, 1982).

There have been several studies that have found a discrepancy between how coaches and athletes perceive training sessions (Herman et al., 2006; Foster, Heimann, Esten, Brice, & Porcari, 2001b). During workouts the coaches intended to be easy and hard, athletes have been shown rating them significantly harder and easier respectively (Rodrigues-Marroyo, Medina, Garcia-Lopez, Garcia-Tormo, and Foster 2014; Foster et al. 2001b). These discrepancies often cause athletes to work harder than the coach desires leading to unfavorable physiological responses to training potentially culminating in a condition known as overtraining syndrome (OTS).

With these ideas in mind, there are the traditional methods of prescribing and measuring exercise intensity. However, within the sport community there is a need for an easy to apply, minimally invasive method of measuring exercise intensity. This is where RPE and sRPE come into play. Using these methods of measuring exercise intensity will help coaches avoid improper exercise prescription leading to maladaptations such as OTS.

PHYSIOLOGICAL MEASUREMENTS OF EXERCISE INTENSITY

Traditionally exercise has been prescribed using percentages of maximum heart rate (HR_{max}) or maximal oxygen uptake ($V0_{2max}$) (Mann, Lamberts, & Lambert, 2013).

VO_{2max} is the gold standard index of cardiorespiratory fitness (Allen et al., 2014). Measuring VO_{2max} requires performing a maximum exercise test using open circuit spirometry where pulmonary ventilation and expired fractions of oxygen and carbon dioxide are measured. After calculating VO_{2max} you can prescribe exercise intensity levels. Calculating percentages of VO_{2max} will give you different categories of exercise intensity. According to the ACSM guidelines (2014) light exercise is considered to be 37%-45% VO_{2max}, moderate is considered to be 46%-64% VO_{2max}, vigorous is considered to be 64%-91% VO_{2max}, and near maximal to maximal intensity is 91% or greater VO_{2max}.

Measuring HR_{max} can done while completing a maximal exercise test using a standard heart rate monitor. One can calculate HR_{max} using the equation 220-age or other age based formulas. However, these equations are not accurate and can underestimate an individual's maximum heart rate (ROBERG?). Because of this it is best to use heart rate monitors to measure HR_{max}. HR_{max} can then been used to create zones for exercise similar VO_{2max}. According to ACSM guidelines in Allen et al. (2014) light exercise is considered 57%-64% HR_{max}, moderate is considered 64%-76% HR_{max}, vigorous is considered 76%-96% HR_{max}, and near maximal to maximal intensity is 96% or greater HR_{max}.

Blood lactate has also become a common method of measuring performance in athletes. Blood lactate is the product of the anaerobic glycolytic energy system. When glycogen is being broken down in our muscles for ATP, a byproduct is pyruvate. When there is no oxygen present pyruvate is converted into lactate. During exercise lactate begins to accumulate in the muscles as glycogen stores are depleted, which can lead to fatigue. However, as exercise prolonged glycogen stores begin to deplete. Costil, Bowers, Branam, and Sparks (1971) showed that during prolonged exercise the utilization of carbohydrates for energy decreases while the utilization of lipids increases. This shift in utilizing lipids as energy substrates, decreases the amount of blood lactate accumulation during prolonged exercise bouts. With no glycogen to be broken down lactate will not form. Blood lactate accumulation during exercise can also decrease due to an improvement in the ability to utilize lactate and remove it from the body. This is a sign of improved performance from optimized training. Foster, Snyder, Thompson, and Kuettel (1988) describe the interpretation of the blood lactate profile as "…the assumption that right shifts in the power output-lactate or velocity-lactate relationship are indicative of improved conditioning status". An example of a shift in a lactate profile can be seen in Figure 7. However, in the presence of glycogen depletion, the PO vs HLa curve can downshift producing an apparent right shift in the PO at a fixed HLa such as 4 mmol, like if performance is decreased rather than being increased.

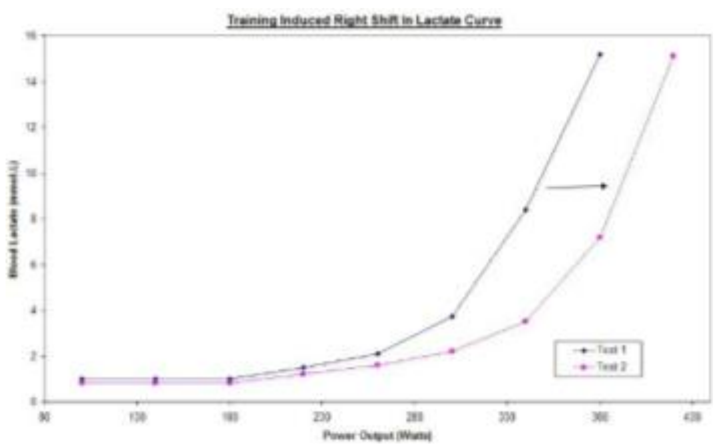

Figure 7. Blood Lactate Curve

Costill et al. (1988) used muscle biopsies to measure muscle glycogen during a period of increased training. An alternative to performing muscle biopsies is to use blood lactate measurements as a surrogate. This allows for the creation of the athlete's lactate profile to monitor their improvements in performance. However, this is a costly and time consuming way of monitoring performance in a large group setting. Thus an easier, more affordable way of monitoring performance is needed.

RATING OF PERCEIVED EXERTION

Rating of Perceived Exertion was created by Borg to quantify subjective symptoms that occur during exercise. It is useful in measuring exercise intensity because it gathers information based on cues from their joints, muscles, and cardiovascular and respiratory functioning during specific points in their training sessions. Borg (1990) states, "Of all single indicators of the degree of physical strain, perceived exertion is one of the most informative". Borg created the 6 to 20 RPE scale to measure subjective perception of exercise intensity. On the scale, 6 represents no exertion at all, while 20 represents maximal exertion. Figure 9. shows the Borg 6 to 20 RPE scale. The 6 to 20 RPE scale has a linear relationship with exercise intensity and physiological parameters such as heart rate (HR) and oxygen uptake (VO_2) (Borg 1982; Onodera & Miyashita, 1976; Borg, 1973). However, this relationship between the scale and heart rate is not to be taken literally as certain (HR) values for individuals during exercise varies depending on factors such as age, type of exercise and environment.

Rating	How Hard you are Exercising
6	No, exertion at all
7	Very, very light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal Exertion

Figure 8. Borg 6 to 20 RPE Scale

Because the RPE scale is a subjective measurement there is skepticism around using it to prescribe exercise because of discrepancies found when comparing RPE and HR. Borg (1982) gives the example of "a patient training with a 'target heart rate' of 130 beats per minute, which can be achieved by walking strenuously, may rate the exertion as 'hard' with an RPE of 15; however, his HR may reach 150 beats per minute when running, but he may perceive the exertion to be the same". Borg (1982) goes on to explain how HR has little evidence supporting it as a better indicator of dangerous strain than a certain RPE. Borg's 6 to 20 RPE scale does increase linearly with HR. Figure 8 depicts Borg's 0-20 RPE scale. However, HLa concentration increases about three times more per scale unit at the top of the scale (Noble, Borg, Jacobs, Ceci, & Kaiser, 1983). Like blood lactate concentrations, exercise intensity does not increase linearly during training bouts for many individuals. Borg developed the category-ratio 10 (CR-10) scale to better relate to the non-linear progression of RPE during exercise.

On the CR-10 scale 0 represents no exertion at all while 10 represents maximal exertion. The CR-10 scale can be seen in Figure 9.

Table 1. The Borg CR10 scale (1982) modifiied by Foster et al. (2001).

Classification	Descriptor
0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	-
7	Very hard
8	-
9	-
10	Maximum

Figure 9. Borg's CR-10 Scale of Perceived Exertion

One of benefits of the formatting of the CR-10 is that it has a simpler number range and can be used and understood even by those who are not familiar with the RPE terminology. This makes it easy for coaches to implement during training sessions that involve a large group of athletes as well as allowing for athletes to have an efficient way of monitoring themselves during training. With little explanation needed, coaches and athletes can gather information on the relative exercise intensity for the training session that day.

The CR-10 scale has also been shown to be reliable across different types of training. Utter et al. (2007) showed that during intermittent exercise, where the average intensity remains constant, RPE ratings do not differ from RPE ratings during continuous exercise. In relation to physiological measures of exercise intensity, the CR-10 scale has been shown to have high correlations with HLa concentrations during exercise (Abe, Yoshida, Ueoka, Sugiyama, & Fukuoka, 2015; Scherr et al., 2013; Borg 1990). It is worth mentioning that even though the CR-10 has high correlations to HLa concentrations during exercise, it has been shown that repeated bouts of exercise within the same day alter the HLa-RPE relation (Weltman et al., 1998). Even though there has been research to support the correlation between RPE and HLa as measurements of exercise intensity, further research is needed on the topic.

SESSION RATING OF PERCEIVED EXERTION

Borg's RPE scales have been shown to be useful in measuring exercise intensity at specific points during exercise. However, it was not useful in showing the actual training load that the athletes were experiencing over the entirety of the training sessions. Session Rating of Perceived Exertion (sRPE) was created by Foster et al. (1995) in order to measure the global subjective exertion level of a bout of training. Using a slightly modified version of Borg's CR-10 RPE scale they recorded the subjective exertion levels of athletes 30-minutes after a training session finished. Multiple research studies have shown that sRPE relates well to other physiological measurements of exercise intensity, thus backing its usefulness for measuring exercise intensity (Foster et al., 2012; Green, McIntosh, Hornsby, Timme, Gover, & Mayes, 2009; Herman et al., 2006; Day et al., 2004; Foster et al., 2001a; Foster et al., 2001b; Foster 1998; Foster et al., 1995). It is especially useful when monitoring training in large group settings when lab techniques would be too costly and time consuming. Along with using sRPE to quantify the overall perceived exertion of a bout of training, it has also been used to calculate the training load of a bout of exercise.

In order to calculate the training load that the athletes were experiencing, sRPE was multiplied by the duration of exercise resulting in a training impulse score that Foster et al. (1995) referred to as the training load. This allows for coaches to compare the actual training loads the athletes are experiencing with what they expect the training load to be. Using sRPE to monitor training has actually been useful in showing the inconsistencies between the intensities designed into the programme and the actual intensities the athletes train at and the likelihood of the onset of OTS (Rodriguez-Marroyo, Medina, Garcia-Lopez, Garcia-Tormo, & Foster, 2014; Herman et al., 2006). It is worth mentioning that even though sRPE has been shown to be a useful tool in measuring exercise intensity and training load in relation to other physiological measurements, the data regarding the relationship to HLa and the effectiveness during high intensity training is lacking. Further investigation is needed in both of these aspects.

OVERTRAINING SYNDROME

Even though most high level coaches are educated individuals who are able to create quality training programs for their athletes, the development of OTS is quite high (Foster et al., 2001b; Foster, Snyder, & Welsh, 1999; Foster, 1998). Foster (1998) describes OTS as, "…a complex condition characterized by a variable group of symptoms and pathophysiologic abnormalities that always include performance incompetence refractory to normal regeneration cycles". It is the coach's goal to push their athletes to obtain the desired physiological response to training. However, when the athletes fail to perform up to expectations at competitions it is often associated with inadequate preparation or training. This causes the typical response of athletes and coaches to push harder and further during the following training sessions. This provides no benefit for the athlete's if they are suffering from OTS since the best known treatment is an extended rest from heavy training or competition (Foster et al., 1999). Even though OTS is very common amongst athletes the exact cause of unknown.

One of the potential causes of OTS that has been researched has been the depletion of muscle glycogen in relation to training sessions. According to Snyder

(1998), “Low muscle glycogen levels due to consecutive days of extensive training have been shown to cause fatigue and thus decrements in performance”. Costil et al. (1988) showed that there was a significant decline in muscle glycogen concentration in swimmers who participated in 10 days of intensified swimming training. The men in this study did not reach the point of being classified as overtrained however, an examination of the swimmer’s muscle glycogen revealed “nearly complete emptying” of the type I or slow twitch fibers as well as a “marked reduction” in type II or fast twitch muscle fibers. It is possible that continuing to exercise at this intensity without allowing the swimmers to replenish muscle glycogen stores could have led to OTS. However, it must be reiterated that muscle glycogen depletion as a cause of OTS has not been confirmed as shown in Snyder, Kuipers, Cheng, Servais, & Fransen (1995). Monitoring muscle glycogen is just one way for coaches to possibly protect their athletes from OTS. Since the method of monitoring muscle glycogen is rather invasive, coaches need a reliable alternative method to monitor their athletes fatigue levels during training sessions. This is where further investigation into the usefulness of sRPE comes into play.

SUMMARY

In conclusion, there has been numerous studies researching the various tools for measuring exercise intensity. VO_{2max}, HR_{max}, and HLa have been shown to be valid and reliable measurements of exercise intensity however, there is a necessity for less invasive and easier applicable measurement tools. RPE and sRPE have been shown to be reliable alternatives to measuring exercise intensity. However, more research is needed to support the correlation between RPE and sRPE with HLa at varying exercise intensities and during continuous bouts of exercise.

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