

UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

EFFECT OF FATIGUE ON MONITORING OF TRAINING INTENSITY

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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College of Science and Health
Clinical Exercise Physiology


December, 2017

EFFECT OF FATIGUE ON MONITORING OF TRAINING INTENSITY

By Keegan Edgerton

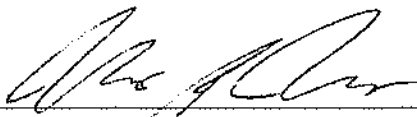
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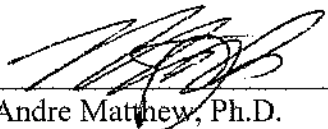
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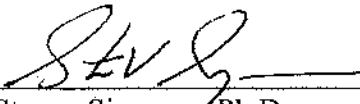
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ABSTRACT

Edgerton, K. Effect of Fatigue on Monitoring of Training Intensity. MS in Clinical Exercise Physiology, May 2017, 45pp. (C. Foster)

Introduction: The purpose of this study is to evaluate the stability and reliability of the Session Rating of Perceived Exertion (sRPE) method compared to objective physiological measures of exercise intensity. **Methods:** Twelve moderately trained male and female college students performed an initial $\text{VO}_{2\text{max}}$ test to determine appropriate workloads for the training sessions. During the first week subjects performed steady-state exercise bouts on a cycle ergometer. The second week subjects performed steady-state at the same intensity but longer duration on a cycle ergometer. Heart rate, Rating of Perceived Exertion (RPE), sRPE and blood lactate (HLA) were recorded during all sessions. **Results:** There was no significant difference between the exercise bouts of comparable duration. There was no significant difference between the HLA of the 30-minute sessions 1 and 2. There were differences within the 60-minute sessions 4 and 8, but when there was adequate recovery there were no between day differences in the two sessions. **Discussion:** During exercise bouts of constant duration sRPE stays constant. sRPE is a reliable marker of internal training load and may reflect how hard one is working compared to objective markers indicating training intensity.

ACKNOWLEDGEMENTS

I would like to thank Dr. Carl Foster for your wisdom, guidance, and assistance with this project. You have helped me have a better appreciation for research. I would also like to thank my committee members Dr. Richard Mikat and Dr. Andre Matthew. I am grateful for the contributions of your time and effort into my thesis.

Chris Dodge, thank you for your patience and help in the lab as well as always putting up with us in the lab. I would like to thank my family and friends for their support throughout my entire education. I appreciate everything you have taught me and have benefited today because of your belief in me.

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INTRODUCTION

Exercise intensity can be described as “the overload on the cardiovascular system that is needed to bring about a training effect” (Powers & Howley, 2012). Our body’s adaptive response to a training program, is dependent on frequency, duration and intensity of a training program. Although all three factors are important aspects within a training program, intensity is arguably the most important and complex factor that coaches, trainers, and therapists must deal with. Research has shown the importance of implementing different exercise intensities or training loads in athlete training programs. Exercise intensity can be reflected by a variety of factors that impact performance. Heart rate (HR), oxygen uptake (V_{O_2}), and blood lactate (HLA) are well established objective physiological markers of training intensity. Subjective ways of measuring intensity such as the Rating of Perceived Exertion (RPE), have recently become a pivotal tool, which is less costly and more widely accessible than objective measurements (Eston, 2012).

Gunnar Borg originally created the 6-20 RPE scale designed to correlate linearly with HR responses during exercise (Borg, 1982). However, this 6-20 scale had limitations and lead to modification into the category scale (CR-10). CR-10 is a 0 to 10 range scale, 0 being at rest and 10 being maximal effort (Borg, 1998). The CR-10 scale is more suitable for determining exercise intensities that are associated with breathing difficulties, aches, pain, and better identifies with fatigue related non-linear physiological

responses such as blood and muscle HLa, compared to Borg's 6-20 scale which is based more on the HR response to training (Borg, 1982; Noble, Borg, Jacobs, Ceci, & Kaiser, 1983).

A more recent modification of the CR-10 RPE scale was developed in 1995, the session Rating Perceived Exertion (sRPE) which quantitates exercise intensity globally over an entire exercise session (Foster, Hector, Welsh, Schrager, Green, & Snyder, 1995). Previous research on sRPE has shown that it is well correlated with the objective physiological measures of exercise intensity such as HR, HLa, and VO₂ (Herman et al., 2006; Day, McGuigan, Brice, & Foster, 2004; Foster et al., 2001a; Foster et al., 1995). Individuals are asked, typically 30-minutes after completing a training session, how their workout felt (Foster et al., 2001a; Foster et al., 1995). To quantitate the exercise training load sRPE is multiplied by the duration of training. Thus, sRPE is used as an indicator of intensity within the concept of the training impulse (TRIMP) score (Foster et al., 1995; Fitz-Clarke, Morton, & Banister, 1991). TRIMP takes into consideration the intensity of exercise, using the %HRR (heart rate reserve), and the duration of exercise. Although TRIMP is an effective method to quantify exercise load, the method is complicated, which led to the development of the sRPE (Foster et al., 2001a; Foster et al., 1995).

Properly executed training programs that implement varying sessions of hard and easy training have been shown to enhance athletic performance (Foster et al., 1996). However, it has become clear that coaches designing these periodized training programs often do not have the same perception of training as their athletes (Foster et al., 2001a; Foster et al., 2001b; Foster, 2016; Rodriguez-Marroyo et al., 2014). The issue coaches and athletes face is identifying the optimal level intensity that should be prescribed

(Seiler, 2010). With the observed discrepancies between coaches and athletes, the training programs may produce undesirable outcomes such as non-functional overreaching and overtraining syndrome (Foster, 1998; Meeusen et al., 2012). On training days that the coach intends to be hard, athletes often perceive the training load to be moderate. On training days that the coach intends as easy or “rest” days, the athlete often perceives the training load harder than the coach intends, creating a decompensating program where the athlete is not recovering properly. This discrepancy between the coach and athletes can cause the onset of a fatigued and stressed stage called overreaching which is the first step toward overtraining syndrome (Meeusen et al., 2012). Glycogen depletion has been linked to overtraining syndrome. High exercise intensities or durations during consecutive training days has been shown to lower muscle glycogen levels and decrease blood lactate, causing fatigue and hindering athletic performance (Costill, Bowers, Branam, & Sparks, 1971; Foster, 1998)

This discordance of perception in exercise intensity between coaches and athletes increases the chance of overreaching during prolonged periods of exercise. With the cost and complexity of using objective exercise intensity measurements, it is desirable to have more evidence regarding the reliability and validity of sRPE during training.

This study is a two-part study. The purpose of part one was to evaluate the stability and reliability of the sRPE method compared to objective physiological measures of exercise intensity. We hypothesized that Session RPE would stay constant during similar exercise bouts, demonstrating that sRPE is reproducible. This study was intended to be an extension of the study of Herman et al., (2006), across exercise duration rather than across exercise intensity.

MATERIALS AND METHODS

Subjects

The subjects for this study were 12 moderately well-trained male (n=6) and female (n=6) college students. All subjects were healthy based on the completion of the physical activity readiness questionnaire (PAR-Q) prior to participation in the study. Subject descriptive characteristics are presented in Table 1. Written informed consent was obtained prior to beginning the study. Approval from the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects was obtained prior to the beginning the study.

Table 1. Subject Descriptive Statistics (N=12). Values are mean \pm standard deviation

	Male (n=6)	Female (n=6)
Age (years)	21.2 \pm 2.93	21.2 \pm 2.99
Height (cm)	176.1 \pm 4.15	171.0 \pm 8.60
Weight (kg)	76.8 \pm 5.75	67.5 \pm 8.81
VO _{2max} (mL/kg/min)	51.8 \pm 6.16	46.8 \pm 2.64
Power Output Max (Watts)	258.5 \pm 31.08	190.5 \pm 24.66

Procedure

An initial maximal incremental exercise test was conducted to evaluate the subject's $\dot{V}O_{2\max}$, peak power output (PO_{\max}), and heart rate max (HR_{\max}). The test was performed on an electrically braked cycle ergometer (Lode, Gronningen, Netherlands). PO_{\max} was used to determine each subject's workloads for subsequent training sessions. Subjects were familiarized with the Borg-10 RPE scale (Figure 1). Subsequently each completed 4 training sessions during the first week and 4 training sessions during the following week, Monday through Thursday. The first week were 30-minute interval training sessions on the cycle ergometer with the fourth day being 60-minutes of interval training. Each session started with a five minute warm-up at 25% of the subject's PO_{\max} . Subjects then were increased to 50% PO_{\max} for five minutes, then decreased to 25% of PO_{\max} for two minutes followed by five minutes at 75% of PO_{\max} , two minutes 25% of PO_{\max} , 100% PO_{\max} for two minutes, back down to two minutes at 25% of PO_{\max} , and 50% of PO_{\max} for seven minutes followed by a five minute cool down to end the session (Figure 2). On the fourth day subjects repeated the same 30-minute protocol twice, with no rest between. After three days off, the following week the training sessions were 60-minutes using the same protocol as the previous week, except on the last day of the training session was 30-minutes. HR was measured using radio telemetry (Polar Electro-Oy, Finland). HLa using dry chemistry (LACTATE PLUS, Nova Biomedical Corporation, Waltham) was measured at the 5, 10, 17, 21, and 30-minutes along with RPE using the CR-10 scale, thirty minutes after the completion of the training session, sRPE was obtained by asking "how was your workout?"

Perceived Exertion Scale	
0	Rest
1	Really Easy
2	Easy
3	Moderate
4	Sort of Hard
5	Hard
6	
7	Really Hard
8	
9	Really, Really, Hard
10	Maximal: Just like my hardest race

Figure 1. Borg CR-10 RPE Scale

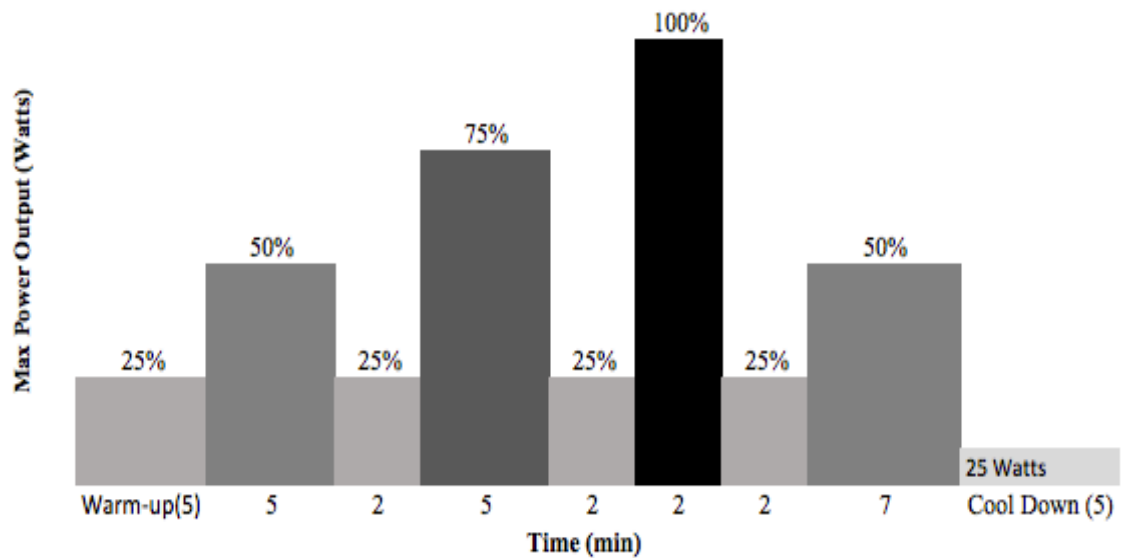


Figure 2. Workload protocol for training sessions.

Statistical Analysis

For this study, to evaluate the reliability of sRPE, only data from days 1 and 2 (30-minute exercise bouts) and 4 and 8 (60-minute exercise bouts) were analyzed. Repeated-measures ANOVA was used to determine the significance of changes in outcome variables. Comparisons were made of HLa, RPE/HLa, and sRPE, for 30-minute and 60-minute exercise sessions. Post hoc tests were performed when justified by ANOVA, using the Fisher's LSD. Alpha was set at 0.05 to achieve statistical significance.

RESULTS

Heart rate, Session Rating of Perceived Exertion (sRPE), blood lactate (HLA) of both 30-minute and 60-minute sessions, and Rating of Perceived Exertion (RPE)/HLA ratio were compared using a repeated measures ANOVA and can be seen in Table 2.

Table 2. Collected Variables, sRPE, HLa and RPE/HLa ratio.

Session	sRPE Average	HLa Average	RPE/HLa ratio
1	4.3±1.74	5.0±0.99	0.7±0.24
2	4.3±1.42	4.4±1.19	0.9±0.41
4	5.3±1.81	4.5±1.25*	0.9±0.43!
8	5.3±1.39	5.1±1.07	0.9±0.42

* denotes significant difference from HLa Average 8

!denotes significant difference from RPE/HLa 8

There was a significant difference ($p=.006$) between the sRPE. Post hoc analysis showed there was no difference between the 30-minute sessions and there was no difference between the first two 60-minute sRPE for sessions 4 and 8, which can be seen in Figure 3.

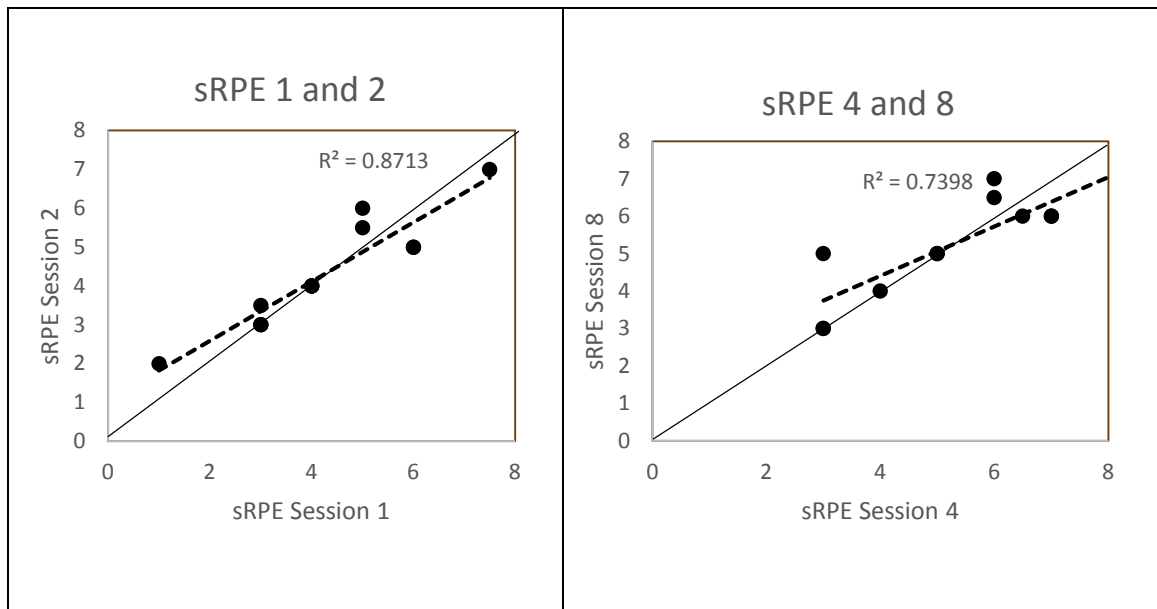


Figure 3. sRPE comparison between sessions 1 and 2 (30-minute bouts) and sessions 4 and 8 (60-minute bouts).

Heart rate response observed during the course of the 30-minute exercise bouts for session 1 and 2 and the 60-minute exercise bouts for session 4 and 8 are represented in Figure 4.

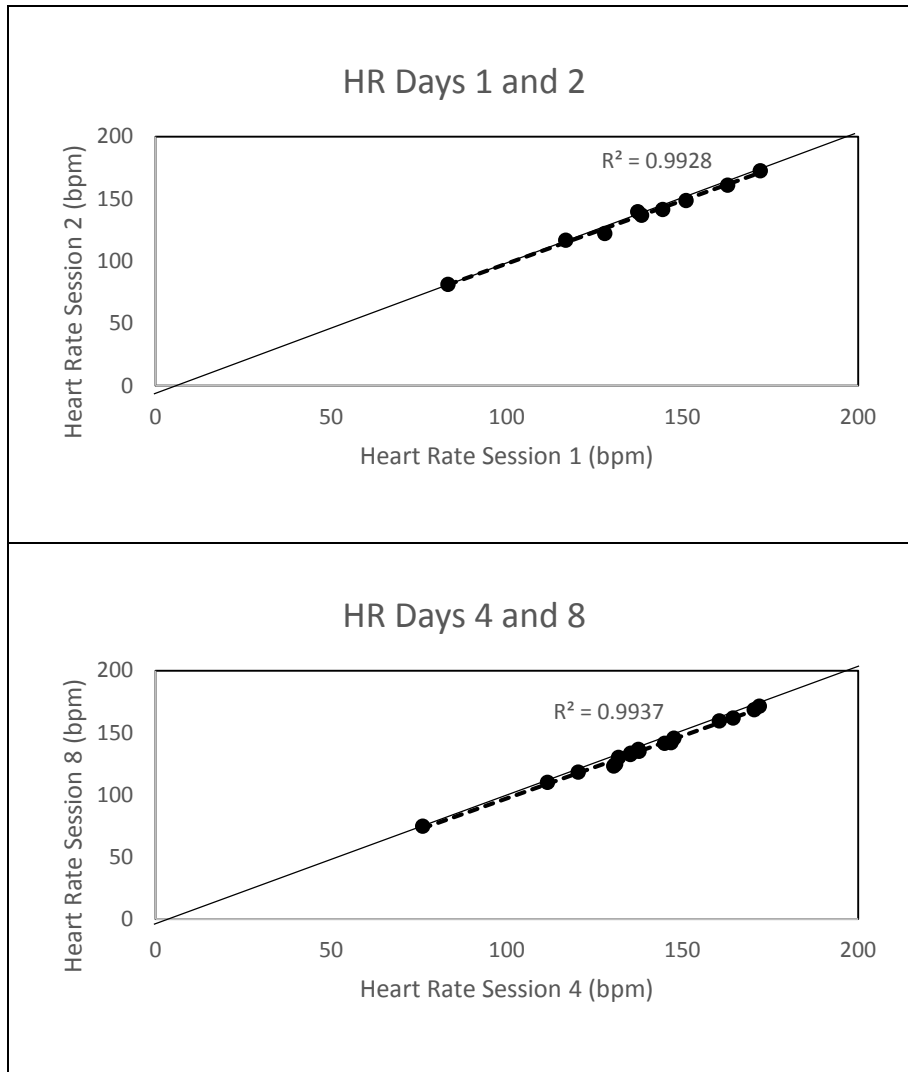


Figure 4. HR response during 30-minute bout and 60-minute bout for sessions 1, 2, 4, and 8.

The analysis of HLa during the easy ($p=.002$) and hard ($p=.002$) sessions (Figure 5) showed significant differences between sessions and can be found in Figure 5.

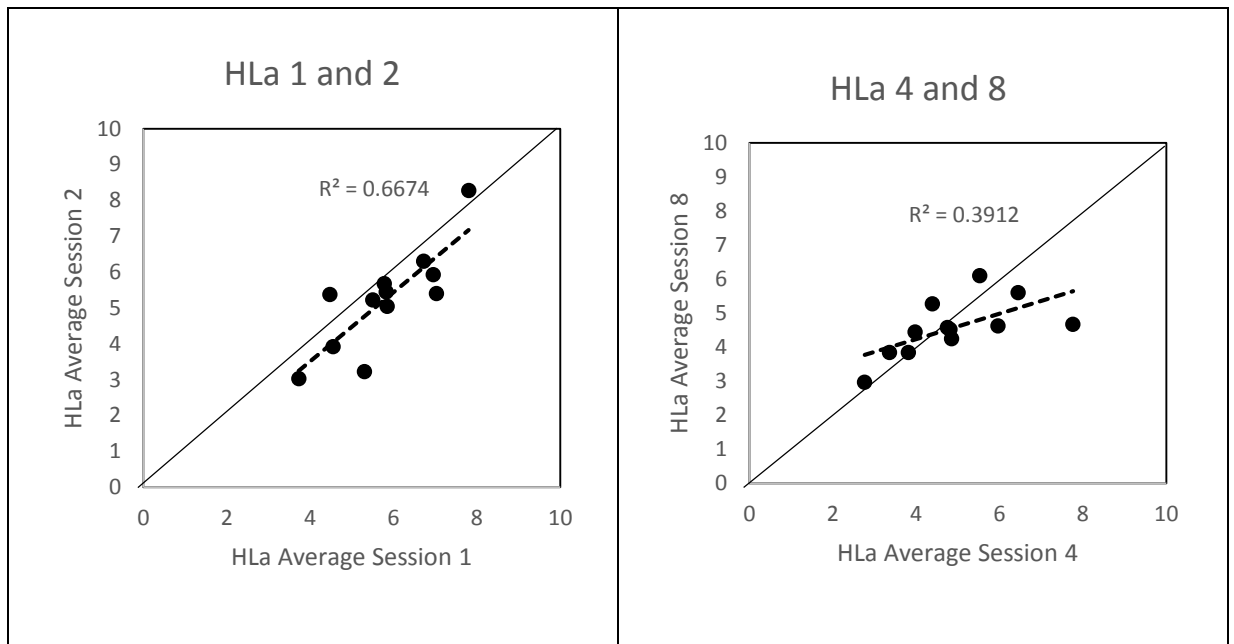


Figure 5. HLa Average comparisons between 30-minute sessions 1 and 2 and 60-minute sessions 4 and 8.

The analysis of the RPE/HLa ratio for each session showed significant differences between the sessions ($p=.003$). These differences can be seen in Figure 6. Fisher's LSD post hoc test was used to analyze pairwise comparisons.

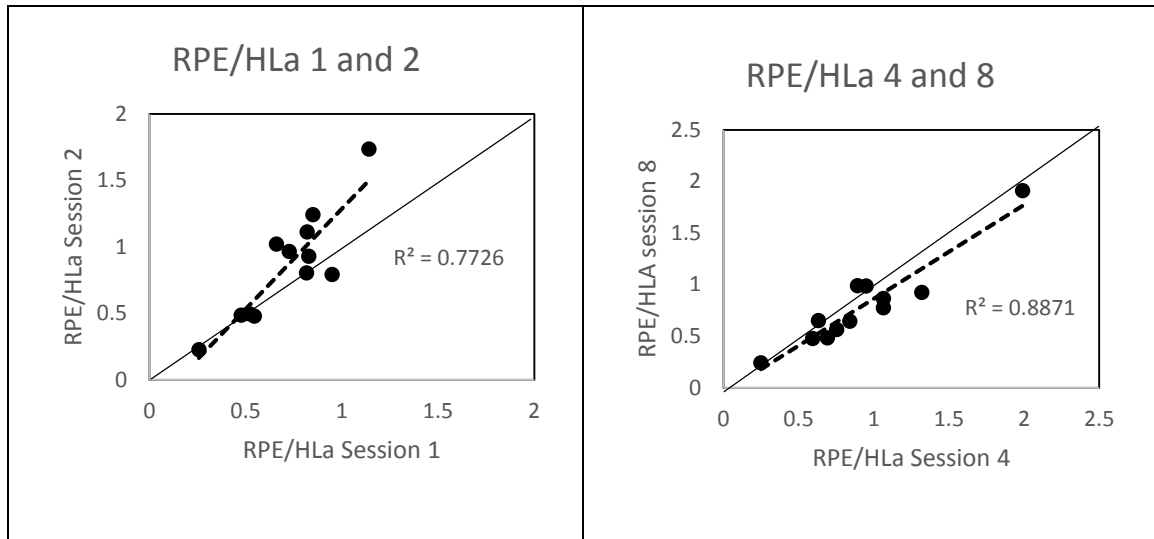


Figure 6. RPE/HLa ratio averages of 30-minute sessions 1 and 2 and 60-minute sessions 4 and 8.

DISCUSSION

The main finding of this study was that there were no significant differences between the sRPE of either the 30-minute sessions or the first two 60-minute sessions, suggesting the subjects perceived the workload as the same intensity throughout the respected session. Similarly, there was no significant difference between the HLa in 30-minute session 1 and session 2, however there was significant differences between the HLa 60-minute sessions 4 and 8. There was no significant difference between the RPE/HLa ratio of either the two 30-minute sessions, but there was a significant difference between the RPE/HLa ratio between the two 60-minute sessions. Although there were differences between the 60-minute sessions (heavier than normal training). This suggests the difference in HLa response did not affect RPE (a maker of internal training load).

This study was part one of a two-part study and the goal of part one was to evaluate the stability and reliability of using the sRPE method compared to objective physiological measures (HR and HLa). The results of this study demonstrated that, sRPE is reliable during consecutive days when challenged by the same exercise intensity.

The present data are comparable with previous studies which have shown sRPE to be a reliable method to quantitate steady-state exercise bouts. Herman et al. (2006) investigated the validity and reliability of sRPE compared to objective measures of exercise intensity. Subjects performed six randomly ordered 30-minute continuous exercise bouts at three different workloads with every workload was repeated. VO_2 and

HR were measured, along with sRPE 30-minutes following the end of the training sessions. They concluded the sRPE method is a valid and reliable tool to subjectively measure exercise intensity. The current study found similar results including the blood HLa response. Our results showed that HLa had a fixed concentration during both the 30-minute and 60-minute exercise bouts and correlated with the sRPE, although there were dimensional differences between 30-minute and 60-minute exercise bouts.

Foster et al. (2001a), looked at monitoring training during multiple types of exercise, including high-intensity interval and prolonged exercise training using the sRPE to quantitate training load. The design was two parts, subjects performed steady state and interval cycling or they practiced playing basketball. sRPE along with HR were collected during the exercise bouts. The findings showed that sRPE is a valid method to quantify exercise training in a variety of types of exercise and corresponded well with HR responses. The current study for part-one only looked at the steady-state sessions and concluded that the sRPE was reliable by demonstrating that on the steady-state sessions subjects produced a constant and comparable sRPE.

Limitations of our findings is that we were limited to collecting HLa samples as a way to measure muscle glycogen concentrations. In future studies muscle biopsies would be better suited to demonstrate glycogen depletion. The subjects all met the physically active requirements. However, it should be noted that some could have been stronger cyclists than the others.

Part-one of this study showed there was no significant differences in the sRPE seen between the 30-minute sessions and the first two 60-minutes sessions. This

demonstrates that sRPE is a reliable and stable method comparable to HR and blood HLa to quantitate exercise intensity during exercise training.

REFERENCES

- Borg, G. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports and Exercise*, 14(5), 377-381.
- Costill, D., Bowers, R., Branam, G., & Sparks, K. (1971). Muscle glycogen utilization during prolonged exercise on successive days. *Journal of Applied Physiology*, 6, 834-838.
- Day, M. L., McGuigan, M. R., Brice, G., & Foster, C. (2004). Monitoring exercise intensity during resistance training using the session RPE scale. *Journal of Strength and Conditioning Research*, 18, 353-358.
- Eston, R. (2012). Use of Ratings of Perceived Exertion in Sports. *International Journal of Sports Physiology and Performance*, 7(2), 175-182.
- Foster, C. (1998). Monitoring training in athletes with reference to overtraining syndrome. *Medicine & Science in Sports and Exercise*, 30, 1164-1168.
- Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L.A., Parker, S., Doleshal, P., & Dodge, C. (2001a). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research*, 15, 109-115.
- Foster, C., Helmann, K. M., Esten, P. L., Brice, G., & Porcari, J. (2001b). Differences in perceptions of training by coaches and athletes. *Journal of Sports Medicine*, 8, 3-7.
- Foster, C., Snyder, A., & Welsh, R. (1999). Monitoring of training, warm up, and performance in athletes. *Overload, Performance Incompetence, and Regeneration in Sport*.
- Foster, C. (2016). Back to the future. *International Journal of Sports Physiology and Performance*, 11, 281-282.
- Foster, C., Snyder, A., & Welsh, R. (1999). Monitoring of training, warm up, and performance in athletes. *Overload, Performance Incompetence, and Regeneration in Sport*.

- Foster, C., Hecter, L. L., Welsh, R., Schrager, M., Green, M. G., & Snyder, A. C. (1995). Effects of specific versus cross-training on running performance. *European Journal of Applied Physiology*, 70, 367-372.
- Herman, L., Foster, C., Maher, M. A., Mikat, R. P., & Porcari, J. P. (2006). Validity and reliability of the session RPE method for monitoring training intensity. *South African Journal of Sports Medicine*, 18, 14-17.
- Meeusen, R., Duclos, M., Foster, C., Fry, A., Gleeson, M., Nieman, D., ... Urhausen, A. (2012). Prevention, Diagnosis, and Treatment of the Overtraining Syndrome: Joint Consensus Statement of the European College of Sport Science and the American College of Sports Medicine. *Medicine and Science in Sports and Exercise*, 186- 205.
- Noble, B., Borg, G., Jacobs, I., Ceci, R., & Kaiser, P. (1983). A category-ratio perceived exertion scale: relationship to blood and muscle lactates and heart rate. *Medicine and Science in Sports and Exercise*, 15(6), 523-528.
- Powers, S. K., & Howley, E. T. (2012). *Exercise physiology: Theory and application to fitness and performance*. New York, NY: McGraw-Hill.
- Rodrigues-Marroyo, J. A., Medina, J., Garcia-Lopez, J., Garcia-Tormo, J. V., & Foster, C. (2014). Correspondence between training load executed by volleyball players and the one observed by coaches. *Journal of Strength and Conditioning Research*, 28, 1588-1594.
- Seiler, S. (2010). What is Best Practice for Training Intensity and Duration Distribution in Endurance Athletes? *International Journal of Sports Physiology and Performance*, 5, 276-291

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 $\text{VO}_{2\text{max}}$ 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

The purpose of this paper is to review the literature regarding the use of subjective measurements of exercise intensity using the session of Rating Perceived Exertion (RPE) method compared to objective measurements and their relation to physiological responses.

Introduction

Exercise intensity can be described as “the overload on the cardiovascular system that is needed to bring about a training effect” (Powers & Howley, 2012). The training effect of our body’s adaptive response to a training program, is dependent on frequency, duration and the intensity of a training program. Although all three factors are important aspects of the training program, intensity is arguably the most important and complex factor. There has been extensive interest within the athletic community on the topic of properly integrating appropriate exercise intensities or training loads for athletes (Foster, Heimann, Esten, Brice, & Porcari, 2001b; Foster, 2016). Exercise intensity can be categorized into three different intensity levels low, moderate, and vigorous. When implemented appropriately within a training program, training load distribution can produce a training effect. An issue coaches and athletes face is identifying the optimal level intensity that should be prescribed. When discussing the fact that there is minimal data showing the quantitative relationship between training load and performance Foster et al. (1996) states, “Although there are some cross-sectional and semi-quantitative data linking training loads to performance, the lack of an accepted method to quantitatively measure the training load makes this problem difficult to address.”

The most commonly used methods used to quantitate exercise intensity are maximum heart rate (HR_{max}) or percentage of HR_{max} ($\%HR_{max}$), metabolic equivalent (METs), maximum oxygen uptake (VO_{2max}) or the measurement of blood lactate (HLA). While these ways of quantitating exercise intensity appear to be reliable and effective, these methods have their limitations and can be costly to measures (Mann, Lamberts, & Lambert, 2013; Arena, Myers, & Kaminsky, 2015; Rodriguez-Marroyo et al., 2014). Exercise intensity is dependent on several factors that impact the performance of an athlete, $\%HR_{max}$, $\%VO_{2max}$, and HLa are well established physiological response markers of intensity. Subjective ways of measuring intensity have become a pivotal tool. They are less costly, and of comparable accuracy compared to objective measurements. Thus, Rating of Perceived Exertion (RPE) method was established (Scherr et al., 2012; Borg, 1982) and more recently a modification of the RPE was developed, the session of RPE method (sRPE) to subjectively quantitate exercise intensity during an entire training session (Foster et al., 1995; Foster et al., 2001a).

Rating of Perceived Exertion

Around 1960 the rating of perceived exertion (RPE) was developed by Dr. Gunnar Borg to assess how hard an individual is working. Instead of having to rely on VO_2 testing or heart rate monitoring, the RPE scale is a subjective measurement of how one is feeling. The original scale Borg developed is still used today and was thought to correlate well with HR and HLa. The scale consists of values ranging from 6 to 20 and can be used to denote HR ranging from 60-200 beats per minute. Borg (1982) believed that the information that RPE integrates is “the many signals elicited from the peripheral working muscles and joints, from the central cardiovascular and respiratory functions, and from the central nervous system.” Scherr et al. (2012) recently investigated the correlation between Borg’s 6-20 RPE scale and physiological measures of exercise intensity. Researchers had 2,560 subjects complete incremental exercise tests on treadmills or a cycle ergometer, while HR, HLa and RPE were measured at the end of each work load. The study demonstrated that the RPE scale 6-20 had a strong correlation with subject’s HR and HLa. This is significant because it allows an individual to assess and monitor training intensity with a valid and inexpensive method compared to costly objective measurements.

The Borg scale 6-20 is still widely used and was developed to illustrate that perceptual ratings increase linearly with power output and HR for exercise on a cycle ergometer (Borg, 1990). However, HLa has a non-linear relation with power output exercise intensities. Thus, Borg developed a new scale that served to simplify and be more understandable, using numbers that are anchored by verbal expressions. The new category scale is a 0 to 10 range and is more suitable for determining exercise intensities

that are associated with breathing difficulties, aches, pain, and better identifies with fatigue related non-linear physiological responses such as HLa (Borg, 1982; Noble, Borg, Jacobs, Ceci, & Kaiser, 1983).

One study looked at the relationship between the 0-10 category ratio scale (CR-10) and blood and muscle lactate as well as HR. Data was collected on seven subjects during a progressive, maximal exercise test on a cycle ergometer. Three RPE measurements were made at each stage of the testing, as well as muscle biopsies, blood samples, and HR throughout the sessions. The researchers hypothesized that blood and muscle lactate would parallel perceptual ratings while heart rate would have a linear relationship. The authors concluded that the CR-10 ratings had a significant relation to the breakdown of glycogen to glucose, leading to lactate accumulation during exercise and all the ratings showed a positive accelerated increase in lactate with exercise intensity while HR increased linearly (Noble et al., 1983). This study demonstrated that the CR-10 is a more accurate scale to be used as a method to quantitate exercise that involves lactate accumulation.

New Method to Monitor Exercise sRPE

In 1995, Foster modified the Borg CR-10 RPE scale. Objective measurements that are used to monitor exercise such as HR and HLa can be costly, not readily available especially in a larger group setting and HR has its limitations regarding the way HR represents training loads during high intensity training sessions (Foster et al. 1995). Instead of asking individuals to rate how hard they are working at different times within a training session, individuals were asked to rate their effort for the entire training session (Foster et al., 1995, Foster et al., 2001a; Herman, Foster, Maher, Mikat, & Porcari, 2006). To quantitate exercise training, training load equals the total minutes of training multiplied by the sRPE. The sRPE is used as an indicator of intensity within a training impulse (TRIMP) score, which is a method to quantify training load. TRIMP takes into consideration the intensity of exercise using the %HRR and the duration of exercise (Morton, 1997). Although TRIMP appears to be an effective method to quantify exercise intensities there are limitations to this method. One limitation is the use of HR monitors, if not worn or malfunctioning the data from that training session is lost. The association between HR and the TRIMP score does not allow for the most appropriate way to evaluate training load in high-intensity exercises (Foster et al., 2001a). Thus, these limitations to quantitate exercise intensity led to the development of the sRPE (Foster et al., 2001a). The significance of creating sRPE is to find a simple way to effectively quantitate exercise training or training load using a single term.

Numerous research studies have been conducted to determine the validity and reliability of the session RPE method for quantifying exercise intensity compared to other measurements such as HR and HLa. For a training study, Foster et al., (1995) created the

sRPE method. In the study Foster discussed previous pilot studies that evaluated the relationship between sRPE, HR, and HLa during 30-minute interval and continuous training sessions. The results showed a strong correspondence between the sRPE and “the behavior of %HRR and in relation to common blood lactate transition zones.”

Another study done by Foster et al., (2001a), looked at successfully monitoring training during multiple types of exercise, especially high-intensity or prolonged exercise training using the sRPE to quantitate the training load. The design was two parts, subjects performed steady state and interval cycling or they practiced playing basketball. sRPE along with HR were collected during the exercise bouts. The findings showed that sRPE is a valid method to quantify exercise training in a variety of types of exercise and corresponded well with HR responses.

To further document the validity and reliability of sRPE compared to objective measures of exercise intensity, one study constructed a training program for 14 subjects who performed six randomly ordered 30-minute continuous exercise bouts at three different workloads and every workload was repeated. VO_2 and HR were measured, along with sRPE 30-minutes following the end of the training sessions (Herman et al., 2006). This study supported the concept that the sRPE method is a valid and reliable tool to subjectively measure exercise intensity.

sRPE has shown to be a viable method to quantitate exercise intensity in aerobic exercise types but it may also be a useful method for monitoring exercise intensity during resistance training. A study took nine individuals and had them perform various training sessions with five different weight lifting exercises. The intensities were adjusted between high, moderate, low and was repeated twice. Results showed that as the intensity

or workload increased the sRPE value was also increased and sRPE also correlated well with the average RPE during the training sessions showing its reliability to be used to quantitate various intensities (Day, McGuigan, Brice & Foster, 2004).

Sweet, Foster, McGuigan, & Brice, (2004) demonstrate sRPE as an effective method to quantitate exercise intensities of resistance training compared to aerobic training. The study had ten men and ten women who performed three aerobic training bouts on a cycle ergometer at different intensities and they also performed three resistance training bouts with varying repetitions and intensities. sRPE was collected after each training bout and the results showed that sRPE could quantify resistance training intensity and is generally comparable to the sRPE of aerobic training intensity.

Blood Lactate and sRPE

HR and HLa have been instrumental for monitoring exercise intensity and have become standard methods. Both of these tools have limitations and are costly. HR increases linearly within a training session but other physiological variables such as HLa are related to exercise intensities non-linearly, Borg developed the same scale that sRPE utilizes to quantitate exercise intensity, CR-10. HLa has been associated with fatigue and Borg needed a scale that would associate fatigue and the non-linear response of HLa (Noble et al., 1983; Powers & Howley, 2012).

One study that compared the relationship between RPE and HLa concentrations took 15 female distance runners, six female race walkers, and eleven untrained females and administered an incremental intensity treadmill test. During the testing HR, HLa and RPE (from the CR-10 scale) were monitored, as well as determining the onset of blood lactate accumulation (OBLA). The findings showed that the relationship between HLa and CR-10 RPE scale was approximated well by two linear regression lines. An interesting finding from the study shows that, “the CR-10 in association with HR responses could be also available to predict the exercising intensity corresponding to the individual OBLA for female endurance athletes” (Abe, Yoshida, Ueoka, Sugiyama, & Fukuoka, 2015). This is significant because OBLA can be defined as the exercise intensity or oxygen consumption at which a specific blood lactate concentration is reached, which can show when the body’s energy system is relying on anaerobic metabolism (Powers & Howley, 2012). With the correlation OBLA has with RPE, RPE can be used to approximate when an individual has reached that point of reliance.

Hetzler et al., (1991), supported other findings that there is a reliable relationship between RPE and HLa concentrations. The researchers took 29 untrained males who completed counterbalanced $\text{VO}_{2\text{max}}$ and lactate threshold protocols on a cycle ergometer and on a treadmill. The study showed that RPE compared to lactate threshold and fixed blood lactate concentrations, did not vary during different modalities of exercise despite different HR and VO_2 measurements between the different modalities. This confirmed that as HLa varies, RPE varies allowing use for RPE as an effective tool for exercise prescription.

Different perception Coaches Versus Athletes

The ability to monitor training workloads using HR, HLa, or VO₂, has athletes to elicit a training effect which in turn can improve performance. However, despite this ability to quantitate training workload using objective methods there is still a substantial incidence of undesired outcomes (Foster et al., 2001b; Foster, Snyder, & Welsh, 1999; Meeusen et al., 2012).

Coaches spend a significant amount of time creating training programs that will allow the athlete to reach top performance. Coaches assign days of lighter intensity to balance days of higher intensity within a training program. Undesired outcomes are produced from unrecognized errors in the different way athletes perceive the workload compared to what the coach intended the workload or intensity to be.

Foster et al. (2001b) compared fifteen competitive runner's training records over a 5-week period. The runners would rate the sRPE of their training sessions and the runner's coaches would also rate what they intended the runners to do during the training program. The results showed that for the training sessions that were to be high-intensity training, the runners trained at a lower RPE than intended by the coaches. In training sessions that were to be low-intensity, the runners trained a higher RPE compared to that intended by the coaches.

It is evident that the coaches periodized training programs are not well executed by their athletes (Foster et al., 2001a; Foster et al., 2001b; Foster, 2016).

This contradiction between coaches and athlete's perception of training is producing undesirable training outcomes such as the phenomenon of overtraining syndrome.

Overtraining and the Need for sRPE

Overtraining is a disorder that has a significant impact on athletic performance hindering the desired outcomes intended by training programs (Foster, Snyder, Welsh, 1999; Meeusen et al., 2012). Powers & Howley, 2012 state that the symptoms of overtraining can include, “elevated HR and HLa levels at a fixed submaximal work rate, loss in body weight due to a reduction in appetite, chronic fatigue, psychological staleness, increased number of infections, and/or a decrease in performance.”

It is believed that some ordinary illnesses are a marker of overtraining syndrome. This allowed Foster, (1998), to conduct a study that observed the training load and training monotony of twenty-five athletes in relation to illnesses. Within the training sessions the athletes recorded their sRPE and duration of the training session. Illnesses that occurred during the training sessions were correlated with indicators of training such as an increase in training load above individually identifiable training thresholds. Foster concluded that methods such as sRPE can be used to monitor training and allow the athlete to minimized unfavorable training outcomes.

Coaches and athletes should carefully plan and design each training program, in order to produce positive outcomes in performance and reduce the risk of overtraining (Foster, Daines, Hector, Snyder, & Welsh, 1996). The sRPE method can be a useful tool to have athletes to quantitate training sessions over a period of time to observe exercise workload patterns.

Glycogen Depletion and Blood Lactate

HLA has become an effective, simple, and common method to evaluate an athlete's responses to training. As intensities of exercise increase blood lactate concentrations rise characterized by the point termed lactate threshold. This rise in HLa can a shift to the anaerobic system. This increase in HLa during increased exercise intensities illustrates the reliance of the glycolysis process, which is the breakdown of glucose or glycogen into lactate (Powers & Howley, 2012).

When athletes have an acute increase in the training intensities or workload this can lead to acute glycogen depletion which has shown to correlate with HLa concentrations decreasing (Foster, Snyder, Thompson, & Kuettel, 1988). The importance of observing glycogen depletion is the effect it may have on sRPE. Glycogen depletion correlates with HLa, which has been thought to be the cause of fatigue during high-intensity exercises and can cause overtraining (Snyder, 1998; Snyder, Kuipers, Cheng, Servais, & Fransen, 1995). Suriano, Edge, & Bishop, (2010) demonstrated the importance of glycogen stores by inducing subjects into a state of glycogen depletion while cycling. The subject's running economy or the energy utilization our body elicits while running at aerobic intensities, was not able to be sustained due to poor glycogen supply.

Tabata & Kawakami (1991) looked at the relationship between blood glucose concentrations and the RPE during prolonged low-intensity exercise. The results showed that RPE had no change when glycogen stayed constant during normal level cycling. Only when it was assumed that glycogen in the muscles was depleted was RPE effected. Costill, Bowers, Branam, & Sparks (1971) showed similar findings in that during

“successive days of prolonged server exertion produced a marked reduction of muscle glycogen concentration.” They also found that during successive days of exercise lactate accumulation was reduced.

The importance glycogen has on the energy system has shown that glycogen depletion can cause decreased performance (Costill et al., 1988). The correlation between glycogen depletion and HLa has a major impact on fatigue during exercise, as well as on monitoring tools to indicate overtraining. If coaches and athletes inadequately apply training intensities to their program, this may cause improper recovery time to restore glycogen levels causing fatigue and unwanted outcomes.

Summary

In conclusion, vast amounts of research have been done to understand reliable ways of measuring exercise intensity. Without administering optimal exercise intensities within a training session athletes are more likely to develop overtraining syndrome. sRPE has shown to be a reliable and valid method, correlating well with other measurements such as HR, VO_2 , and HLa. Glycogen depletion is a phenomenon that is well documented and it's associating with decrease in HLa levels allow for a comparison with sRPE but the correlations with sRPE and glycogen depletion needs to be evaluated to a further extent as does the reliability and validity of sRPE.

REFERENCES

- Abe, D., Yoshida, T., Ueoka, H., Sugiyama, K., & Fukuoka, Y. (2015). Relationship between perceived exertion and blood lactate concentrations during incremental running test in young females. *BMC Sports Science, Medicine, and Rehabilitation*, 1-9.
- Arena, R., Myers, J., & Kaminsky, L. (2016). Revisiting age-predicted maximal heart rate: Can it be used as a valid measure of effort? *American Heart Journal*, 173, 49-56.
- Borg, G. (1990). Psychophysical scaling with applications in physical work and the perception of exertion. *Scandinavian Journal of Work, Environment & Health*, 16, 55-58.
- Borg, G. A. V. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise*, 14, 377-381.
- Costill, D., Bowers, R., Branam, G., & Sparks, K. (1971). Muscle glycogen utilization during prolonged exercise on successive days. *Journal of Applied Physiology*, 6, 834-838.
- Costill, D. L., Flynn, M. G., Kirwan, J. P., Houmard, J. A., Mitchell, J. B., Thomas, R., & Park, S. H. (1988). Effects of repeated days of intensified training on muscle glycogen and swimming performance. *Medicine and Science in Sports and Exercise*, 20, 294-253.
- Day, M. L., McGuigan, M. R., Brice, G., & Foster, C. (2004). Monitoring exercise intensity during resistance training using the session RPE scale. *Journal of Strength and Conditioning Research*, 18, 353-358.
- Foster, C., Snyder, C., Thompson, N. N., & Kuettel, K. (1988) Normalization of the blood lactate profile in athletes. *International Journal of Sports Medicine*, 9, 198-200.
- Foster, C., Hecter, L. L., Welsh, R., Schragger, M., Green, M. G., & Snyder, A. C. (1995). Effects of specific versus cross-training on running performance. *European Journal of Applied Physiology*, 70, 367-372.
- Foster, C., Daines, E., Hector, L., Snyder, A. C., & Welsh, R. (1996) Athletic performance in relation to training load. *Wisconsin Medicine Journal*, 370-374.
- Foster, C. (1998). Monitoring training in athletes with reference to overtraining syndrome. *Medicine & Science in Sports and Exercise*, 30, 1164-1168.

- Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L.A., Parker, S., Doleshal, P., & Dodge, C. (2001a). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research*, 15, 109-115.
- Foster, C., Helmann, K. M., Esten, P. L., Brice, G., & Porcari, J. (2001b). Differences in perceptions of training by coaches and athletes. *Journal of Sports Medicine*, 8, 3-7.
- Foster, C. (2016). Back to the future. *International Journal of Sports Physiology and Performance*, 11, 281-282.
- Foster, C., Snyder, A., & Welsh, R. (1999). Monitoring of training, warm up, and performance in athletes. *Overload, Performance Incompetence, and Regeneration in Sport*.
- Herman, L., Foster, C., Maher, M. A., Mikat, R. P., & Porcari, J. P. (2006). Validity and reliability of the session RPE method for monitoring training intensity. *South African Journal of Sports Medicine*, 18, 14-17.
- Hetzler, R., Seip, R., Boutcher, S., Pierce, E., Snead, D., & Weltman, A. (1991). Effect of exercise modality on ratings of perceived exertion at various lactate concentrations. *American College of Sports Medicine*, 23, 88-92.
- Mann, T., Lamberts, R. P., Lambert, M. I. (2013). Methods of prescribing relative exercise intensity: Physiological and practical considerations. *Sports Medicine*, 43, 613-625. doi: 10.1007/s40279-013-0045-x
- Meeusen, R., Duclos, M., Foster, C., Fry, A., Gleeson, M., Nieman, D., ... Urhausen, A. (2012). Prevention, Diagnosis, and Treatment of the Overtraining Syndrome: Joint Consensus Statement of the European College of Sport Science and the American College of Sports Medicine. *Medicine and Science in Sports and Exercise*, 186- 205.
- Morton, R. (1997). Modelling training and overtraining. *Journal of Sports Sciences*, 15, 335-340.
- Noble, B., Borg, G., Jacobs, I., Ceci, R., & Kaiser, P. (1983). A category-ratio perceived exertion scale: relationship to blood and muscle lactates and heart rate. *Medicine and Science in Sports and Exercise*, 15(6), 523-528.
- Powers, S. K., & Howley, E. T. (2012) *Exercise physiology: Theory and application to fitness and performance*. New York, NY: McGraw-Hill.

- Rodrigues-Marroyo, J. A., Medina, J., Garcia-Lopez, J., Garcia-Tormo, J. V., & Foster, C. (2014). Correspondence between training load executed by volleyball players and the one observed by coaches. *Journal of Strength and Conditioning Research*, 28, 1588-1594.
- Scherr, J., Wolfarth, B., Christle, J. W., Pressler, A., Wagenpfeil, S., & Martin, H. (2012). Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *European Journal of Applied Physiology*, 113, 147-155. doi: 10.1007/s00421-012-2421-x
- Snyder, A. C. (1998). Overtraining and glycogen depletion hypothesis. *Medicine & Science in Sports & Exercise*, 30, 1146-1150.
- Snyder, A. C., Kuipers, H., Cheng, B., Servais, R., & Franssen, E. (1995). Overtraining following intensified training with normal muscle glycogen. *Medicine & Science in Sports and Exercise*, 1063-1070.
- Suriano, R., Edge, J., & Bishop. (2010). Effects of cycle strategy and fiber composition on muscle glycogen depletion pattern and subsequent running economy. *British Journal of Sports Medicine*, 44, 443-448.
- Tabata, I., & Kawakami, A., (1991). Effects of blood glucose concentration on ratings of perceived exertion during prolonged low-intensity exercise. *Japanese Journal of Physiology*, 41, 203-215.
- Sweet, T., Foster, C., McGuigan, M., & Brice, G. (2004). Quantitation of Resistance Training using the Session Rating of Perceived Exertion Method. *Journal of Strength and Conditioning Research*, 18(4), 796-802.