UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

THE EFFECT OF POST-EXERCISE RATING TIME 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

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December, 2012

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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.

The candidate has completed the oral defense of the thesis.

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ABSTRACT

Christen, J.D. The effect of post-exercise rating time on session RPE. MS in Clinical Exercise Physiology, December 2012, 49pp. (C. Foster)

This study evaluated the effect of post-exercise time on session rating of perceived exertion (sRPE) following steady-state and interval exercise bouts on a cycle ergometer. Fifteen subjects completed one steady-state ride and four different interval rides. The order of rides was counterbalanced. The steady-state ride was conducted at a workload equal to 90% of VT. The work-to-rest ratios of the interval rides were 1:1, 2:2, and 3:3. The high-intensity component of each interval was 75% of PPO. Heart rate (HR), blood lactate (BLa), and ratings of perceived exertion (RPE) were measured during each ride. The sRPE was measured at 5, 10, 15, 20, 25, 30, 60 minutes and 24 hours after completion of each ride. No significant differences ($p > 0.05$) in sRPE were found based on time post-exercise. Significant differences ($p < 0.05$) in sRPE did exist between the steady-state ride vs. 3:3 ride (3.7 ± 0.2 vs. 6.2 ± 0.1) and the 1:1 ride vs. 3:3 ride (3.9 ± 0.2 vs. 6.2 ± 0.1). Post-exercise time has no meaningful effect on sRPE after steady-state or interval cycling exercise bouts. The sRPE does discriminate between different exercise intensities.

ACKNOWLEDGEMENTS

It was my honor to have the privilege of completing a thesis under the supervision of Dr. Carl Foster. He is the best in the field. I am thankful for his patience, encouragement, and sense of humor (often times having to find me at the PM LEHP program) as I tactfully avoided completion of the thesis for nearly as long as possible. Thank you, Carl. You are brilliant, but most importantly you have a very good heart.

I would also like to acknowledge my committee members: Dr. John Porcari and Dr. Richard Mikat. Both asked important questions which helped shape the thesis and both contributed significantly to my education here at UW-L.

There were many other contributors whom I would like to acknowledge. Chris Dodge of the Human Performance Lab is one. He kept data collection afloat and shared with me some old Indian tricks. I would like to thank my subjects. They were outclassed by none. They were always on time and never surrendered.

Special thanks to my brother, Jesse, for being here. It's good to see you, bro. Best wishes in your new adventures. I'd also like to acknowledge those who laid my foundation: my parents who molded my character, my coach—Tony Bralick—who taught me to be joyful *no matter what*, all my relatives from the Apsáalooke Nation who inspired me to go forward and be brave and be strong, and my instructors at Montana State University who prepared me for success in graduate school better than they know.

Lastly, thanks to all of my classmates and the participants of LEHP who made this an exceptional year. Special thanks to Jyoti Swami, who was always a positive ray of light and taught me more than she gives herself credit for.

Without these people none of this would have been possible. Thank you!

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INTRODUCTION

The session Rating of Perceived Exertion (sRPE) is a global subjective rating of an exercise bout's perceived intensity: e.g. how hard was your workout? This is a central concept to the quantification of training load and the development of monitoring training (Borresen & Lambert, 2008; Foster et al., 2001), and represents a simplification of the training impulse (TRIMP) concept developed by Morton, Fitz-Clarke, & Banister (1990).

Training load has three components: frequency, duration, and intensity. Frequency and duration of training are easily accounted for as number of exercise bouts per week and total minutes per session. However, the intensity of training is far more difficult to quantify (Thompson, Gordon, & Pescatello, 2010). The dominant paradigm in exercise science has been the use of objective physiological variables to quantify exercise intensity: oxygen consumption (VO_2), heart rate (HR), blood lactate (BLa), and ventilatory threshold (VT). The sRPE has been shown to be a valid alternative to these objective methods and to correlate well with objective measures of exercise intensity (Foster et al., 1995; Foster et al., 2001). Outside of the laboratory, sRPE may even be preferable to objective methods given its practicality and ease of use.

The sRPE first appeared in the literature in 1995 as Foster et al. examined specific versus cross-training effects on running performance. The researchers needed a way to quantify the intensity of an entire exercise bout in order to keep training load constant between trials. Because of the practical difficulty in obtaining objective measures of intensity such as HR or VO_2 across multiple modes of exercise, in groups with large numbers of subjects, and due to the inability of HR to represent intensity during intervals, the subjects were instructed to use the Borg category-ratio 1-10 scale (CR10) to give a global rating of the intensity of the entire exercise bout. This value was multiplied by the duration of the exercise bout in minutes to produce a training load score, conceptually similar to the TRIMP (Morton et al., 1990). Thus, sRPE simplified the challenge of quantifying the intensity of any given exercise bout.

The use of sRPE as a tool to monitor exercise intensity and assist in quantifying training load across several exercise disciplines has been reported extensively in the literature (Serrano, Salvador, Gonzalez-Bono, Sanchis, & Suay, 2001; Day, McGuigan, Brice, & Foster, 2004; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Seiler & Kjerland, 2006; Wallace, Coutts, Bell, Simpson, & Slattery, 2008; Minganti, Capranica, Meeusen, Amici, & Piacentini, 2010; Milanz et al., 2011). For example, it has been shown to be a reliable method of quantifying exercise intensity in resistance training across different intensities and protocols—strength, hypertrophy, and power (Day, McGuigan, Brice, Foster, 2004; Sweet, Foster, McGuigan, & Brice, 2004; Singh, Foster, Tod, McGuigan, 2007). Impellizzeri, Rampinini, Coutts, Sassi, & Marcora (2004) concluded that sRPE was an effective marker of intensity in soccer, while Wallace, Coutts, Bell, Simpson, & Slattery (2008) recommended the use of sRPE to monitor the intensity of swimming exercise bouts. Two studies conducted in 2011 and 2010 by Milanez et al. and Minganti et al. support the use of sRPE as a valid and practical tool in measuring exercise intensity in activities such as karate and Teamgym, respectively.

In spite of the growing amount of literature in support of sRPE as a tool for quantifying global exercise intensity, questions regarding post-exercise rating time on sRPE have not been sufficiently addressed. Originally, Foster et al. (1995) chose to rate the sRPE 30-minutes post-exercise. No evidence in the literature existed to substantiate this decision. Rating the 30 minute post-exercise time was thought to be enough time to prevent the end of the last part of the exercise bout from overly influencing the subject's rating (Foster et al., 2001).

Since 1995, only one study has examined sRPE at multiple time intervals post-exercise (Singh et al., 2007). This study examined only resistance training and measured sRPE at 5-minute intervals for only 30-minutes post-exercise. Significant differences were observed between the sRPE at 5- and 10-minutes post-exercise as compared to 30-minutes post-exercise. These findings appear to support the notion that the perceptions of exercise intensity immediately after an exercise bout are skewed by specific elements at the end of the bout, whereas perceptions of intensity at 30-minutes post-exercise are unaffected.

Kilpatrick et al. (2009) compared the sRPE at 15-minutes post-exercise to both the momentary RPE during the final minute of exercise and to the average of all momentary RPE ratings during an exercise bout on a treadmill. The sRPE at 15-minutes post-exercise showed no difference to the momentary RPE obtained in the final minute of exercise; however, the sRPE at 15-minutes post-exercise was significantly higher than the average of all momentary RPE ratings attained during the exercise bout. Consequently, this study suggested that the sRPE rating at 15-minutes post-exericse continued to be influenced primarily by higher exertion in the final minute of exercise rather than reflecting a global value of the bout. Unfortunately, this study did not measure sRPE at any other time post-exercise.

Thus, the effect of post-exercise rating time on sRPE is unclear. Little is known about the sRPE at times greater than 30 minutes post-exercise. The dynamics of sRPE following steady-state and interval bouts of non-resistance training modalities is also unknown.

This study examined the effect of post-exercise rating time on sRPE after steady-state and interval bouts on a cycle ergometer. It was hypothesized that the sRPE at 5- and 10- minutes post-exercise would be significantly higher than at all other post-exercise rating times.

METHODS

Subjects

The subjects for this study were 15 apparently healthy college-aged individuals (7 women and 8 men). Subjects were recruited from a general education fitness class at the University of Wisconsin-La Crosse. The training status of subjects was self-reported. All subjects reported to engage in moderate to vigorous physical activity for 30 minutes at least five times per week.

Protocol

After gaining approval from the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects, each subject provided written informed consent before participation (Appendix A).

Each subject completed a total of 5 trials on an electrically braked cycle ergometer. Prior to the first trial, subjects were taught the concept of scaling exertion via the Borg CR10 scale and the global rating of the sRPE (Noble, Borg, Jacobs, Ceci, Kaiser, 1983). Subjects were then shown how to scale exertion using a visual analog scale.

The first trial was an incremental exercise test to volitional exhaustion. Following a 3-minute warm-up at 25 W, the power output was increased every minute by 25 W until the subject reached volitional exhaustion. The VO_2max was measured using open circuit spirometry on a MOXUS Modular Metabolic System (AEI Technologies, Bastrop, TX). The ventilatory threshold (VT) was determined using the V-slope method

(Schneider, Phillips, & Stoffolano, 1993). Each subject's peak power output (PPO) and VT was used to determine specific workloads for the subsequent trials.

The order of subsequent trials was counterbalanced. The trials consisted of a steady-state ride at 90% of VT and three interval rides with work-to-rest ratios of 1:1, 2:2, and 3:3. The high intensity aspect of the interval rides were completed at 75% of the subject's PPO. The active rest period of the interval rides were at a PO that would yield a mean power output (PO) for the ride equivalent to 90% of the subject's VT. Thus, each ride was of the same mean PO.

Each trial began with a 3-minute warm-up 25 W, immediately followed by a 24-minute ride at the predetermined PO, and concluded with a 3-minute cool-down at 25 W. Heart rate, blood lactate, and RPE were measured at rest and at 3, 11, 19, 27, and 30 minutes into each ride (Minganti, Capranica, Meeusen, Amici, & Piacentini, 2010; Minganti, Capranica, Meeusen, & Piacentini, 2011).

After each trial, subjects reported sRPE using a visual analog scale at 5, 10, 15, 20, 25, 30, 60 minutes, and 24 hours post-exercise.

Statistical Analysis

Descriptive statistics were used to calculate the mean and standard deviation of outcome variables. Repeated measures ANOVA was used to analyze the within-subjects effect of post-exercise rating time on sRPE and the between-subjects effect of ride type and gender on sRPE. Tukey post-hoc analysis was used to examine significant differences. Alpha was set at 0.05 to achieve statistical significance.

RESULTS

The descriptive characteristics of the subjects are summarized in Table 1. The changes in power output over time for each ride are visualized in Figure 1. The four different rides each had an equivalent mean power output (PO) of 90% of VT. Other physiological responses are graphically presented in Figures 2-4.

The sRPE at different post-exercise rating times is graphically displayed in Figure 5 and summarized in Table 2.

Table 1. Descriptive characteristics of the subject population (N=15)

	Overall (15)	Women (7)	Men (8)
Age (years)	18.9 ± 0.7	19.0 ± 0.8	18.9 ± 0.6
Height (cm)	172.3 ± 9.4	164.6 ± 6.7	179.1 ± 5.1
Body Mass Index	23.1 ± 2.7	23.4 ± 2.4	22.9 ± 3.0
Mass (kg)	68.6 ± 10.6	62.8 ± 7.3	73.6 ± 10.7
Heart Rate Max (bpm)	188.0 ± 9.5	183.7 ± 9.6	191.5 ± 8.2
VO_2max (ml/kg/min)	44.1 ± 8.4	36.2 ± 3.7	51.0 ± 3.8
Peak Power Output (watts)	257.0 ± 56.3	207.1 ± 27.8	300.0 ± 32.7
Peak Power Output (watts/kg)	3.8 ± 0.8	3.3 ± 0.3	4.2 ± 0.9

The characteristics of the subjects are displayed in Table 1. The observed differences between women and men were expected. On average men were taller, had more mass, consumed more oxygen at maximal effort, and produced greater peak power than did women.

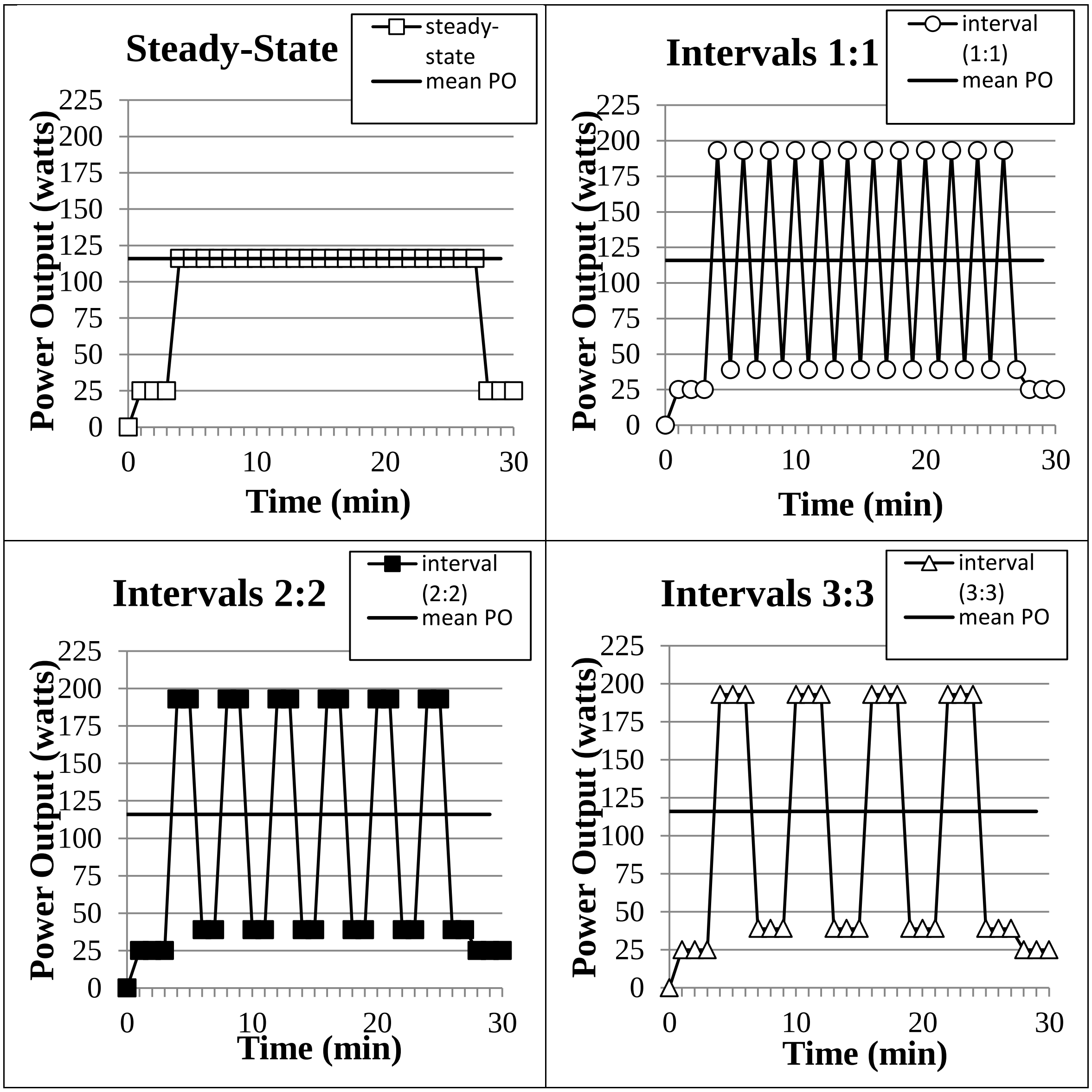

Figure 1. Power output during steady-state and interval rides.

Each of the four rides consisted of an overall workload that was of an equivalent mean power output. The steady-state ride was completed at 90% of VT. Each of the interval rides consisted of a high intensity segment at 75% of peak power output (PPO) and an active rest period at a workload that would produce a mean PO for that ride equivalent to 90% of VT.

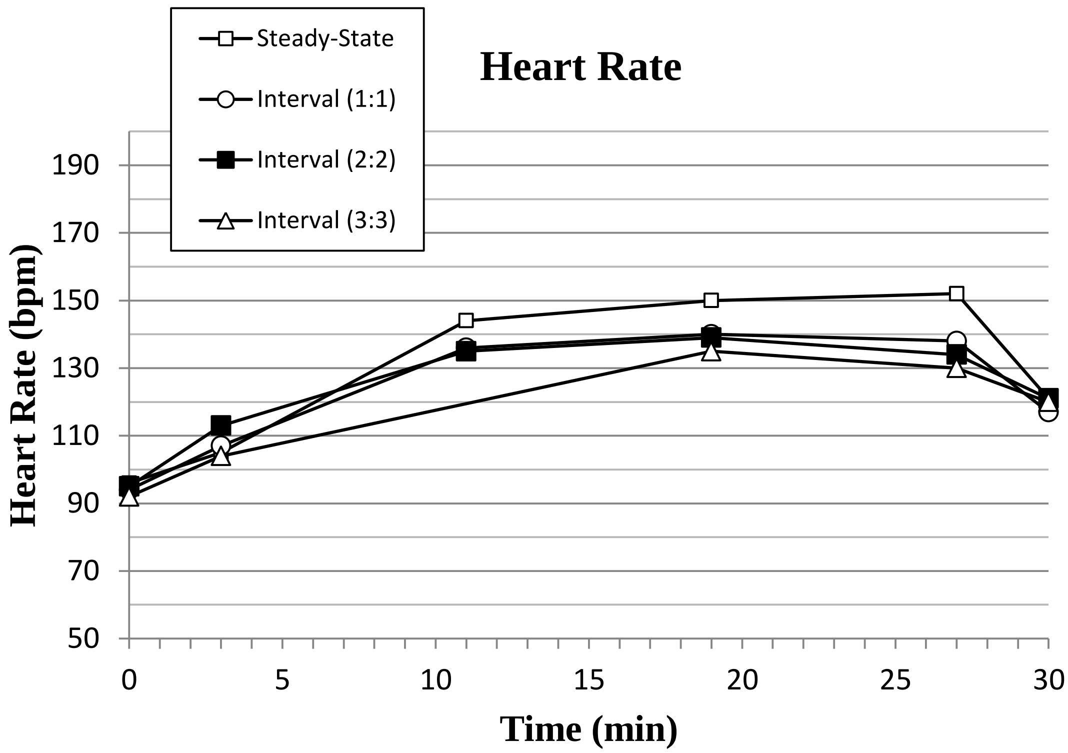

Figure 2. Heart rate response during steady-state and interval rides.

The heart rate response of the subjects is portrayed in Figure 2. Heart rate increased upon commencement of the exercise bout, although there was no significant difference in heart rate attributable to the type of ride.

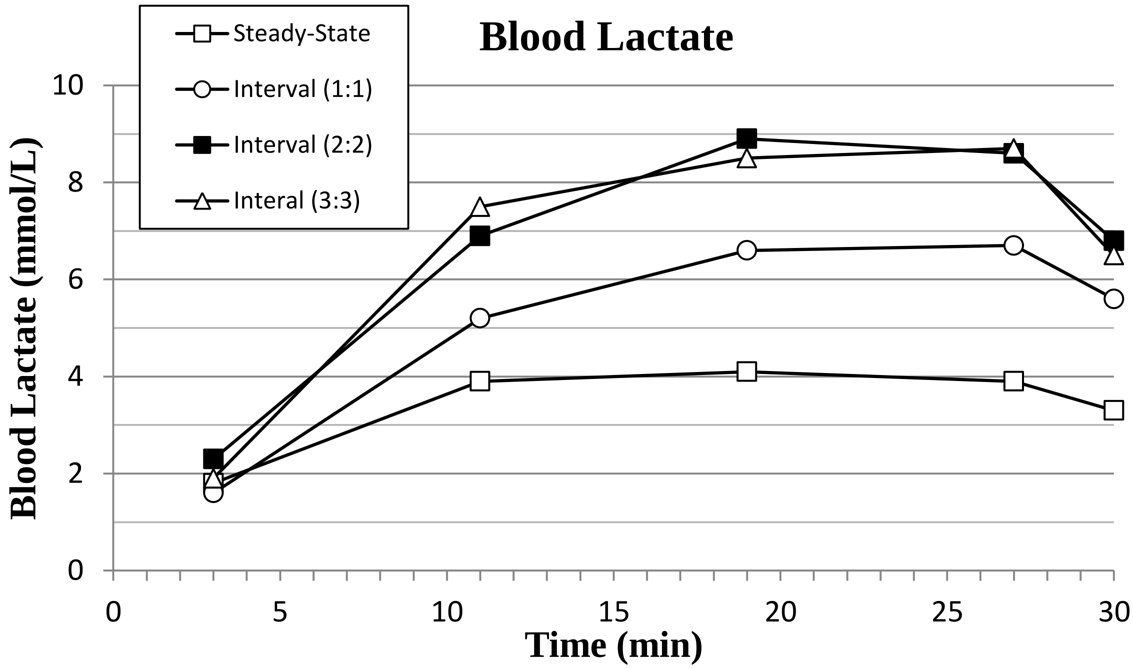

Figure 3. Blood lactate concentration during steady-state and interval rides.

The blood lactate (BLa) response is presented in Figure 3. Blood lactate concentration was measured at the completion of the warm-up, at 11, 19, and 27 minutes into the ride, and at the completion of the cool-down. The lactate concentration at the conclusion of the warm-up showed little difference between rides. The steady-state ride yielded the smallest increase in [BLa], followed by the 1:1 interval ride. The 2:2 and 3:3 interval rides showed no significant difference in [BLa]. The [BLa] of the 2:2 and 3:3 interval rides were both significantly higher than the 1:1 interval ride and the steady-state ride. This pattern was still evident after completion of the cool-down.

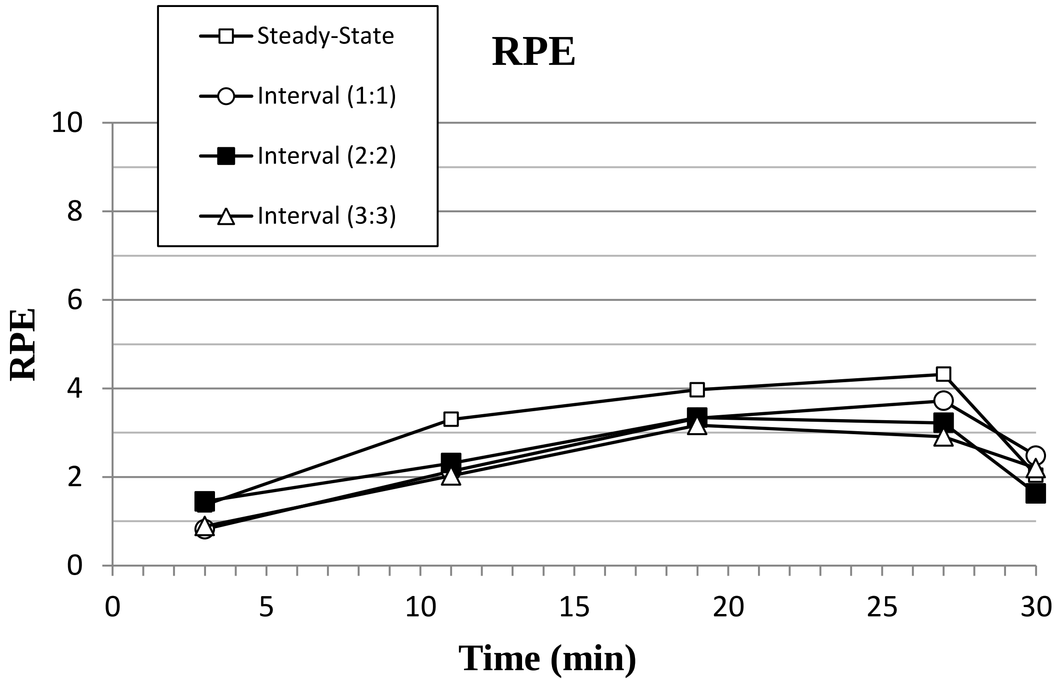

Figure 4. RPE during steady-state and interval rides.

The subjects used the visual analog scale (Appendix B) during the ride to rate momentary exertion. The visual analog scale is of a range from 0 to 10 centimeters. The results are visualized in Figure 4. Subjects rated momentary exertion immediately after the 3-minute warm-up, every 8 minutes into the ride, and at the completion of the 3-minute cool-down. The steady-state ride elicited the highest RPE of all rides at 11, 19, and 27 minutes.

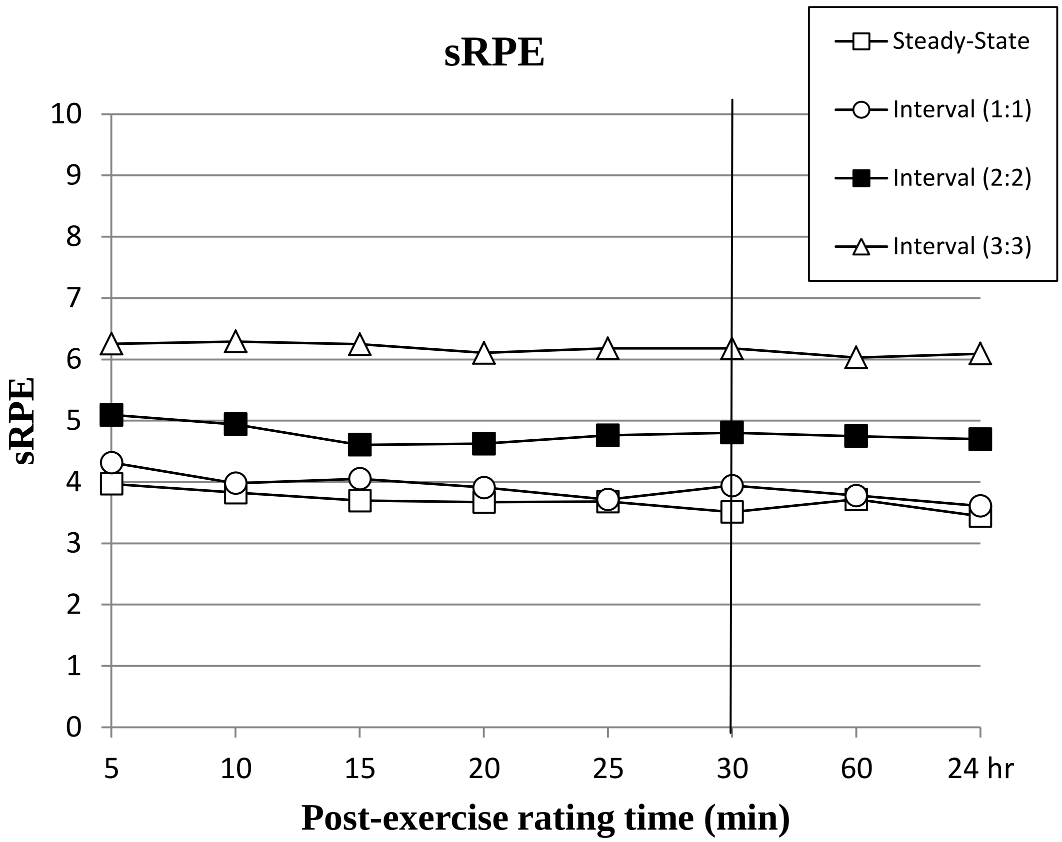

Figure 5. sRPE at different post-exercise times following steady-state and interval rides. The vertical line indicates the standard post-exercise rating time.

After completion of each ride subjects provided a sRPE at 5, 10, 15, 20, 25, 30, 60 minutes and 24 hours post-exercise. Subjects were asked "How hard was your ride?" The visual analog scale (Appendix B) was used to measure the sRPE. The results are graphically presented in Figure 5 and summarized in Table 2. No significant differences ($p > 0.05$) were found in sRPE at the various post-exercise times in any ride.

Significant differences ($p < 0.05$) in sRPE were found between ride types. Based on Tukey post-hoc analysis, sRPE differed significantly between the steady-state versus the 3:3 interval rides. The mean sRPE of the steady-state versus 3:3 interval rides were 3.7 ± 0.2 and 6.2 ± 0.1, respectively. Significant differences in sRPE were also found between the 1:1 interval versus the 3:3 interval rides. The mean sRPE were 3.9 ± 0.2 and

6.2 ± .1, respectively. Neither gender nor the interactive effect of gender and ride type had a significant effect ($p < 0.05$) on sRPE.

Table 2. sRPE at different post-exercise times following steady-state and interval rides.

	Steady-State	Interval (1:1)	Interval (2:2)	Interval (3:3)
Post 5	3.97 ± 1.42	4.31 ± 1.69	5.09 ± 1.47	6.25 ± 1.48
Post 10	3.82 ± 1.23	3.98 ± 1.68	4.94 ± 1.55	6.29 ± 1.50
Post 15	3.69 ± 1.47	4.05 ± 1.70	4.60 ± 1.41	6.24 ± 1.47
Post 20	3.67 ± 1.34	3.91 ± 1.67	4.62 ± 1.37	6.10 ± 1.63
Post 25	3.68 ± 1.28	3.71 ± 1.75	4.76 ± 1.44	6.18 ± 1.69
Post 30	3.51 ± 1.17	3.94 ± 1.98	4.80 ± 1.36	6.18 ± 1.54
Post 60	3.71 ± 1.60	3.78 ± 1.88	4.74 ± 1.41	6.03 ± 1.58
Post 24 hours	3.44 ± 1.44	3.61 ± 1.87	4.69 ± 1.39	6.09 ± 1.99

DISCUSSION

This study was designed to determine the effect of post-exercise rating time on sRPE. The same 15 subjects completed 4 different types of cycle exercise bouts, rating sRPE at 5, 10, 15, 20, 25, 30, 60 minutes and 24 hours post-exercise. The subjects were asked "How hard was your ride?" and were provided with a visual analog scale (VAS) to report the sRPE at each post-exercise time.

Commonly the category-ratio scale (CR10) is used when reporting the sRPE; however, one study showed that the VAS is interchangeable with the CR10. Minganti et al. (2011) used both the CR10 and the VAS to measure sRPE in research that quantified the training load in divers, finding that the CR10 and the VAS yielded sRPE that were significantly correlated.

Given the proximity of post-exercise times in which the sRPE was to be measured, bias was a large concern in the initial design of the experiment. For this reason, the VAS was used in place of the category-ratio (CR10) scale. This way, subjects would not have the opportunity to memorize the sRPE reported at antecedent post-exercise times.

Nonetheless, no significant differences were found in the sRPE of sequential post-exercise times in any ride. These results conflict with the theory that difficult or easy elements in the closing minutes of exercise may significantly influence sRPE for up to 15 minutes post-exercise. The closing minutes of exercise appear to have little significant influence on the sRPE at least in the context of aerobic interval training and with a brief cool-down period at the end of the exercise bout. Thus, these results indicate that the traditional method proposed by Foster et al. (2001) of waiting 30 minutes post-exercise to measure sRPE is unnecessary and that sRPE may be obtained without particular attention to post-exercise time.

The present results are contradictory to the findings of Singh et al. (2007) and Kilpatrick et al. (2009). Singh et al. reported that sRPE at both 5 and 10 minutes post-exercise was significantly different than at 30 minutes post-exercise. These differences were found after completion of 1-repetition maximum testing (1-RM) in 5 resistance training exercises. The 1-RM testing was maximal intensity anaerobic exercise, and this differed from the present study in which the highest-intensity intervals were designed to be 75% of the work achieved at a subject's maximal aerobic capacity (e.g. aerobic intervals).

Kilpatrick et al. (2009) assessed the relationship between perceived exertion before, during, and after 30 minutes of light, moderate, and vigorous treadmill exercise. The sRPE was measured immediately after the exercise cool-down and at 15 minutes post-exercise. These sRPE measures were then compared to 6 RPE measures taken during exercise as well as to the average of all 6 RPE measures taken during exercise. It was found that the sRPE both immediately after cool-down and at 15 minutes post-exercise were significantly greater than the average of RPE measures taken during the moderate and vigorous exercise. The average of RPE measures taken during exercise has been shown to be consistent with the sRPE taken 30 minutes post-exercise (Day et al., 2004).

Furthermore, Kilpatrick et al. (2009) found no significant differences when comparing the post-exercise ratings to the RPE of the final minute of the vigorous exercise bout, and no significant differences were found between the sRPE immediately after cool-down and the RPE of the final minute of the moderate or light exercise bout. Kilpatrick et al. concluded that the sRPE is influenced for at least 15 minutes post-exercise primarily by the closing minutes of moderate to high-intensity exercise.

One possible explanation for this conflict with the previous literature is that the present study did not elicit intensity high enough to create immediate post-exercise effects on the sRPE. The 3:3 ride produced the highest sRPE of any ride. This is visualized in Figure 5. However, even in this ride the sRPE was a mean of 6.2 ± 0.1 on a scale—the VAS—of 10 cm, equivalent of a 6 on the CR-10 scale, placing the perceived exertion of the ride between the anchors "hard" and "really hard." This is not a maximal effort as was the case in the study conducted by Singh et al. (2007). In the present study, even at the high-intensity aspect of the interval rides—75% of PPO—subjects still had a large cardiovascular reserve.

A second possible explanation is related to the design of the experiment. At the completion of each ride subjects continued to pedal for an additional 3 minutes at 25 W. This was considered a cool-down period. Immediately after the cool-down period the post-exercise timer began. Due to this design, the first post-exercise sRPE in the steady-state ride was measured 8 minutes after subjects completed riding at the steady-state intensity. In order to match the work-to-rest ratio of the interval rides—the number of high-intensity aspects to the number of active-recovery aspects—each of the 3 interval rides were concluded with an active-recovery aspect. This active-recovery aspect was then followed by the 3-minute cool-down at 25 watts after which the post-exercise timer began. Due to this design the first sRPE was measured 9 minutes, 10 minutes, and 11 minutes after completion of the last high-intensity aspect of the ride in the 1:1, 2:2, and 3:3 rides, respectively. Therefore, the particularly hard aspects of each ride were distanced from the first sRPE rating due to the design of the experiment. Because the previous research by Singh et al. (2007) and Kilpatrick et al. (2009) primarily observed differences in the sRPE immediately after exercise, this may explain why no significant differences were observed in the present study. However, Kilpatrick et al. also began the post-exercise timer after an active cool-down period.

Further research is needed to clarify whether particularly hard aspects in the final minutes of an exercise bout influence the sRPE. Research should measure the sRPE at frequent time intervals, focusing on securing a sRPE immediately post exercise (IPE) regardless of whether an active cool-down is to be performed. It is also unknown whether the nature of recovery—active or passive—affects the sRPE.

Although no meaningful differences in sRPE were observed between post-exercise times, a subsidiary finding was the observance of significant differences in sRPE between ride types. The sRPE of both the steady-state and 1:1 rides differed significantly from the sRPE of the 3:3 ride. These results support previous research that has shown the sRPE to be significantly different between varied protocols of the same exercise modality. In a study conducted by Day et al. (2004) subjects completed 3 different resistance training protocols at 50%, 70%, and 90% 1-RM. Each protocol consisted of a different number of repetitions. Due to the differences in number of repetitions, the greatest total workload was the low-intensity 50% 1-RM protocol. Objective intensity was defined as percentage of 1-RM. The sRPE of the 90% 1-RM protocol was significantly greater than the 70% and 50% 1-RM protocols. The sRPE of the 70% 1-RM protocol was significantly greater than that of the 50% 1-RM. This demonstrated that the sRPE associated with resistance training is directly proportional to exercise intensity and independent of total workload.

Sweet et al. (2004) found a similar trend in sRPE associated with cycling bouts of different intensities. Sweet et al. had subjects complete 3 steady-state rides of a 30 minute duration on a cycle ergometer at 70%, 90%, and 110% of VT. The sRPE increased in an ascending pattern as the intensity between rides increased. Intensity was defined as the percentage of VT.

It has been proposed that the mechanism responsible for this effect is related to motor unit recruitment and firing rate. As motor unit recruitment and firing rate increase the motor cortex sends proportionally stronger signals to the sensory cortex. This mechanism is thought to increase perceived exertion (Noble & Robertson, 1996; Suminski et al., 1997; Gearhart et al., 2001; Lagally et al., 2001; Day et al., 2004).

This mechanism makes sense in terms of increasing sRPE proportionally to the intensity of resistance training. Greater percentages of 1-RM are heavier loads which would necessitate increased motor unit recruitment and an increased firing rate. But does this mechanism make sense for the present study? Increased motor unit recruitment and firing rate may occur in fatiguing muscle.

In the present study each ride represented a constant-load which had to be matched by the subject. If fatigue did occur, to maintain the power output necessary to match the constant-load applied by the cycle ergometer either an increased number of motor units would have to be recruited or an increase in firing rate would have to occur so to compensate for the fatiguing units. Significant differences in sRPE were observed between the steady-state and 1:1 rides when compared to the 3:3 ride, with the 3:3 ride yielding the highest sRPE. The high-intensity aspect of the 3:3 ride may have been long enough in duration to elicit muscle fatigue of a magnitude significantly greater than in either the steady-state or 1:1 rides.

Indeed, the blood lactate levels reported in the 3:3 ride were consistently 2 mmol/L and 4 mmol/L greater than the 1:1 and steady-state rides, respectively. Increased blood lactate is often associated with fatigue. The mechanism responsible is referred to as the accumulation hypothesis (George & MacLaren, 1988). Lactate is generated by working muscles faster than it is removed, accumulating in the blood and stalling metabolic pathways responsible for generating adenosine-triphosphaste (ATP). Insufficient ATP leads to fatigue.

Overall, the mean sRPE of the 4 rides increased in ascending order from steady-state to 3:3. This makes sense given the proposed mechanism for changes in perceived exertion and the role of fatigue in motor unit recruitment. In this study blood lactate levels increased in the same ascending pattern as sRPE, indicating that the duration of the high-intensity aspect of intervals is proportional to the magnitude of fatigue, the number of motor units recruited, and sRPE.

CONCLUSION

This study found no meaningful effect of post-exercise time on sRPE after steady-state and interval cycling bouts. The data indicates that the original suggested guideline to report the sRPE 30 minutes after exercise is unnecessary. The sRPE is so robust that it is unaffected by time.

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APPENDIX A

INFORMED CONSENT

1. INFORMED CONSENT FOR "Pacing Strategy in Athletes: Test of a Model"

2. I, ___________________, give my informed consent to participate in this study designed to evaluate performance during time trials in relation to pacing strategies identified by a mathematical model of human energy expenditure. I have been informed that the project is under the direction of Carl Foster, Ph.D., who is a Professor in the Department of Exercise and Sport Science at the University of Wisconsin-La Crosse, although other professional persons or students may act for him. I consent to the presentation, publication and other release of the summary data from the study which is not identifiable with myself.

3. I have been informed that my participation in this study will involve my completing one or more visits to the Human Performance Laboratory (MH 225) at UW-La Crosse or to a venue close to where I train. During each of these visits I may complete an incremental exercise test on a cycle ergometer or treadmill, a training session on the cycle or treadmill or a cycle or treadmill time trial. During the time trial, I will exercise according to directions provided by the investigators and complete the trial as rapidly as possible. Most of the trials will be very much like competitive time trials that I might compete in as part of my athletic career. During the trials my metabolic rate will be measured by breathing through a facemask and I may have small samples of blood obtained from my fingertip.

4. I have been informed that the known or expected discomforts to be expected are fatigue from the exercise tests or training and sore fingers from the blood sampling. I have been informed that the risk of complications during exercise test in patients suspected of having heart disease is about 6/10,000 tests for minor complications and 1110,000 tests for serious complications (e.g. cardiac arrest). For prospectively healthy, athletic individuals like myself the risk is thought to be much less (approximating zero), but is less well documented simply because complications are so rare.

5. I have been informed that the primary benefit that I might expect from participating in this study is a better understanding of my performance characteristics and guidelines that may help me individualize my training.

6. I have been informed that there are no "disguised" procedures in the study. All procedures can be taken at face value.

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

8. I have been informed that I am free to withdraw from the study at any time without penalty.

9. Concerns about any aspects of the study may be referred to Dr Foster at 608 7858687 (work), Questions regarding the protection of human subjects may be addressed to the chair of the UW-La Crosse Institutional Review Board at (608) 785 8161

Investigator__________ ___________Participant______________ __________________Date__________

Signature________________________Signature__________________________________Date_________

Parental signature for minors ____Date_________

APPENDIX B

VISUAL ANALOG SCALE

Rest ———————————— Maximal

Subject #: ____________

Rating Time: ____________

Ride Type: ____________

APPENDIX C

REVIEW OF LITERATURE

REVIEW OF LITERATURE

This document aims to review the literature regarding the use of Rating of Perceived Exertion (RPE) scales as tools to assess intensity across different modes of exercise. The historical development of the RPE scale will be traced from its inception as a single scale to its differentiation into variants. Supplemental literature that has assessed the reliability, validity, and correlation of RPE scales to objective measures of intensity will be examined.

Ratings of Perceived Exertion

Swedish psychologist Gunnar Borg (1973) observed that "There are two ordinary things in a man's life that make his heart beat faster: walking up stairs and watching pretty girls." This observation highlights the genesis of research associated with subjective RPE scales. Borg understood that physiological variables alone did not paint the whole picture of exercise intensity. Psycho-physical scales, Borg argued, had the capacity to account for both physiological responses and the psychological costs of work, effectively integrating the body's peripheral and central signals into a gestalt interpretation of intensity (Borg, 1982; Robertson, 1982; Noble & Robertson, 1996). Scales of this nature would be useful tools in a number of settings, including clinical diagnosis, assessment of functional capacity, and exercise prescription (Borg, 1973; Borg, 1982; Borg, 1998).

Thus, Borg's first studies focused on subjective perceptions of work during cycling bouts of less than one minute. He found that subjective perceptions of the pedal resistance followed a positively accelerating function as resistance was increased linearly. This was confirmed in subsequent trials of longer exercise durations (Borg, 1973). However, Borg's intent was to be able to apply his findings to practice, a simple tool that could be utilized by anyone to assess exercise intensity was called for.

The Borg RPE Scale

Borg established a twenty-one point category scale, capable of estimating intensity directly at any given moment. The use of a category scale was a departure from early psycho-physical scaling that utilized purely ratio scaling. Ratio scaling was effective at measuring functions across an entire group; however, it was anchored to no standard scale for comparisons between individuals. Borg's use of a category scale enabled comparisons between individuals to be made. In his first twenty-one point category scale ratings were anchored to verbal cues such as "hard," "light," or "very light." Consequently, if one person rated a given workload as "hard" and a second individual rated the same workload as "very light," it was clear that the workload for the first individual was more difficult than for the second (Borg, 1982). Thus, Borg's use of a twenty-one point category scale was an important development in psychophysical scaling.

Additionally, the original twenty-one point category scale was shown to produce positive correlations with heart rate (HR) between 0.80 and 0.90. However, to produce stronger linearity to heart rate, Borg modified this twenty-one point category scale to a fifteen-point category scale known today as the Borg RPE scale. It was thought that at any given RPE on the 15-point scale, HR should be approximately ten times that value (Borg, 1973; Borg, 1982).

Next, important research by Eston & Williams (1988) and Dunbar et al. (1992) demonstrated that the Borg RPE scale could be used to effectively produce desired intensities in parallel to target HR or target oxygen consumption (VO_2). In both studies, subjects were given a previously estimated RPE value that had been measured against HR and VO_2, and were told to produce that same level of intensity in a new trial. This technique would, in theory, demonstrate the usefulness of RPE in exercise prescription.

Eston & Williams (1988) had subjects cycle at self-adjusted workloads over multiple trials based on their perceptions of 9, 13, and 17 on the Borg RPE scale. Once steady-state was achieved at each self-adjusted workload, VO_2 and HR were measured and juxtaposed to a control trial in which RPE had been estimated against VO_2 and HR. The results indicated that both males and females produced a similar %VO_2max at each RPE level—9, 13, and 17. Likewise, there was a strong correlation coefficient between objective measures across trials, indicating that the Borg RPE scale could be used reliably to produce desired exercise intensities. Dunbar et al. (1992) showed similar results when asking subjects to produce intensities based on RPE values associated with 50% and 70% of VO_2max during treadmill and cycling exercise. Overall, it was observed that no more than a 2% difference occurred between the RPE-produced intensity and the target VO_2.

The Borg CR10 Scale

From the earliest psycho-physical scaling studies it was evident that central signals such as HR and VO_2 were not the only mediators of RPE. In fact, peripheral signals were considered to be of the largest significance, especially at higher intensities (Robertson, 1982). These peripheral signals also were observed to increase in a non-linear, positively accelerating fashion with increases in exercise intensity. For example, blood lactate was observed to increase as a positive accelerating function of exercise intensity (Noble, Borg, Jacobs, Ceci, Kaiser, 1983). This led to the development of the Borg CR10 scale. The Borg CR10 scale utilized ratio scaling to account for the non-linear growth of the perception of sensation, especially at higher intensities. It also utilized the notion of the category scale used in the 15-point Borg RPE scale, anchoring verbal cues to the scaled ratio numbers.

In a study published in 1983, Noble et al. examined the relationship between the Borg CR10 scale and HR, blood lactate, and muscle lactate in subjects who cycled to voluntary exhaustion. The results confirmed the notion that heart rate increases in a linear fashion with intensity while both blood and muscle lactate were best expressed as non-linear functions of intensity. Borg, Van Den Burg, Hassmen, Kaijser, & Tanaka (1987) confirmed these observations in a study examining the relationship between HR, blood lactate, and RPE in cycling, running, and walking exercise modalities. HR increased nearly linearly with cycling and running while blood lactate was observed to positively accelerate in all modes of exercise.

Later, Suminski et al. (1997) obtained similar results when examining RPE as assessed by the Borg CR10 scale during resistance exercise. In this study, subjects completed two trials of multiple resistance exercises. Exercises of the first trial used resistance at 70% of one-repetition maximum (1-RM), whereas exercises of the second trial used resistance at 50% of 1-RM. Suminski et al. found that resistance exercises at 70% of 1-RM produced significantly higher average blood lactate values and RPE values than resistance exercises at 50% of 1-RM. Interestingly, the difference in HR between trials was not significant. This indicated that blood lactate may be a better indicator of increases in absolute intensity than HR.

Today, both the 15-point Borg RPE scale and the Borg CR10 scale are frequently utilized in a number of clinical, research, and performance settings, and still the notion of RPE scales has continued to evolve as the measurement of exercise intensity presents new challenges.

The OMNI Scale

One such evolution of the RPE scale has been the development of pictorial anchors to be paired with the traditional verbal anchors. This type of RPE scale, referred to as the OMNI category scale, was developed out of the concern that children have difficulty understanding verbal anchors associated with feelings of exertion (Robertson et al., 2000). The OMNI category scale utilizes a ten-point category scale. Robertson et al. (2000) examined the validity of the OMNI category scale in a cohort of children. Subjects—children—rode a cycle ergometer and estimated varying workloads using the ONMI category scale. As expected, the reported RPE values were a linear function of both HR and VO_2. These results made sense given the earlier observations by Borg (1973; 1982) that HR and VO_2 followed category RPE scales in a linear fashion. This OMNI category scale was then extrapolated and validated in populations of exercising adults (Robertson et al., 2003; Utter et al., 2004).

The Session RPE

A second evolution of Borg's original RPE scaling models, and central to the purpose of the present research project, is the concept of Session RPE. Session RPE first appeared in the literature in 1995 as Foster et al. examined the specific versus cross-training effects on running performance. Foster et al. needed a way to quantify the intensity of an entire given exercise session in order to hold training doses constant between trials. Because of the difficulty in obtaining objective measures of intensity such as HR or VO_2, and due to the incompetence of HR at representing intensity during intervals of high intensity, subjects were instructed to use Borg's CR10 scale to give a global rating of the intensity of the entire exercise bout. This value was multiplied by the duration of the bout in minutes to produce a training impulse score. Thus, Session RPE seemingly simplified the challenge of measuring the overall intensity of any given dose of exercise. Furthermore, the development of Session RPE made it possible for any athlete or coach with nothing more than a wristwatch to quantify doses of exercise training with accuracy.

In the seminal study, Foster et al. (1995) analyzed the relationship between Session RPE, percent heart rate reserve (%HRR), and time spent within common blood lactate training zones during both steady-state and interval exercise. The results indicated that Session RPE followed a course similar to %HRR and blood lactate. The same correspondence was observed in a second study by Foster et al. (2001). In this second study, Foster et al. used two different groups of subjects. One group completed eight different cycling training bouts, consisting of steady-state and interval work. The second group was monitored during basketball practices and games. In both groups, HR, blood lactate, RPE, and Session RPE were recorded. In spite of the differences between groups, the relationships between the measured variables were very strong. This was strong evidence that the usage of Session RPE to calculate a training impulse score was valid across a number of different exercise modalities.

Reliability and Validity of Session RPE

Literature has assessed the use of Session RPE to help quantify training loads in sports such as soccer. One study sought to assess the correlation of Session RPE modeled training loads with other methods such as HR response (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). For seven weeks within a competitive season soccer players' training was monitored. Average HRs and Session RPEs were recorded for each bout and training impulse scores were calculated based on three common HR methods and the Session RPE method. Impellizzeri et al. found that correlations between the methods ranged from 0.50 to 0.85. It was suggested that the moderate correlations may be attributable to anaerobic contributions to the exertion associated with soccer. For this reason, Impellizzeri et al. recommended that Session RPE may potentially be more sensitive than HR at assessing performance related phenomena such as fatigue. Consequently, Session RPE was supported by this study as an effective tool to monitor exercise training in soccer.

Likewise, Wallace, Coutts, Bell, Simpson, & Slattery (2008) also supported the application of Session RPE, this time to measure the training load in swimmers. More than 160 individual training sessions were assessed over a 4-month training period and training impulse scores were juxtaposed between three common HR methods and the Session RPE method. Correlations between the HR methods and the Session RPE method ranged from 0.74 to 0.77. Again, the moderate correlation was justified by the logic that HR methods underestimate the intensity of high intensity interval sessions of an increased anaerobic nature. Furthermore, Wallace et al. (2008) reported that swimming coaches often prescribe these types of exercise bouts. Thus, Session RPE would be more effective than HR methods at quantifying training loads in swimmers.

Recently, Minganti, Capranica, Meeusen , Amici, & Piacentini (2010) concluded that the training load in a given session of teamgym could be effectively quantified by Session RPE. This was based on three 120-minute training sessions of ten elite female teamgym athletes. Heart rate was recorded continuously throughout the bout and the average HR of the bout was used to calculate a training impulse score. Session RPE was also measured in each trail, used to calculate training impulse, and then the training impulse scores of the objective and subjective methods were compared. The results revealed correlations of 0.77-0.92 between the HR and Session RPE methods.

Furthermore, Milanez et al. (2011) examined how Session RPE related to the same objective measures of intensity during a karate training session. National and international level athletes skilled in the ways of karate completed one session of controlled karate techniques and sparring. Heart rate, blood lactate, RPE, and Session RPE were recorded. The results showed significant relationships between Session RPE and the mean values of blood lactate, %HRmax, %HRR, and RPE, also suggesting that Session RPE has a high level of validity.

In other research, Day, McGugian, Brice, & Foster (2004) monitored the exercise intensity of resistance training by Session RPE. Subjects completed high-, moderate-, and low-intensity resistance training protocols a total of two times each. The intensity was determined as a %1-RM. Thirty-minutes following each session, subjects rated the intensity of the entire bout. Not only did Day et al. find that lifting fewer repetitions of heavier weight was perceived as easier than more repetitions of lighter weight, but

Session RPE was found to be a consistent value across two different trials of equal intensity. This demonstrates the reliability of Session RPE as a method to monitor resistance training exercise.

In the same year, Sweet, Foster, McGuigan, & Brice (2004) compared changes in Session RPE to changes in $\%VO_2peak$ in cycling exercise and %1-RM in resistance training. Subjects completed three 30-minute steady-state trials on a cycle ergometer equivalent to 70%, 90%, and 110% of their measured ventilatory thresholds. Session RPE was recorded 30-minutes post-exercise. The same subjects performed three resistance training bouts. The trials consisted of exercises at resistances of 50%, 70%, and 90% of 1-RM, respectively. Again, Session RPE was reported 30-minutes post-exercise. Sweet et al. found that a strong agreement existed between comparable intensities—percentages of maximal effort—of the cycling and resistance training groups with Session RPE.

Next, in 2007, Singh, Foster, Tod, & McGuigan evaluated different types of resistance training as monitored by the Session RPE. Subjects completed three different resistance training protocols, designed with specific quantities of sets and repetitions so as to elicit strength, hypertrophy, or power. Resistances for each protocol were determined as a subject’s given %1-RM. RPE using the Borg CR10 scale was assessed after each set, culminating in an overall average RPE for the entire session. Session RPE was reported at 5-minute intervals until 30-minutes post-exercise. The results demonstrated a significant difference between the average RPE values and Session RPE values of the strength and hypertrophy protocols; however, the power protocol produced no difference. Likewise, a significant difference in Session RPE was observed at 5- and

10-minutes post-exercise when compared with 30-minutes post-exercise. This pointed to the possibility that difficult elements at the end of the exercise bout may bias the Session RPE for some time immediately after exercise.

In spite of the growing amount of literature in support of Session RPE as a valid tool for assessing global exercise intensity for a given bout, questions regarding post-exercise rating time on Session RPE have not been sufficiently addressed. Originally, Foster et al. (1995) chose to rate the Session RPE 30-minutes post-exercise. This time frame wasn't chosen based on any scientific evidence. Rather, 30-minutes post-exercise was chosen because it was assumed to be enough time post-exercise to prevent the end of the previous exercise bout from influencing the subject's rating (Foster et al., 2001).

Only one study has seriously examined Session RPE at different time intervals post-exercise (Singh et al., 2007). This study examined only resistance training exercise and it measured Session RPE at 5-minute intervals for only 30-minutes post-exercise. Significant differences were observed between Session RPE values at 5- and 10-minutes post-exercise as compared to 30-minutes post-exercise. These findings appear to support the notion that the perceptions of exercise intensity immediately after an exercise bout are skewed by specific elements at the end of the bout, whereas perceptions of intensity at 30-minutes post-exercise are unaffected. However, Kilpatrick, Robertson, Powers, Mears, & Ferrer (2009) raised more doubts about the specific Session RPE rating time post-exercise, finding that Session RPE 15-minutes post-exercise persisted to reflect the end of the exercise bout as opposed to reflecting a global value of the bout. Unfortunately, this study did not measure Session RPE at 30-minutes post-exercise.

Summary

In practical applications of exercise and sport science, quantifying the training load of an individual is catamount to understanding the relationship between exercise prescription and performance outcomes. The American College of Sports Medicine (2010) has characterized this as a dose-response relationship. Measurement of the response is as simple as observing the performance outcomes themselves; however, measurement of the exercise dose is more complicated. It is generally accepted that exercise dosage—training load—is a combination of exercise duration and intensity. Thus, the displayed reliability and validity of Session RPE indicate that it has a promising future in applied circumstances.

However, the effect of post-exercise rating time on Session RPE remains unclear. Absolutely nothing is known about what happens to Session RPE at 60-minutes post-exercise, nor are the dynamics of Session RPE at post-exercise time intervals after steady-state, incremental, and various interval sessions following non-resistance training modalities clear. Consequently, the effects of post-exercise rating time on Session RPE must be a question of further investigation.

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