MONITORING WORK INTENSITIES DURING RESISTANCE TRAINING USING A SESSION RPE SCALE

A MANUSCRIPT STYLE THESIS PRESENTED

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MASTER OF SCIENCE DEGREE

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ABSTRACT

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This study investigated the reliability of the session RPE scale to quantify work during high intensity (HIP), moderate intensity (MIP), and low intensity (LIP) resistance training. Nine men (24.7 ± 3.8 years) and 10 women (22.1 ± 2.6 years) performed each intensity twice. Each protocol consisted of one set of five exercises: back squat, bench press, overhead press, biceps curl, and triceps pushdown. The HIP consisted of 4-5 repetitions at 90% of the subject's 1 repetition maximum (1-RM). The MIP consisted of 10 repetitions at 70% 1-RM and the LIP consisted of 15 repetitions at 50% 1-RM. RPE was collected following the completion of each set and thirty minutes post-exercise (session RPE). Session RPE was higher for the HIP than MIP and LIP ($p<0.05$). Performing fewer repetitions at a higher intensity is perceived to be more difficult than performing more repetitions at a lower intensity. The intraclass correlation coefficient for the session RPE was 0.88. The session RPE is a reliable method to quantify various intensities of resistance training.

COLLEGE OF HEALTH, PHYSICAL EDUCATION, RECREATION, AND

TEACHER EDUCATION

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THESIS FINAL ORAL DEFENSE FORM

Candidate: Meghan Lee Day

We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

Master of Science in Human Performance

The candidate has successfully completed the thesis final oral defense.

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Thesis Committee Chairperson Signature	Date
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This thesis is approved by the College of Health, Physical Education, Recreation, and Teacher Education.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

The Borg Rating of Perceived Exertion (RPE) scale was developed to enable reliable and valid estimations of exercise intensity (2,18). Widely accepted as a method of quantifying aerobic exercise intensities, perceived exertion has been used infrequently in resistance exercise prescription (13). Gunnar Borg based the RPE scale on the idea that a measure of perceived exertion is the level of strain and/or heaviness experienced during physical effort as estimated by a specific rating method (2). Since the unveiling of the original scale over forty years ago, the CR-10 RPE scale has become a standard method to evaluate perceived exertion in exercise testing, training, and rehabilitation (2).

The RPE scale is used in exercise science primarily to monitor exercise intensity and is most often used as a method to quantify work intensities during aerobic training (6,7,18). Commonly utilized to monitor perceived exertion during specific stages of exercises, Foster et al. (6) developed the idea of using a "session RPE" scale to quantify an entire aerobic exercise session. The findings of Foster et al. (6) indicated that the session RPE scale is an effective method of quantifying exercise through a wide variety of exercise types. Gearhart et al. (8) provided additional evidence of the effectiveness of the Borg scale, which extended the use of the RPE scale to resistance exercise.

Studies have shown that the Borg CR-RPE scale is an effective method of measuring perceived exertion during resistance training (4,9,11,15,17). Additionally, the session RPE method has been shown to be an effective method of quantifying entire aerobic exercise bouts (6). However, no research has been conducted as to the

effectiveness of the session RPE method as it relates to perceived exertion during an entire resistance training workout.

The importance of monitoring exercise training load and intensity during resistance training is an integral part of a successful periodized exercise plan since careful manipulation of intensity, volume, and recovery phases is vital for optimal results (1,5). The effects of training are related to the type of exercise used, its intensity, and its volume (1). High intensity exercise such as resistance training is particularly difficult to quantify as this type of exercise cannot be objectively evaluated using heart rate measurements (6). This problem supports the need for a valid and reliable method of monitoring training intensity, such as the session RPE method. This method would allow for easy and reliable resistance training program manipulations required for continued increases in strength (1).

The purpose of this study was to evaluate the effectiveness of the session RPE method as a tool to quantify work during resistance training sessions. A secondary purpose of the study was to determine the reliability of the session RPE method of quantifying resistance training. In addition, this study was also designed to support the findings of Gearhart et al. (8) in which performing fewer repetitions using heavier weight was perceived as more difficult than lifting lighter weight with more repetitions.

It was hypothesized that work intensity throughout an entire resistance training session can be successfully quantified through the use of a session RPE scale. Additionally, performing fewer repetitions using a heavier weight was expected to be

perceived to be more difficult than lifting comparatively lighter weight with more repetitions.

METHODS

Experimental Approach to the Problem

A randomized, crossover experimental design was used for this study. Each subject participated for a total of seven days, six of which were spent completing a high, moderate, and low intensity weightlifting protocol (i.e., HIP, MIP, and LIP respectively). Each protocol was performed twice to establish reliability of the RPE measurements. Day One consisted of a familiarization session that included informed consent procedures, instruction on how to use the CR-10 RPE scale and its perceptual anchors (high and low), demonstration of each exercise, one repetition maximum (1-RM) testing of each of the five exercises, and body composition analysis. An individual's 1-RM was defined as the heaviest weight that could be used for one complete repetition of an exercise (5). Each subject performed multiple sets of each exercise at sub-maximal resistance with step-wise increases in resistance until he/she could perform the lift with the maximal amount of resistance for one repetition. The 1-RM for each exercise was used during the testing to determine the weight each participant was required to lift for each exercise. Each weightlifting protocol consisted of the five exercises listed in Table 1. One session was completed each day with at least 48 hours between sessions. Subjects were randomly assigned to the order they completed each of the training intensities.

Table 1. Order of Exercises and Corresponding Repetitions for High, Moderate, and Low Intensities

Exercise	Sets	HIP Repetitions	MIP Repetitions	LIP Repetitions
Back Squat	1	4-5	10	15
Bench Press	1	4-5	10	15
Overhead Press	1	4-5	10	15
Biceps Curl	1	4-5	10	15
Triceps Pushdown	1	4-5	10	15

Subjects

Twenty subjects were recruited for this study. Ten females (22.1 ± 2.6 years) and ten males (24.7 ± 3.8 years) volunteered as participants. Nineteen subjects successfully completed the entire experimental protocol with one male subject withdrawing due to an injury unrelated to the present study. Subjects were required to have had experience in resistance training for no less than six months, be familiar with the technique involved with the back squat and bench press and have no pre-existing injuries that would limit their participation. All subjects provided written documented informed consent and completed a health history questionnaire prior to participation in the study. All experimental procedures were approved by the Institutional Review Board for the Protection of Human Subjects of the University of Wisconsin–La Crosse prior to commencement of testing.

Exercise Protocol

Before completing each exercise of the HIP, MIP, and LIP, each subject performed an exercise specific warm-up consisting of eight repetitions with 15% of the individual's predetermined 1-RM (8). Following the warm-up set, the subjects performed the exercise according to the intensity and number of repetitions required for the session. This set was termed the "working" set. The training intensities and the corresponding number of repetitions are displayed in Table 1. The resistance for each exercise was set to the nearest five pounds of the appropriate percentage of each individual's 1-RM. During the HIP subjects were asked to complete five repetitions if they had not reached exhaustion upon completion of the fourth repetition. Each intensity was composed of one warm-up set and one working set of each exercise with a two-minute rest period between exercises (8).

Subjects were asked to rate their perceived exertion following the completion of each working set based on the CR-10 RPE scale. This scale is represented in Table 2.

Table 2. CR-10 RPE scale

Rating	Descriptor
0	Rest
1	Very, Very Easy
2	Easy
3	Moderate
4	Somewhat Hard
5	Hard
6	-
7	Very Hard
8	-
9	-
10	Maximal

Thirty minutes following each exercise session the subjects were asked to rate their perceived exertion for the entire resistance training session based on the same scale by answering the question "How was your workout?" (6). The session RPE rating was taken thirty minutes following the end of the session so that particularly difficult or easy elements toward the end of the session would not skew the subject's rating of the entire resistance training bout (6).

Instrumentation

All familiarization and testing sessions were completed in the Musculoskeletal Research Center at the University of Wisconsin–La Crosse. Body composition data was obtained via anthropometry (16). 1-RM testing and data collection were completed usin' the procedures previously described. RPE has been shown to be related to the percentage of 1-RM lifted during exercise (17). Additionally, the RPE scale has been shown to be a valid instrument in which to evaluate perceived exertion and thus the regulation and quantification of exercise intensity in a variety of populations (2,6,9,11,17).

Statistical Analyses

A two-way within subjects repeated measures analysis of variance (ANOVA) was to test for differences in RPE among the HIP, MIP, and LIP. Each subject's five RPE values were averaged and compared to his/her session RPE rating. These values were tested for significant differences as part of the within-subjects repeated measures ANOVA. This test was completed to identify if significant differences exist between the session RPE rating and the accumulated RPE ratings obtained during each resistance

training session. Interclass correlation coefficients (ICC) and coefficient of variation (CV) were calculated to establish the reliability of the session RPE method.

RESULTS

Descriptive characteristics of the subjects are presented in Table 3.

Table 3. Descriptive characteristics of subjects

	Male Mean ± SD (n = 9)	Female Mean ± SD (n = 10)
Age (years)	24.7 ± 3.8	22.1 ± 2.6
Height (cm)	180.8 ± 5.7*	168.7 ± 5.9
Mass (kg)	94.2 ± 21.1*	60.7 ± 4.9
Body fat (%)	14.5 ± 3.8*	20.8 ± 2.5
Squat 1-RM (kg)	148.2 ± 29.8*	71.4 ± 18.3
Bench 1-RM (kg)	122.7 ± 18.3*	44.1 ± 9.8
Press 1-RM (kg)	72.2 ± 11.2*	31.8 ± 5.5
Curl 1-RM (kg)	56.3 ± 5.7*	28.6 ± 4.2
Pushdown 1-RM (kg)	100.8 ± 6.2*	52.1 ± 8.8

*Denotes significant difference between genders ($p<0.05$)

The trial 2 mean RPE values for each exercise and the trial 2 average and mean session RPE values were calculated for the three work intensities. These values are found in Table 4 and represented in Figures 1 and 2. A within-subjects repeated measures ANOVA showed a significant difference among the mean RPE values of each intensity ($p<0.05$) for each lift. The 70% intensity RPE values were significantly higher than the 50% intensity RPE values and the 90% intensity RPE values were significantly higher than the 50% and 70% intensities RPE values as displayed in Figures 1 and 2.

Table 4. Individual exercise, session, and average RPE values for high, moderate, and low intensities

Exercise	50% 1-RM Mean RPE ± SD	70% 1-RM Mean RPE ± SD	90% 1-RM Mean RPE ± SD
Squat	3.5 ± 1.5	4.9 ± 1.4	6.6 ± 1.9
Bench	3.2 ± 1.2	5.5 ± 1.2	7.7 ± 1.8
Press	3.9 ± 1.3	6.2 ± 1.6	7.2 ± 1.3
Curl	3.7 ± 1.6	5.8 ± 1.7	5.8 ± 1.7
Pushdown	2.8 ± 1.0	4.7 ± 1.1	6.8 ± 1.4
Average	3.7 ± 1.2	5.6 ± 1.3	6.9 ± 1.4
Session	3.3 ± 1.4	5.2 ± 1.5	6.9 ± 1.4

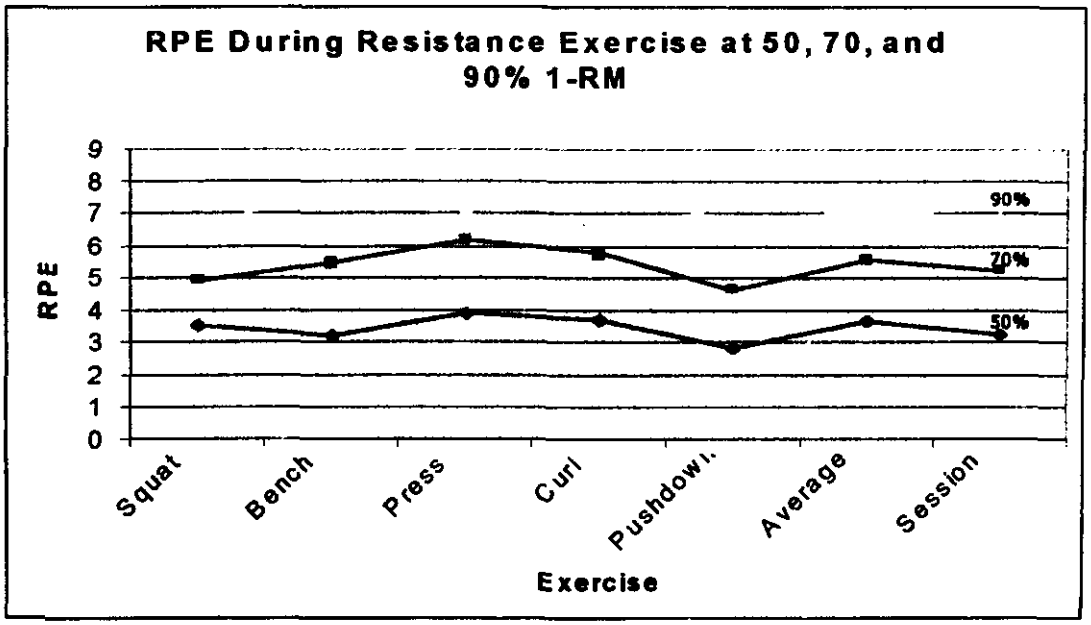

Figure 1. RPE during resistance exercise at 50, 70, and 90% 1-RM

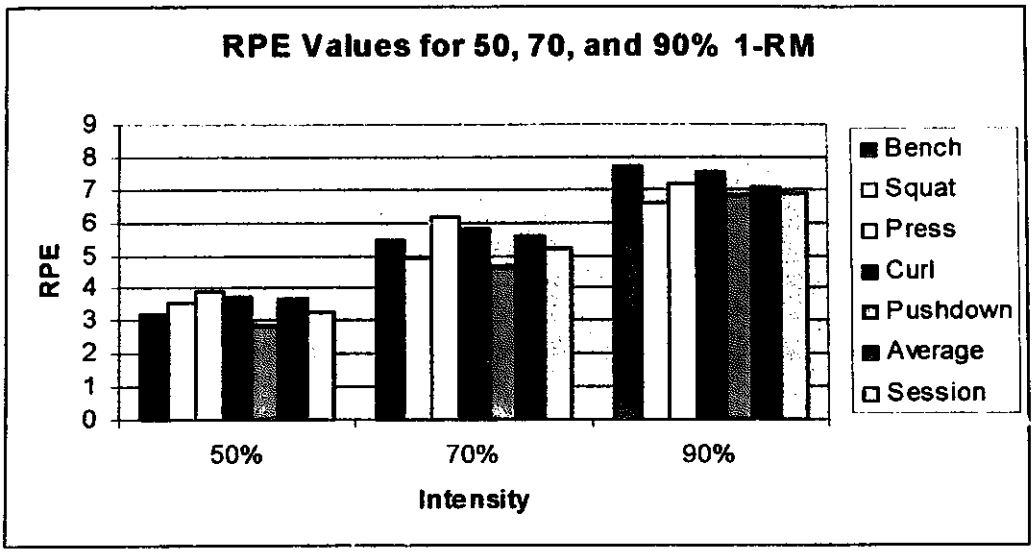

Figure 2. RPE values for 50, 70, and 90% 1-RM

The within-subjects repeated measures ANOVA revealed no significant difference between the average RPE value and the session RPE value during each intensity. Also, no significant differences were found between the mean bench press RPE value and the session RPE value and the mean back squat RPE value and the session RPE value for each intensity. Significant differences existed between the mean overhead press RPE value and the session RPE value, the mean biceps curl RPE value and the session RPE value, and the mean triceps pushdown RPE value and the session RPE value ($p<0.05$) for each intensity.

A test for reliability of the session RPE to predict the same value across two different trials of the same intensity was also performed. This data is represented in Figure 3. The ICC was 0.88 with the 95% confidence interval of 0.70-0.96. The CV was 14.5%.

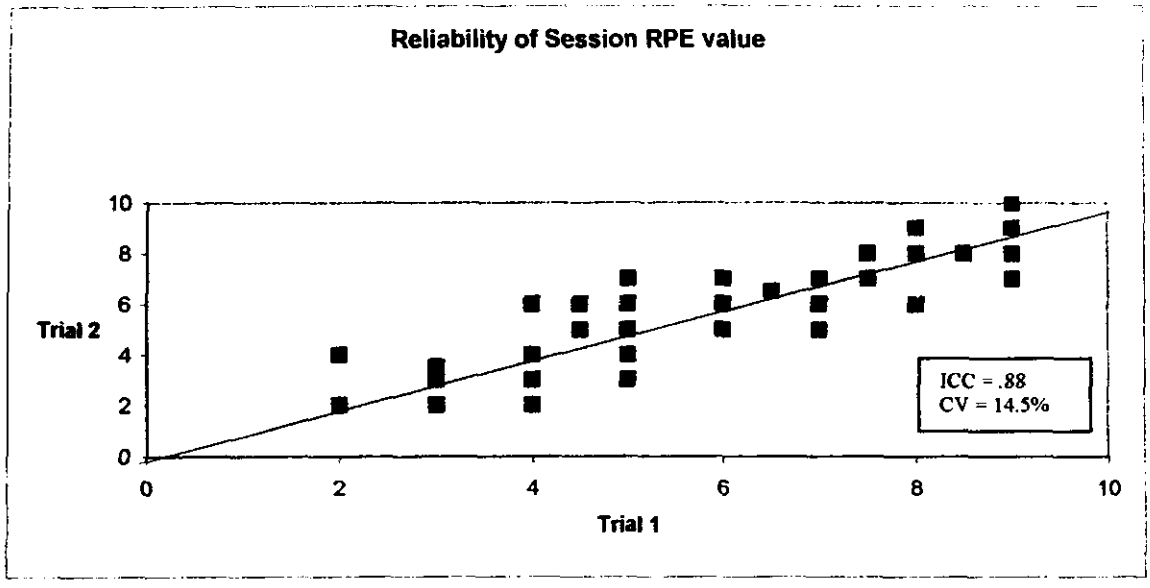

Figure 3. Reliability of session RPE value

DISCUSSION

The purpose of this study was to evaluate the effectiveness of the session RPE method as a tool to quantify work during resistance training sessions. This study was also performed to further validate the findings of Gearhart et al. (8) in which performing fewer repetitions of a heavier resistance was perceived to be more difficult than performing more repetitions of a comparatively lighter resistance. The results of the present study indicated that performing fifteen repetitions of a lighter resistance was perceived to be less difficult than performing ten and five repetitions of heavier intensities. Additionally, performing the least number of repetitions at the highest absolute intensity was perceived to be the most difficult when compared to a moderate number of repetitions performed at a moderate intensity and performing high repetitions at a low intensity. No significant differences were found when comparing the session RPE with each subject's average RPE. In addition, the session RPE method of

quantifying resistance training was shown to be a reliable measure across two different trials of the same training intensity (Figure 3).

Several studies have demonstrated the Borg scale to be an effective method of quantifying resistance training (4,9,11,15,17). Gearhart et al. (8) examined the RPE in active muscle (RPE-AM) during a high intensity (HIP) and low intensity (LIP) weightlifting protocol. Each protocol consisted of performing one set of each of seven exercises. The HIP involved lifting 90% 1-RM for five repetitions with RPE-AM values obtained following each repetition. The LIP involved lifting 30% 1-RM for fifteen repetitions with RPE-AM values obtained following every third repetition. This study found that performing fewer repetitions using heavier weight was perceived as more difficult than performing more repetitions of a lighter weight when total external work was held constant. Lagally et al. (11) examined the RPE during resistance training in women by having subjects perform three sets of the biceps curl exercise. Each subject was randomly assigned to the intensity she would complete first, 30%, 60% or 90% of 1-RM, performing 12, 6, and 4 repetitions, respectively. This combination of intensity and repetitions allowed for total work to be held constant. Data for the RPE-AM and overall RPE (RPE-O) were collected upon the completion of each set. This study also found corresponding increases in RPE-AM and RPE-O with increases in exercise training intensity. Suminski et al. (17) also examined the perception of effort during resistance exercise. This study involved seven exercises at 50% 1-RM and 70% 1-RM to fatigue. RPE-O was obtained immediately following each set. The researchers found the increase in intensity resulted in an increase in RPE-O, which supported the use of the Borg scale

for monitoring resistance exercise intensity (17). The results of the present study further support the findings of these previous studies in that performing few repetitions with a heavier weight is perceived as being more difficult than lifting lighter weights for more repetitions.

The experimental protocol of this study did not keep external work performed constant. The training intensities and their corresponding repetitions allowed for variation in the amount of work performed among intensities. Performing fifteen repetitions at 50% 1-RM is actually more total work than performing 70% 1-RM for ten repetitions or 90% 1-RM for four or five repetitions. The low intensity protocol produced the lowest RPE despite that this intensity required the most total work to be performed. This finding indicates the overriding importance of the intensity of training on RPE. Therefore, this indicates a fundamental similarity to the use of RPE with monitoring aerobic exercise.

As previously demonstrated, muscles forced to overcome a heavy load require greater tension development, which requires an increase in motor unit recruitment and firing frequency (8,12). For greater motor unit recruitment to be accomplished, the motor cortex may send stronger signals to the sensory cortex, this gives rise to increased perception of effort (8). It has been theorized that these stronger corollary signals may be the primary cause of the differences in RPE of varying intensities as shown by previous studies and the present study (3,8,11,12,17). The difference in RPE has also been observed in increasing intensities of aerobic cycling (14) suggesting that the increase in RPE demonstrated by this and several previous studies pertains not only to the anaerobic

energy system but to the aerobic energy system as well. Gearhart et al. (8) have proposed that something other than the energy system utilized during exercise influences an individual's RPE. This speculation prompts further investigation of the underlying mechanism that produces increasing RPE values for increases in exercise intensity and suggests electromyography to investigate the intensity at which the motor signal triggers an active muscle contraction (8).

The average RPE for each trial (i.e., average RPE of the five lifts) was compared to its corresponding session RPE value. A statistical analysis of this data found no significant difference between the two RPE values. Despite the vast use of the RPE scale during various modes of exercise, the session RPE method is a relatively new instrument with very few studies examining its ability to quantify entire bouts of exercise. This is the first study confirming the ability of the session RPE method to accurately complement an average RPE value during an entire bout of resistance training. The accuracy of the session RPE value to correspond with the average RPE given throughout the training session found in the present study supports the session RPE method as a valid method of quantifying entire bouts of resistance training intensity.

Foster et al. (6) examined the session RPE method as a tool to quantify exercise intensities during entire sessions of aerobic training. Their study compared the session RPE method to the summated heart rate zone method of quantifying aerobic exercise. Subjects either performed steady state and interval aerobic exercise on an electrically braked cycle ergometer or practiced basketball. For each type of exercise, the session RPE method was found to give a higher score than the summated heart rate zone method.

However, after regression analyses, the two methods were found to be highly correlated and suggested that either method can be used successfully to quantify training intensities for various modes of aerobic exercise. The results of the present study support the concept proposed by Foster et al. (6) in that the session RPE value was shown to accurately correspond to the average RPE value obtained throughout the resistance training session.

One of the primary concerns of the present study was to establish the reliability of the session RPE method to quantify entire bouts of resistance training. This was achieved by comparing the RPE value from trial 1 to the RPE value from trial 2 for each of the three training intensities. The ICC of 0.882 indicates the ability of the session RPE method to reproduce a near identical value between trials with a relatively high degree of accuracy. As previously stated, little research has been completed concerning the use of the RPE scale during resistance training. The establishment of reliability of the session RPE scale corresponds with the findings of Gearhart et al. (8) in which five subjects repeated exercises in each of the high intensity and low intensity protocols to evaluate the test-retest reliability of the RPE measure. The r values ranged from 0.73 - 1.00 for this data.

Based on the data, the session RPE method appears to be a reliable method of quantifying resistance training intensities. This was demonstrated by the corresponding increase in the session RPE value with an increase in training intensity. The session RPE value was also found to consistently match the average RPE during the training session,

further demonstrating the usefulness of this method when attempting to quantify resistance training bouts.

PRACTICAL APPLICATIONS

The results of this study have shown the session RPE method to be a reliable and useful tool for researchers, strength coaches, athletes, and recreational weightlifters to assess work intensity during resistance training. On the basis of the results of this study, the session RPE method can be considered a reliable technique to prescribe work intensities and provide for progressive increases in resistance. The existence of a session RPE scale would be of great significance to all those involved in resistance training. Through the use of a session RPE scale, one could choose an intensity at which to work (e.g., RPE 7) prior to the start of a workout and be confident that work intensities will stay within the "very hard" range. This would be much easier than having to use multiple measures of RPE throughout a workout. A session RPE scale would be an easy and effective method to prescribe work intensities for resistance training sessions as well as to provide for progressive increases in intensity that have been found to be necessary for continued increases in strength (1).

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APPENDIX A

PAR-Q HEALTH HISTORY QUESTIONNAIRE

Name:
Age:

Revised Physical Activity Readiness Questionnaire (PAR-Q)

YES	NO	
____	____	1. Has a doctor ever said that you have a heart condition and recommended only medically supervised activity?
____	____	2. Do you have chest pain brought on by activity?
____	____	3. Have you developed chest pain in the past month?
____	____	4. Have you on one or more occasions lost consciousness or fallen as a result of dizziness?
____	____	5. Do you have a bone or joint problem that could be aggravated by the proposed physical activity?
____	____	6. Has a doctor ever recommended medication for your blood pressure or heart condition?
____	____	7. Are you aware, through your own experience or a doctor's advice, of any physical reason that would prohibit you from exercising without medical supervision?

*If you answer "yes" to any of these questions, call your personal physician or healthcare provider before increasing your physical activity.

*If you answer no to all of the questions, you can be reasonably sure that you can:

- Start becoming more physically active---begin slowly and build up gradually
- Take part in a fitness appraisal

APPENDIX B

INFORMED CONSENT

UNIVERSITY OF WISCONSIN- LA CROSSE
MUSCULOSKELETAL RESEARCH CENTER
INFORMED CONSENT FORM

Name of Project: Monitoring work intensities during resistance training using a session RPE scale.

You are invited to participate in a study to investigate the effectiveness of a rating of perceived exertion scale to monitor the intensity of resistance exercise. The RPE scale is a ten category scale ranging from 0 (nothing at all) to 10 (almost maximal). If you decide to participate, we will ask you some general questions about your health, activity level, medications and diet. All volunteers will be required to participate in 7 individual testing occasions over a 4-week period. The tests involved will include: (1) maximal strength testing; and (2) two high, moderate, and low intensity resistance exercise sessions. All testing will take place in the Musculoskeletal Research Center in 13 Wittich Hall.

During each resistance exercise trial, you will perform either high, moderate, or low intensity resistance exercise. After a warm-up, you will perform one set of six different exercises. The exercise bouts are interspersed with two-minute recovery bouts. Following the completion of each exercise you will be asked to assign a numerical value to the intensity you feel you were working at during the exercise. Approximately thirty minutes following the completion of each workout you will be asked to assign a numerical value to the intensity you feel you were working at for the entire resistance training session. The total time commitment will be approximately 7 hours spread over a period of 4 weeks.

The procedures and circumstances encompassed in this protocol provide for a high degree of safety. This study has been carefully monitored and planned to avoid injury to the musculoskeletal system. Every effort will be made to make this investigation safe for your participation by familiarizing you with all procedures, including close supervision by experienced personnel and medical screening. This study has been approved by the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects. The specific risks associated with the study include muscle soreness, fatigue, cramping, or muscle strain with the strength testing and resistance training protocols. However, these risks are no greater than those present during any high intensity exercise.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. If you decide to participate, you are free to withdraw your consent and to discontinue participation at any time without prejudice. Questions regarding the protection of human subjects may be addressed to Dr. Dan Duquette, Chair, UW-La Crosse Institutional Review Board for the Protection of Human Subjects, (608) 785-8161. Questions regarding study procedures may be directed to Meghan Day (608) 782-4409 or Dr. Carl Foster (608) 785-8687.

Participation in all testing procedures and the training study itself is strictly voluntary. There is no charge for participation in this study. I have been informed that it is my responsibility to provide costs for any needed medical care as a result of an accident occurring due to my participation in this study. In the unlikely event that any injury or illness occurs as a result of this research, the Board of Regents of the University of Wisconsin System, and the University of Wisconsin-La Crosse, their officers, agents and employees, do not automatically provide reimbursement for medical care or other compensation. Payment for treatment of any injury or illness must be provided by you or your third-party payor, such as your health insurer or Medicare. If any injury or illness occurs in the course of research, or for more information, please notify the investigator in charge. I have been informed that I am not waiving any rights that I may have for injury resulting from negligence of any person or the institution.

I have been informed of the procedures involved in this study. I have been fully informed of the nature of the tests and potential risk involved. Participation in all testing procedures and the training study itself is strictly voluntary. There is no charge for participation in this study.

Subject:_____ Date:_____

Investigator:_____ Date:_____

APPENDIX C

REVIEW OF RELATED LITERATURE

REVIEW OF RELATED LITERATURE

Introduction

An athlete or member of the general population who engages in resistance training is often concerned with the intensity at which he/she is working. This is most often due to the fact that differing intensities and progressive increases in intensity are necessary for continued increases in strength (2). The need to monitor training intensity is also important to prevent overtraining and optimize the training-performance relationship (7). The Borg Rating of Perceived Exertion (RPE) scale is widely used to monitor aerobic work intensities (6,9,21). Use of this scale to evaluate work intensities during resistance training is limited with no studies attempting to use the RPE scale to quantify entire resistance training sessions.

This review is primarily focused on the use of the RPE scale in resistance training to establish how the session RPE scale could be implemented into a resistance training program. Few studies have utilized the RPE scale during resistance training. Several articles on the use of perceived exertion in aerobic exercise are reviewed to establish validity and reliability of the RPE scale to evaluate work intensity. Additionally, one study has been done on the use of the session RPE scale to evaluate entire aerobic workout sessions, which provides important background for this study. Articles utilizing various populations were also included to evaluate the effectiveness of the RPE scale to monitor work intensities in a wide range of age groups.

Effectiveness of RPE scale to Monitor Aerobic Exercise

Many methods of measuring training intensity during aerobic exercise exist including ventilatory threshold (VT), percentage of maximal oxygen consumption (VO_2 max), percentage of maximal heart rate, the Talk Test, and Rating of Perceived Exertion (19). Since its development in 1960, the Borg RPE scale has been used in both clinical and experimental settings to monitor exercise intensity (13). It has evolved to become a standard method to evaluate perceived exertion in exercise testing, training, and rehabilitation (3).

Researchers have effectively demonstrated the RPE scale to be a valid and reliable means to monitor exercise intensity (4,5,7,12). Dunbar et al. (4) and Eston et al. (5) assessed the reliability of RPE for the prescription of exercise intensity during cycling. Dunbar et al. suggested that RPE provides a simple and physiologically valid method of regulating training intensity. Similarly, Eston et al. found RPE to be useful for the regulation of high levels of exercise intensity in healthy men and women.

Glass et al. (12) looked at the accuracy of RPE to establish intensity in graded exercise and found RPE obtained from a graded exercise test (GXT) can accurately serve as a method of prescribing exercise intensity during treadmill running. Additionally, these investigators found an advantage of RPE to be that an individual does not need to stop during exercise and measure his/her heart rate in order to monitor work intensity. Rather, adjustments to training intensity can be made while exercising based on the individual's current RPE (12).

Dunbar et al. found the target RPE estimated during cycling to be more accurate for regulating exercise intensity than when used during a treadmill test (4). This difference may be attributed to the treadmill protocol used in the study, which incorporated relatively slow speeds and large inclines. This finding questions the accuracy of the RPE scale when used with different modes of aerobic exercise.

Effectiveness of RPE Scale to Monitor Resistance Training

A limited number of studies have looked at the use of the RPE scale to monitor intensities in resistance training. Several groups have investigated this topic and have provided evidence as to the effectiveness of the Borg scale in the evaluation of perceived exertion during resistance training (10,11,14,16,17).

Gearhart et al. (10) utilized the RPE scale to evaluate high and low work intensity exertion in active muscle. For this study, ten males and ten females performed the same seven exercises for each intensity. The high intensity protocol consisted of subjects completing five repetitions of 90% of their predetermined one-repetition maximum (1-RM) for each exercise while the low intensity protocol had subjects completing fifteen repetitions of 30% of 1-RM. Each subject was asked for his/her active muscle RPE (RPE-AM) following every repetition of each set of the high intensity protocol and after every third repetition of the low intensity protocol. RPE-AMs were significantly greater for the high intensity protocol when compared to the low intensity protocol when external work was held constant (10). Results of this study suggest that RPE-AM could be used to assess intensity during the different demands of strength and endurance resistance training protocols (10).

Lagally et al. (14) assessed both rating of perceived exertion for the overall body (RPE-O) and active muscle RPE (RPE-AM) during resistance training in twenty female volunteers. Subjects performed one set of the biceps curl exercise at 30%, 60%, and 90% of their 1-RM for that exercise. The number of repetitions done at each intensity varied in order to keep work constant (14). Results indicated corresponding increases in both RPE-AM and RPE-O as resistance exercise intensity increased. Lagally et al. suggest that RPE increases as the resistance exercise intensity increases (14).

The purpose of one study was to investigate the validity and accuracy of the CR-10 RPE scale for evaluating perceived exertion (17). This study consisted of fifteen male and fifteen female volunteers performing nine different intensities of a five-second isometric contraction of the quadriceps femoris muscles. Results indicated a linear trend in RPE as the lower intensity contractions (10-50%) yielded relatively smaller RPEs than the higher intensity contractions (60-90%) (17). This study demonstrated how the CR-10 RPE scale closely approximates perceived exertion in isometric contractions of the quadriceps femoris (17). Further, these investigators have shown the CR-10 RPE scale to be an accurate tool for assessing perceived exertion during brief, five-second muscle contractions, but they also point out that varying levels of fatigue during a sustained muscular contraction can negatively impact the effectiveness of the CR-10 RPE scale for monitoring perceived exertion (17).

Suminski et al. (18) used RPE-O to examine RPE during resistance exercise. Eight men were used as subjects with each completing two intensities of resistance exercise. The same seven exercises were completed for the 50% and 70% 1-RM training

protocols. Subjects were asked to perform three sets of ten repetitions for each of the intensities. A significant increase in RPE-O was shown from the 50% to 70% 1-RM exercise intensity, which suggested that the perception of effort increased along with increases in percentage of 1-RM lifted. Suminski et al. further support the use of the Borg scale for monitoring exercise intensity (18).

Standardized Instructions for RPE Scale

In addition to testing the validity and reliability of the RPE scale, one study has looked at how instructions for using the scale affect the values it yields (11). The American College of Sports Medicine states, "approximately 5 to 10% of individuals tend to underestimate RPE during the early and middle stages of an exercise test" (1). Whaley et al. suggest the percentage of subjects who produce atypical RPE during sign-symptom limited maximum GXT is closer to 30% (20). This study demonstrated the need to adequately instruct subjects on how to use the RPE scale in order to ensure an accurate measure. Several researchers recognized this need and utilized generalized instructions in which to minimize testing error when using the RPE scale (4,5,21). Gearhart et al. (11) suggested the current scaling instructions used with the Borg 15-category scale to be valid for use during resistance training.

Gender Differences in RPE and Linearity

An article tested for differences in RPE values between genders at ten different intensities during an isometric contraction of the quadriceps (17). Pincevero et al. (17) found no significant differences between genders in perceived exertion at any of the ten levels of contraction intensities and suggested that no gender differences exist in relation

to RPE. No difference in RPE between genders were reported by others as well (15). Furthermore, several groups of investigators have established a linear relationship between increases in perceived exertion across relatively higher exercise intensity levels (7,11,15,18,21). Lower RPE values are seen during lower intensity resistance exercise taken as a percentage of 1-RM than are seen during sets involving weights of higher percentages of an individual's 1-RM.

Monitoring Aerobic Training Using a Session RPE Scale

Many methods of monitoring training intensity exist (19); however, practicality and ease of use must be considered when deciding which method to use. Ventilatory threshold and percentage of maximum oxygen consumption are both recognized methods of monitoring training intensity (19), but the equipment and knowledge required to utilize these methods make them impractical when training athletes on a day-to-day basis. Mechanical heart rate monitors have eliminated the need for an individual to stop exercising in order to take his/her pulse and provide an easy way to monitor training intensity (7). However, malfunctions of the heart rate monitor or simply not wearing it throughout an exercise session make monitoring intensity more difficult (7). Additionally, heart rate does not effectively represent the net input during very high intensity exercise such as interval or resistance training (7).

In an attempt to develop an easily administered measure of training intensity, Foster et al. examined the use of a session RPE scale to quantify work intensity during entire bouts of aerobic tr[illegible]g. Recognizing the difficulties that exist in quantifying high intensity exercise, Foster et al. used cycling and basketball practice sessions to evaluate

the ability of the session RPE method to quantify non-steady state and prolonged exercise. They compared the session RPE method and summated heart rate zone methods of quantifying exercise training (8). Six male and six female recreational cyclists performed eight exercise training bouts on an electronically braked cycle ergometer of varying power output percentages and interval magnitudes. Heart rate, blood lactate, and perceived exertion measurements were taken at rest and at ten-minute intervals throughout each training bout. Additionally, subjects were asked thirty minutes following the completion of each exercise training bout for their overall rating of the difficulty of the exercise bout. Exercise scores were then calculated by multiplying the duration of the exercise bout by the session RPE and also by using the summated heart rate zone method of quantifying exercise. During the second part of this study, subjects' heart rates were monitored using radiotelemetry during basketball practice and were asked to give an overall RPE for each exercise bout thirty minutes following the completion of each practice. Exercise scores were then calculated in the same fashion as described for part one of the study.

Both the cycling and basketball practice sessions of this study showed significant differences between the different methods of quantifying exercise. The session RPE method consistently gave a higher exercise score than the summated heart rate zone method (8). A high correlation was found between the session RPE and summated heart rate zone methods of evaluating training sessions (8). Accordingly, the session RPE may be a valid method of evaluating a wide variety of exercises including even very high-intensity exercise such as resistance training and plyometrics (8).

Monitoring work intensities during resistance training is an important aspect of one's workout whether he/she is a recreational weightlifter or athlete training for improved strength and performance. Quantifying high intensity modes of exercise, such as resistance training, is quite difficult and variations in intensity are essential for improvements in strength. Researchers in preliminary studies suggest that the session RPE scale would provide an easy and effective way to prescribe different work intensities for reliable manipulations of one's resistance training program.

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