UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

GROWTH OF RPE DURING RESISTANCE TRAINING

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

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College of Science and Health

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GROWTH OF RPE DURING RESISTANCE TRAINING

By Jeena Lucas-Komarek

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

The candidate has completed the oral defense of the thesis.

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ABSTRACT

Lucas-Komarek, J.L. Growth of RPE during resistance training. MS in Clinical Exercise Physiology, December 2011, 42 p. (C. Foster)

Purpose: This study was conducted to understand teleoanticipation throughout various resistance training sets using the Rating of Perceived Exertion (RPE) scales. Methods: Twenty-one men performed four sets for bench press and leg press consisting of a 5 repetition maximum (RM), 10RM, 20RM, and 30RM. RPE was measured after each repetition. Results: The results showed that regardless of the number of repetitions completed, RPE increased throughout each set in a linear fashion. When normalized to the relative number of repetitions, RPE had scalar properties, and there was a strong correlation between RPE and repetitions. Conclusion: This study reinforced that the RPE scale can be used to measure intensity during resistance training. Since RPE was strongly correlated to the relative number of repetitions, this suggests that teleoanticipation occurs during resistance training as in aerobic training. Regardless of the number of repetitions, the brain recruits the anticipated muscle fibers and develops a pacing strategy in order to complete the task at hand.

ACKNOWLEDGMENTS

I would like to first send a special thanks to Dr. Carl Foster for serving as my chairperson and for all the devoted hours spent reading and revising. I also want to thank my subjects. If it were not for your dedication and cooperation, I would not have been able to successfully complete my study. To my best friend and future husband, Richie, I want to thank you for all of your patience and support while I was working on my study. You are not only understanding, but very encouraging in all that I do. Lastly, I would like to thank my family and friends who have always been there for me.

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INTRODUCTION

The Rating of Perceived Exertion (RPE) has become accepted as a valid and reliable way to measure intensity during both aerobic and resistance exercise. Unlike aerobic training, methods such as heart rate (HR), oxygen consumption (VO_2) and blood lactate concentration cannot be used to measure intensity for resistance training; therefore, RPE offers a method of measuring intensity during resistance exercise. The RPE scale measures the global perception of the difficulty of physical exercise (Borg, 1998). It takes into account the subject's breathlessness, exertion, muscle/joint aches, and fatigue during physical work (Borg, 1998). Other factors such as motivation, past memories of the exercise, fatigue from previous training sessions, and emotions at the time of exercise can also influence RPE (Borg, 1998).

Tucker (2009) suggests that there are numerous signals to the brain from various physiological systems. These afferent signals together with the pre-exercise template of expected responses regulate skeletal muscle activation during exercise in order to regulate the body's physiological limits (Tucker, 2009). This concept is called teleoanticipation (Faulkner et al., 2008). Therefore, the subconscious brain takes into account anticipated "finishing points" and receives afferent feedback from physiological systems to develop a pacing strategy (Faulkner et al., 2008). This pacing strategy is based on motor unit recruitment throughout the anticipated duration of the exercise in order to protect the body from unreasonably large homeostatic disturbances. When individuals use the RPE scale, they are using the "language" of teleoanticipation to express the intensity of the exercise. This process is shown in the figure below (Tucker et al., 2009).

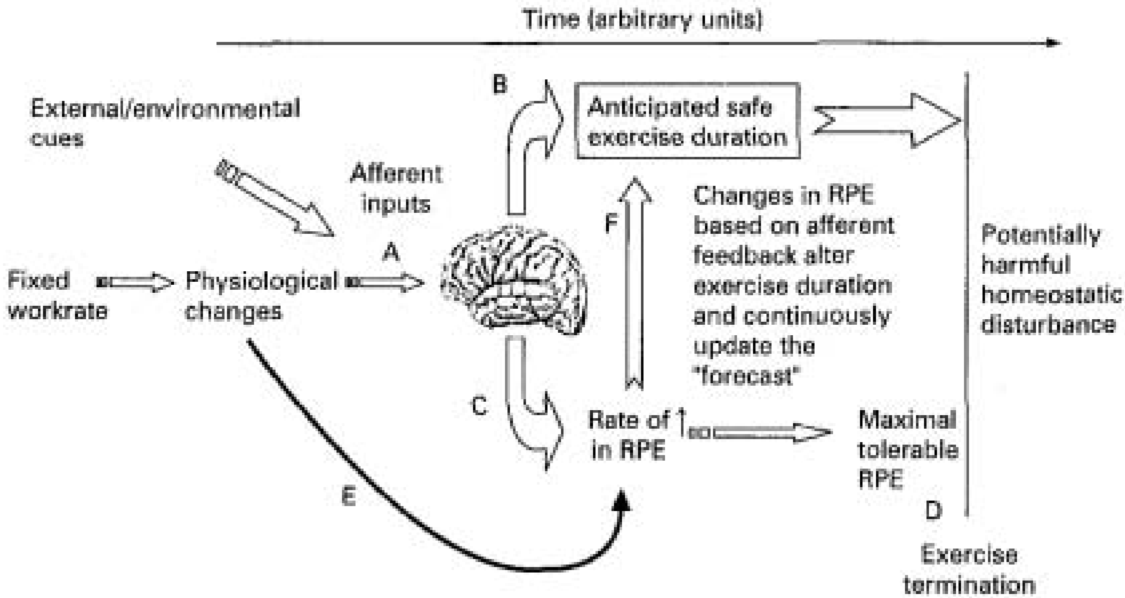

Figure 1. Model of Anticipatory Regulation for Exercise and RPE (Tucker et al., 2009).

In order to study RPE and teleoanticipation, Joseph et al. (2008) studied RPE during cycling trials of three different distances. Ten subjects completed three separate cycling time trials of 2.5km, 5km, and 10km, while RPE was measured every 10% of the trial distance. Results showed that the RPE at 20% of the distance was typically 5 (e.g. hard), regardless of which distance was being completed. Similarly, RPE at 80% of the distance was typically 8 (e.g. very, very hard), regardless of which distance was being completed. This study suggests that RPE has scalar properties and increases in relation to relative distance rather than total distance performed (Joseph, 2008). Because of teleoanticipation, the brain was apparently anticipating the body's pace for that particular distance.

Faulkner et al., (2008) studied the relationship between RPE and %time of running. Subjects completed a 7 mile road race and half marathon and recorded their RPE score at each mile point among other measures. When Faulkner et al. (2008) compared RPE to %time of the two runs, the regression lines nearly overlapped regardless that one run was nearly twice the distance of the other. This again shows that RPE has scalar properties and increases by relative distance rather than total distance performed.

Eston et al., (2007) showed that RPE increases in relation to relative time rather than actual time performed during cycling. Ten participants completed a graded exercise test on a cycle ergometer to find their VO_2max. After 15 minutes of rest, the participants cycled at 75% of their VO_2max until exhaustion. The investigators measured RPE before and after the test and randomly throughout so participants were unaware of their time. The average time until exhaustion was 21.06 minutes. Between 48-72 hours of rest, two trials (separated by 48-72 hours of rest) were performed at 75% of VO_2max until exhaustion. These "nonfatiguing" trials lasted much longer (35.32 and 34.43 minutes) than the fatiguing trial. RPE was again measured randomly throughout the tests. Results showed that the slope of RPE in both the fatiguing trial and rest trial showed no differences when compared to relative time, regardless of total time completed. The start and end RPE were also the same for both the fatigued condition and nonfatigued conditions. This supports the concept that RPE has scalar properties and will act in an anticipatory manner when compared to relative time.

While these studies have been important in the understanding of RPE, it is unknown how RPE acts during high muscle force exercise. RPE has been shown to be a valid method to quantify intensity of resistance training and after the completion of a set

(McGuigan & Foster, 2004; Foster et al., 2001; Gearhart, 2002), but has yet to address teleoanticipation throughout a set. Therefore, the purpose of this study was to understand teleoanticipation throughout various resistance training sets using the RPE scale. It is hypothesized that regardless of the number of repetitions being performed, RPE will have scalar properties when compared to the % of repetitions completed.

METHODS

Subjects

The subjects were 21 physically active, apparently healthy men, 18-45 years of age. All subjects had been strength training at least twice a week for the previous six months prior to start of the study. The physical characteristics of the subjects are presented in Table 1.

Table 1. Descriptive Characteristics of Subjects (N=21).

	Mean ± SD
Age (years)	22.1 ± 2.3
Height (centimeters)	181.7 ± 8.1
Weight (kilograms)	86.2 ± 12.7
1RM Bench Press Weight (kg)	109.9 ± 19.5
1RM Leg Press Weight (kg)	437.2 ± 60.9

Procedures

Following approval from the University of Wisconsin - La Crosse Institutional Review Board for the Protection of Human Subjects, the subjects provided written informed consent before any practice or testing was conducted. All subjects initially performed a 1 Repetition Maximum (1RM) on bench press and leg press exercises. Since subjects were experienced in weight lifting, they predicted what they thought their 1RM weight would be for each exercise. Two warm-up sets were completed consisting of eight reps at 50% of their predicted 1RM and four reps at 70% of their predicted 1RM. Their first attempt to reach their 1RM was tried at 90% of their predicted 1RM. Following this attempt, weight was adjusted to find their 1RM weight within the next three attempts. Two minutes of rest was given between the warm-up sets and each additional attempt to reach their 1RM. Subjects were randomized to complete bench press or leg press first and had five minutes of rest between the two exercises. After completing their 1RM on each exercise, subjects rested for five minutes and then practiced using the Borg RPE 1-10 scale at 65% of their 1RM weight for 12 repetitions. They stated their RPE score between each repetition on the concentric part of the exercise.

Following their maximal tests, subjects completed four separate trials with at least 72 hours between each trial. The four trials consisted of sets designed to be 5RM, 10RM, 20 RM, and 30RM on both bench and leg press. Leg press weight was respectively set at 90%, 78%, 58%, and 43% of 1RM, and bench press weight was respectively set at 87%, 75%, 55%, and 40% of their 1RM. The weight for each RM was modified from Baechle et al. (2008). Subjects were given two warm-up sets with two minutes of rest in between, and five minutes of rest between the two exercises. Ideally, subjects reached the predicted number of maximum repetitions with a given percentage of 1RM weight, however, subjects were told to exercise to fatigue and measured to the number of repetitions actually accomplished. Their RPE score was stated in between each repetition.

Statistical Analysis

Descriptive statistics was used to characterize the subject population. Regression lines were used to analyze the correlation between the number of repetitions and RPE. The number of repetitions was then normalized to the maximum number of repetitions in each set in order to combine all four trials. This was done for each individual subject and then combined to create one overall regression line for all subjects.

RESULTS

All 21 male subjects initially recruited completed the study protocol. The experimental data for each trial are presented in Table 2.

Table 2. Experimental Data for each Trial.

		Mean ± SD			
Bench Press	Target Reps	5	10	20	30
	Actual Reps Completed	5.2 ± 1.2	11.6 ± 1.9	22.67 ± 2.0	30.8 ± 3.2
	%1RM Weight	87.7 ± 1.1	76.4 ± 2.4	56.8 ± 1.6	47.2 ± 2.9
	Max RPE	9.2 ± 0.9	9.4 ± 0.6	9.4 ± 1.0	9.6 ± 0.8
Leg Press	Target Reps	5	10	20	30
	Actual Reps Completed	5.5 ± 1.5	11.4 ± 1.6	20.2 ± 3.0	32.4 ± 4.2
	%1RM Weight	91.2 ± 3.5	80.7 ± 4.6	64.3 ± 6.1	52.4 ± 7.2
	Max RPE	9.5 ± 0.8	9.9 ± 0.3	9.7 ± 0.6	9.7 ± 0.5

A regression line was used for each subject's trials to show the relationship between the number of repetitions and RPE score. The data was then normalized to their maximum number of repetitions to show their trials on a comparable scale. Next, the four trials were combined to create one overall regression line. Figures 2-4 are an example of this for a representative subject.

Figure 2 shows the relationship between RPE and repetitions during leg press for a representative subject. All other subjects' data looked very similar. This figure shows that as repetitions increased, RPE increased as well. R^2 values ranged from 0.96 to 0.99 indicating a very strong correlation.

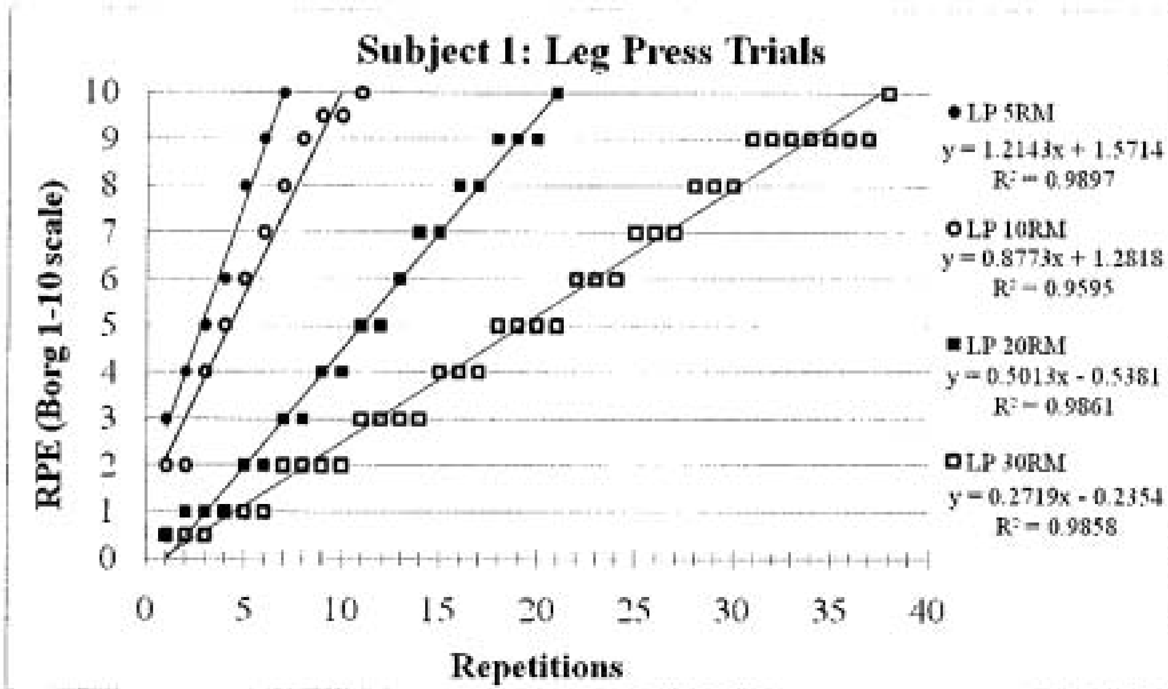

Figure 2. Individual Data Comparing RPE and Repetitions.

Figure 3 represents the four leg press trials for the same representative subject with trials normalized to the relative number of repetitions completed. The four regression lines nearly overlapped. This was similar in all other subjects' data for both exercises. Again, the data was strongly correlated with R^2 values ranging from 0.96 to 0.99.

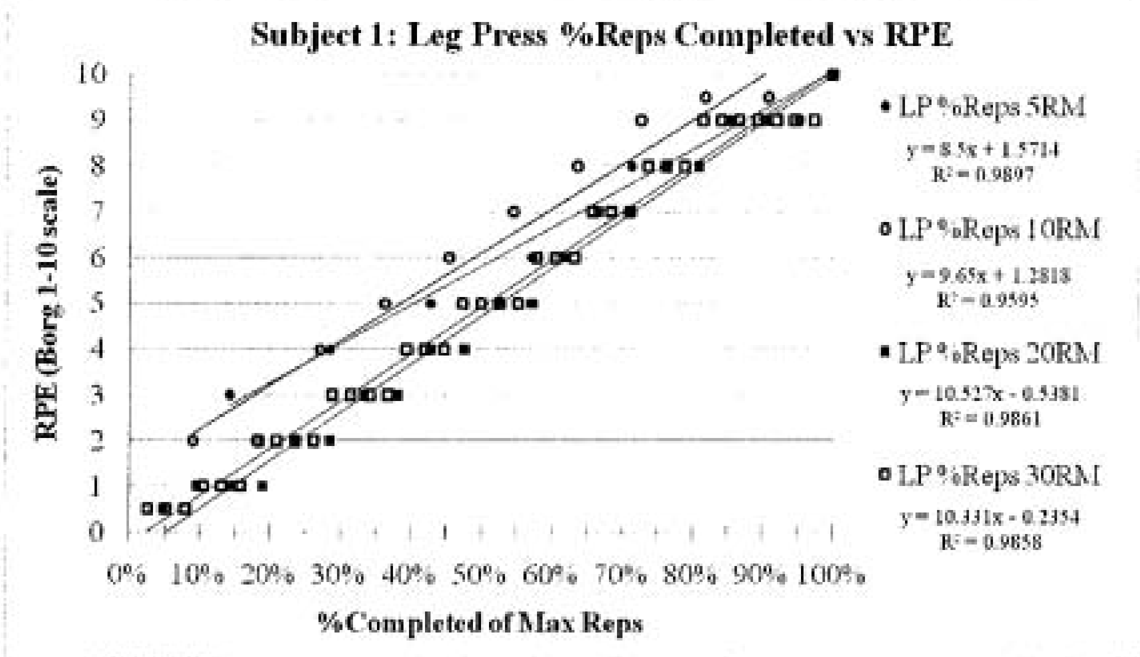

Figure 3. Individual Data Comparing RPE and the Relative Number of Completed Repetitions.

Figure 4 combines all four trials into a single regression line for the representative subject. This shows that at a given RPE, the subject will generally be at a certain percentage of their maximum number of repetitions regardless of the total number of repetitions being completed. The R^2 value is 0.96.

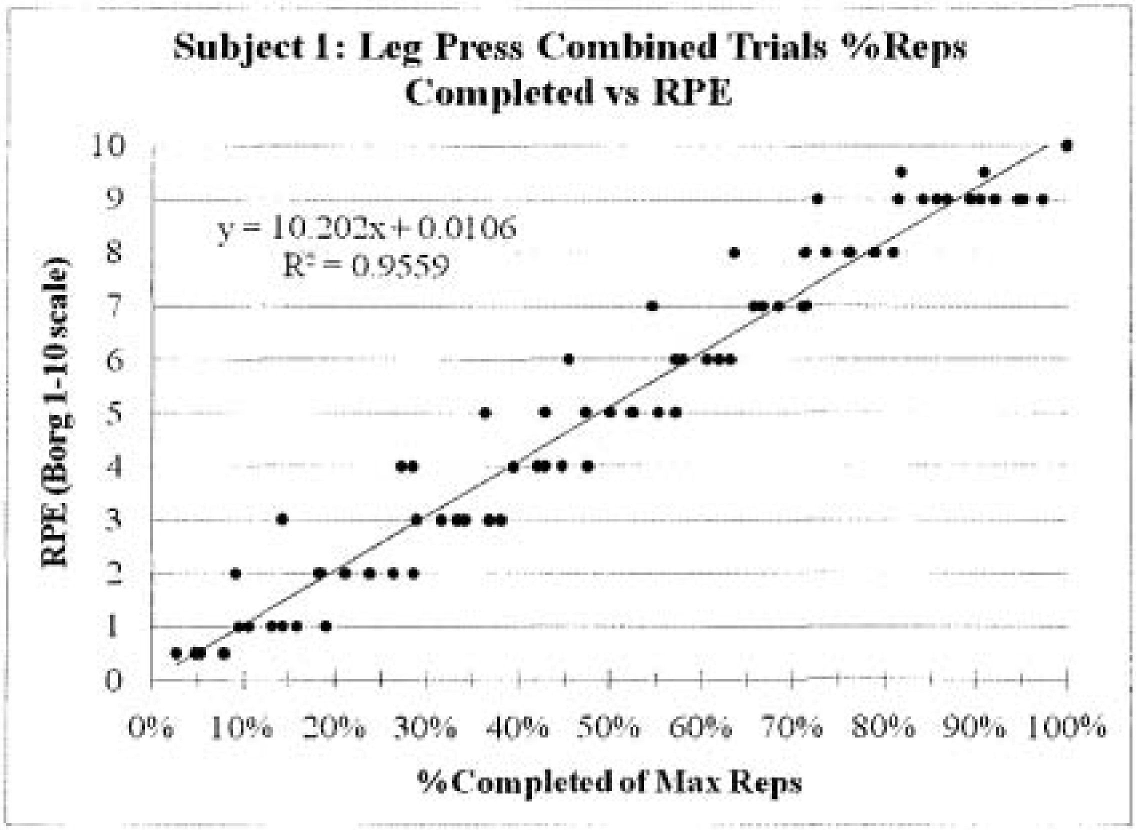

Figure 4. Individual Data Combining All Four Trials.

All individual data was combined to create a group regression line in order to compare RPE and the relative number of completed repetitions for all four trials. This was done separately for bench press and leg press (Figures 5 and 6). Then, the group data for bench and leg press was combined to represent strength training overall rather than a single exercise (Figure 7).

Figure 5 shows the group data for bench press comparing the relative number of repetitions to PRE. A regression line was created to represent the entire data. Similar to individual data, at a given RPE value, a subject was at a certain percentage of the maximum repetitions. For example, if RPE is 5, an individual is at approximately 53% of the maximum number of repetitions. The R^2 value is lower than that of a single individual, at $R^2 = 0.79$, but is still a strong correlation.

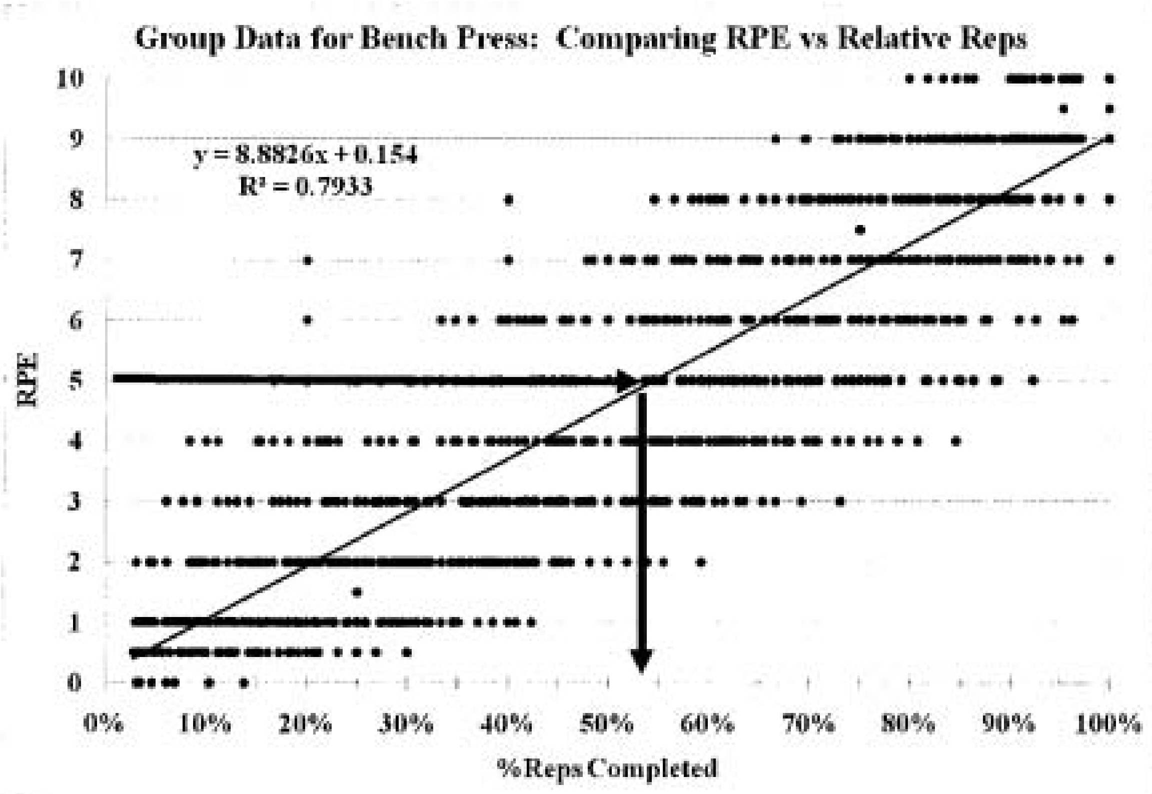

Figure 5. Group Data for Bench Press.

Figure 6 shows the group data for leg press comparing the relative number of repetitions to PRE. A regression line was created to represent the entire data. This shows that at a given RPE value, a subject will be at a certain percentage of the maximum repetitions. For example, if RPE is 5, an individual is at approximately 42% of the maximum number of repetitions. The R^2 value is 0.81 which again, is a very strong correlation.

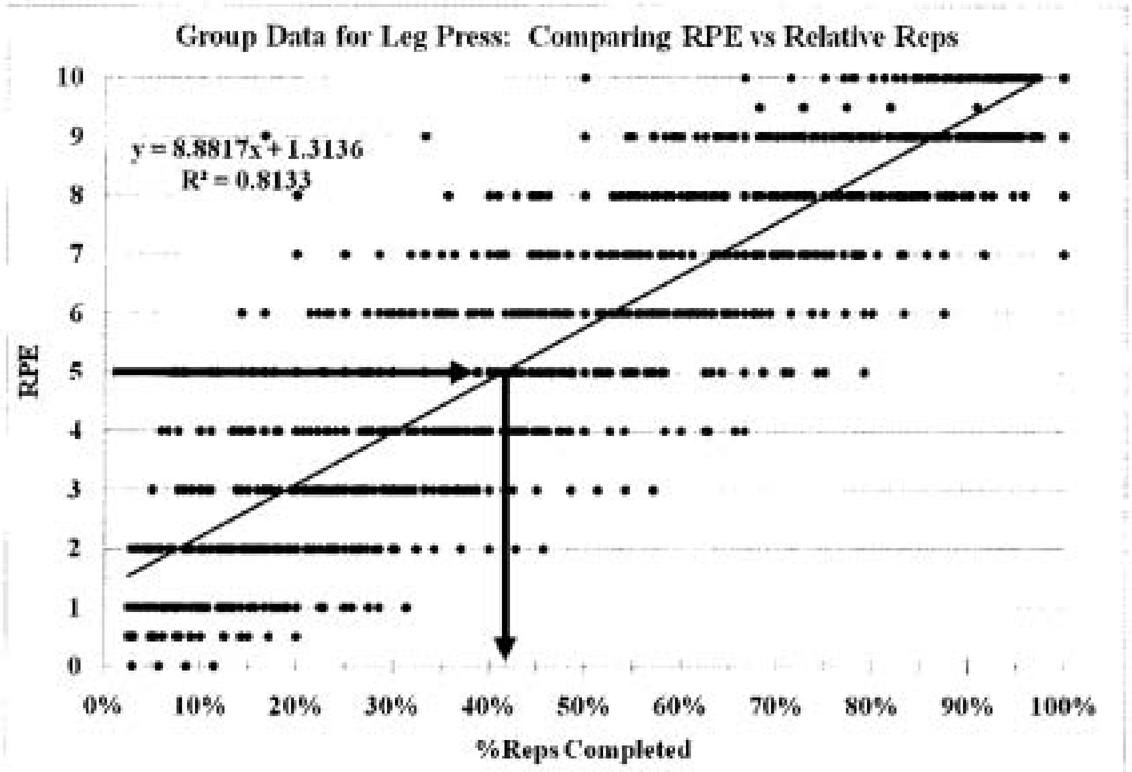

Figure 6. Group Data for Leg Press.

Figure 7 shows the group data combining bench and leg press to represent strength training generally. A regression line was created to compare the relative number of repetitions to RPE. This shows that at a given RPE value, a subject will be at a certain percentage of the maximum repetitions. For example, if RPE is 5, an individual is at approximately 47% of the maximum number of repetitions. The R^2 value for both exercises is still strongly correlated (0.77).

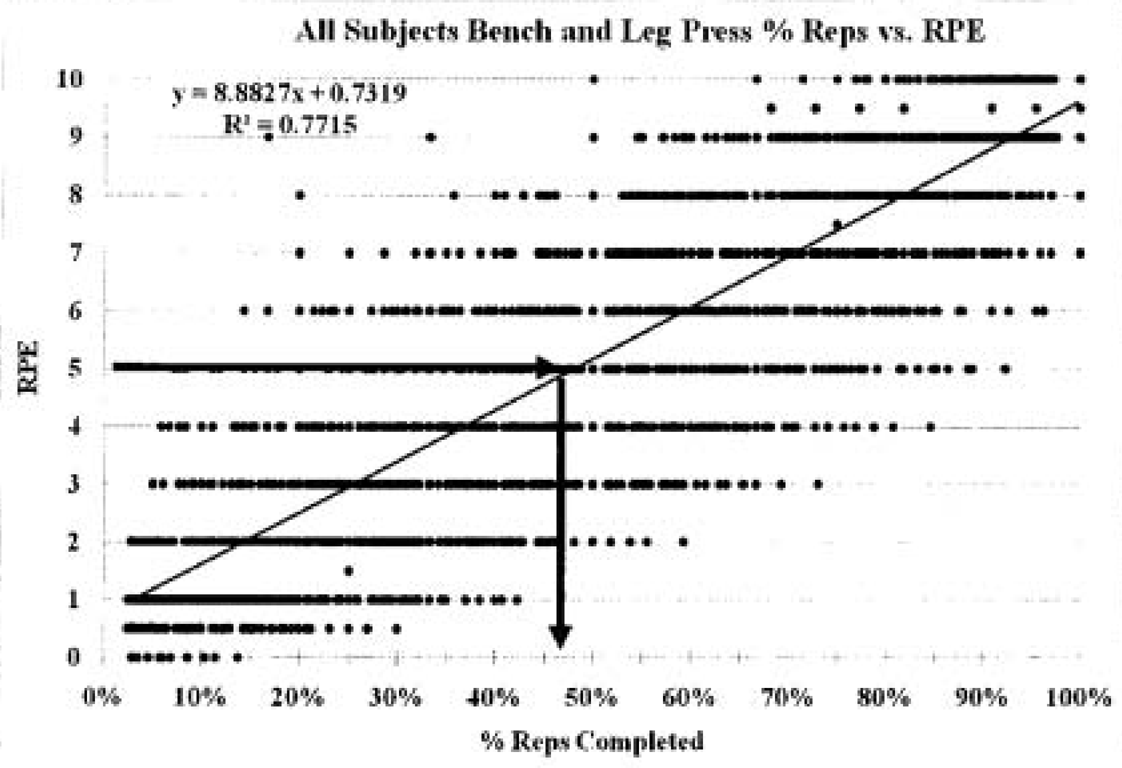

Figure 7. Group Data for Bench and Leg Press.

DISCUSSION

Past research has shown that RPE has scalar properties and works in an anticipatory manner (Eston et al., 2007; Faulkner, et al., 2008; Joseph et al., 2008; Tucker, 2009). This is caused by afferent signals going to the brain from different physiological systems throughout the body (Tucker, 2009). Joseph et al. (2008) has showed that there is a strong linear relationship between RPE and relative distance. There has also been research supporting a linear relationship between RPE and relative time (Eston et al., 2007; Faulker et al., 2008). This research has helped in understanding how RPE works when an individual is performing aerobic physical exercise.

The present study was designed to examine the relationship between RPE and anaerobic resistance training. Although some research has been done comparing session RPE and RPE after the completion of a set, it is unknown how RPE would act throughout the duration of a set. The results showed that there was a very strong correlation between RPE and the number of repetitions in that when number of repetitions increased, RPE increased as well. The results also showed that when RPE was compared to the relative number of repetitions completed, the regression lines nearly overlapped. This was the case for each individual as well as their combined data. Although the subjects completed four different trials of different weights and number of repetitions, their RPE scores were relevant to the % of repetitions they actually completed.

The relationship between RPE and the relative number of repetitions completed is very similar to the studies of Joseph et al. (2008), Eston et. al. (2007), and Faulkner (2008). Figure 8 shows the results from Faulkner et al. (2008) comparing RPE to relative running time, Joseph et al. (2008) comparing RPE to relative distance, and the results from this study comparing RPE to relative repetitions completed. As shown, the regression lines are very similar in that they show RPE increases as the %time, %distance, or %maximum repetitions also increases. The data also shows that RPE grows in a very linear fashion and has scalar properties.

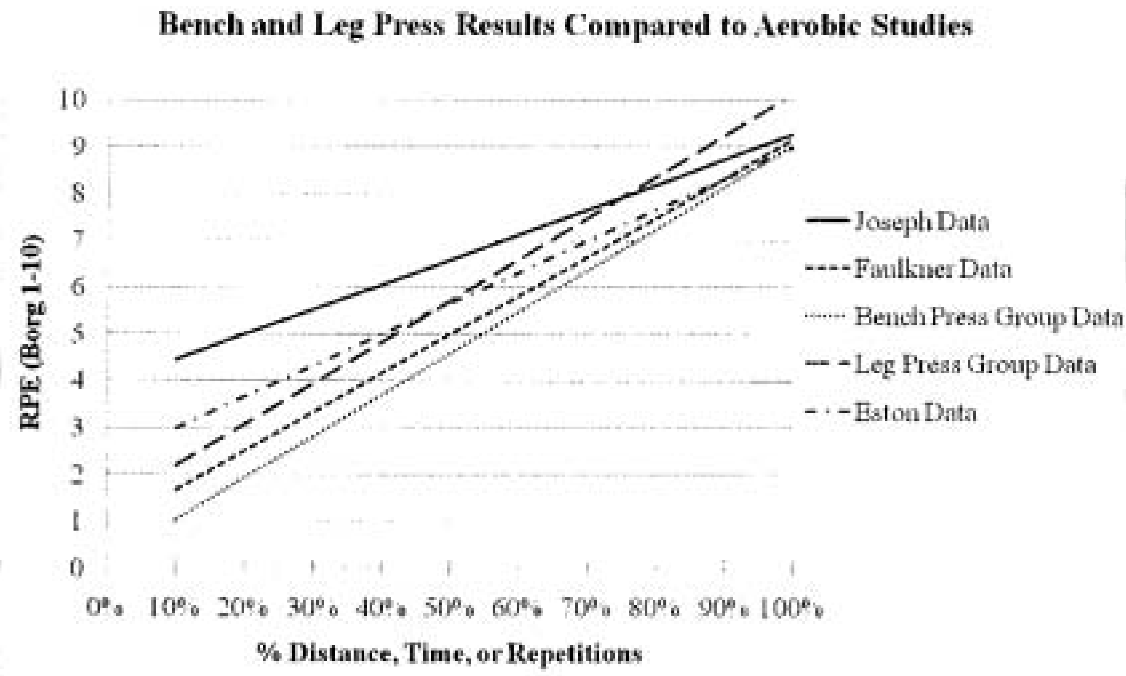

Figure 8. Bench and Leg Press Results Compared to Data from Faulkner et al. (2008), Eston et al. (2007), and Joseph et al. (2008).

This study shows that the RPE scale can be used during resistance training just as it is in aerobic training. This study also shows that teleoanticipation occurs during resistance training as in aerobic training. Regardless of the number of repetitions, the brain recruits the anticipated muscle fibers and develops a pacing strategy in order to complete the task at hand.

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APPENDIX A

INFORMED CONSENT

Proposal Title: Growth of RPE within Repetitions of Resistance Training

Principal Investigation: Jeena Lucas-Komarek
231 North 10th Street Apt. #9
La Crosse, WI 54601
715-370-0411

Emergency Contact: Dr. Carl Foster
133 Mitchell Hall
University of Wisconsin-La Crosse
608-785-8687

Why have you been asked to take part in this research?

This study is evaluating the relationship between RPE and number of repetitions during resistance training. You have been invited to participate in this study because you are already resistance training, and we are interested in better understanding exercise patterns using resistance training. Participating in this study is voluntary, and you may quit this study at any time. Please do not hesitate to ask questions about this consent form or the procedures if you do not understand something.

How many people will be in this study and how long will it last?

There will be 20 men, 18-45 years old, who will participate in this study. Subjects need to have been resistance training at least twice a week for the previous 6 months to reduce fatigue and soreness throughout the study. The overall study will last approximately eight weeks. You need to participate during four weeks of the study and will have 5 different sessions which will last about 45 minutes each.

What will happen if you agree to be part of this study?

If you agree to be part of this study, you will participate in five different sessions. The first meeting will be an orientation to the two different exercises you will perform, bench press and leg press. You will also learn about the RPE scale and get standardized instructions on how to use it. Then you will complete a 1 repetition maximum (1RM) on each of the two exercises. After your 1RM tests, you will rest for 5 minutes and have a practice trial on each exercise using the RPE scale.

The next four sessions will consist of randomly completing a certain number of repetitions with a corresponding amount of weight for both bench press and leg press. You will complete a 5 repetition maximum, 10 repetition maximum, 20 repetition maximum, and 30 repetition maximum with an amount of weight depending on your 1RM weight. Between each repetition, you will state your RPE score and that score will be recorded.

What are the possible risks and discomforts from this study?

Because you are completing a maximum test each time, just with a different number of repetitions, you may feel fatigue or sore. However, these effects will only be temporary. You will have more that 72 hours to rest between completing your next session. There is very low risk for serious injury or complications in healthy, already resistance trained, individuals.

How will you benefit from participating in this study?

There is a possibility that you will know more about your physical fitness level and may gain improvements in strength. Additionally, you will help other researchers understand the relationship between repetition RPE and resistance training.

Do you have to participate?

Participation in this study is voluntary. You may stop participating in any point without penalty.

What the costs of participating?

There are no costs for you to participate in this study.

What are your rights and confidentiality during this study?

All of the data will be kept confidential through the use of number codes. If this study is published or presented for scientists and teachers, you data will not be personally identifiable.

Questions regarding the requirements of this study will be answered by Jeena Lucas-Komarek, (715-370-0411), or her advisor (Dr. Carl Foster, 608-785-8687). Questions regarding the protection of human subjects may be addressed to the UW-La Crosse Institutional Review Board for the Protection of Human Subjects (608-785-8124).

Subject's Understanding:

Have all your questions regarding how the research study might affect you been answered? Yes / No (Circle one)

If you are interested in participating in this study, please sign your name. **You will not be penalized or treated differently for not participating in this study.**

Participant's name: ______________________________

Participant's signature: ____________________________ Date: __________

Researcher's signature: ____________________________ Date: __________

APPENDIX B

RATING OF PERCEIVED EXERTION

1 - 10 Borg Rating of Perceived Exertion Scale

0	Rest
1	Really Easy
2	Easy
[illegible]	[illegible]
5	Hard
6	
7	Really Hard
8	
[illegible]	[illegible]

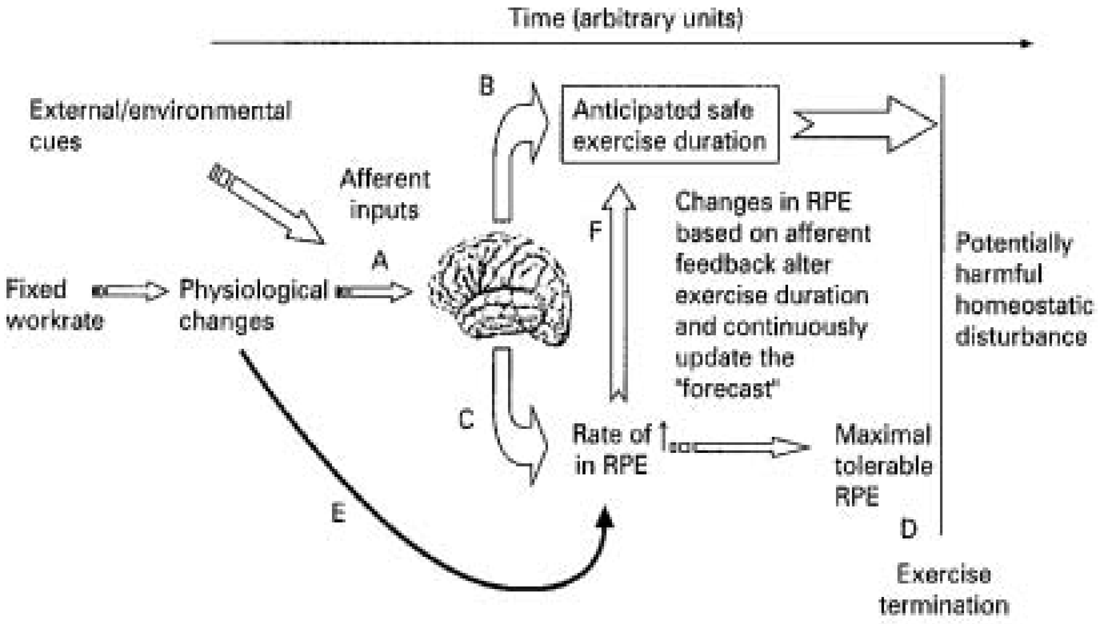
APPENDIX C

REVIEW OF LITERATURE

Intensity is an essential part of both aerobic and anaerobic exercise and can be measured in a variety of ways. In laboratory testing, intensity has been measured using % of maximum volume of oxygen consumed (%VO_2max), % maximal heart rate (HR), blood and muscle lactate levels, along with other methods (Sweet et al., 2004). Recently, the Rating of Perceived Exertion (RPE) has been used as another method to measure intensity, including intensity during resistance training (McGuigan, & Foster, 2004). Unlike aerobic training, the use of RPE is a particularly valuable method for resistance training because methods appropriate to continuous aerobic exercise are not suitable to high intensity intermittent exercise (McGuigan, & Foster, 2004). Thus, measuring RPE during resistance training may be the most practical method to gain an accurate understanding of intensity and in turn, create meaningful training programs.

Gunnar Borg developed the RPE scale (6-20) in the 1950s (Borg, 1998). He later modified it into the Category Ratio (CR) scale (0-10) in the 1980s (Borg, 1998). RPE is based on the subject's global perception of breathlessness, exertion, muscle and joint aches, and fatigue during physical work (Borg, 1998). Motivation, past memories of the exercise, fatigue from previous training sessions, and emotions at the time of exercise can also influence RPE. The two scales are essentially the same except the RPE 6-20 scale is comparable to heart rate if the number is multiplied by 10. (Borg, 1998). For example, the number 6 would represent 60 beats per minute (bpm) and would correspond to resting. Likewise, 20 would represent 200bpm and would be maximal exertion. The CR scale is more comparable to blood lactate concentrations.

Tucker (2009) suggests that there are numerous signals to the brain from various physiological systems. These afferent signals regulate skeletal muscle activation during exercise in order to regulate the body's physiological limits (Tucker, 2009). This is called teleoanticipation (Faulkner, 2008). Therefore, the subconscious brain takes into account anticipated "finishing points" and receives afferent feedback from physiological systems to develop a pacing strategy (Faulkner, 2008). This pacing strategy is based on motor unit recruitment throughout the anticipated duration of the exercise in order to protect the body from unreasonably large homeostatic disturbances. When individuals use the RPE scale, they are using the "language" of teleoanticipation to express the intensity of the exercise. This concept is shown in the figure below (Tucker et al., 2009).



Borg's RPE scale was first used to measure intensity in aerobic training. Skinner et al. (1973) tested Borg's scale by doing two different cycle ergometer tests on university students. One test included an increasing work load until exhaustion, and the other test randomly varied the workloads. They then would rest and randomly perform another workload until all workloads were completed. RPE was measured throughout the progressive test and the randomly assigned workload tests. Subjects' RPE rating throughout the progressive tests corresponded with the random assignment tests (Skinner et al., 1973). Therefore, RPE was thought to be a reliable and valid measurement for both progressive and random workloads.

A decade later, Noble et al. (1983) compared RPE values with HR, blood and muscle lactate levels during cycle ergometer tests. Ten active males completed a progressive, maximal test and were asked to give three ratings for leg effort, cardiorespiratory effort, and leg pain during every stage. The results concluded that RPE correlated with HR and blood and muscle lactate levels, implying that RPE is a reliable way to measure intensity during aerobic tests (Nobel et al., 1983).

There have also been studies using RPE in reference to the overall workout; this is called session RPE (Foster et al., 1995). The subjects' RPE is measured 30 minutes after they complete their workout in order to determine the intensity of the overall workout; therefore, a particularly easy or hard exercise towards the end wouldn't bias their rating (McGuigan, & Foster, 2004). Session RPE was first introduced by Foster et al. (1995) where he tested the significance of cross training to a running group. Thirty participants were randomized to either a control group, a group with additional running, or a group with additional swimming to evaluate overall improvements in running performance. Because of the large group of participants and difference in training loads for each exercise, they used session RPE to measure intensity rather than heart rate. To calculate training load from session RPE, they multiplied the session RPE by the duration of the training to find a training impulse score. They also compared session RPE during interval and continuous exercise to the percentage of time in various blood lactate transition zones

(Foster et al., 1995), because blood lactate has been used as a biological marker for effort (Serrano et al., 2001). The use of session RPE for both training load and blood lactate showed to be an easy, yet dependable way to measure intensity.

This was also shown by Serrano et al. (2001) who compared session RPE to intensity during judo competition. They measured RPE 10 minutes and 30 minutes following the last fight. The 10 minute RPE was used to represent the intensity of the last fight whereas the 30 minute RPE was to represent the overall competition of fights. The results showed that the blood lactate concentrations measured 1 and 3 minutes following the last fight, corresponded with the 30 minute RPE score (Serrano et al, 2001). This supported the concept that session RPE is a dependable way to measure overall intensity.

Recently, RPE has been used as a way to measure intensity during resistance training. Because resistance training is a non-continuous exercise, HR, VO_2max, and lactate concentration cannot be used effectively (Sweet et al., 2004). It has been suggested that perception of aerobic exertion is different from that of resistance training. Perception of aerobic exercise is based on respiratory-metabolic factors while perception of resistance training exercise is based on input from the peripheral skeletal muscles (Gearhart et al., 2008). In order to compare intensity using session RPE of aerobic tests to resistance tests, they tested 10 men and 10 women on both a cycle ergometer and resistance training trials. Three bouts on the cycle ergometer consisted of 70%, 90%, and 110% of ventilatory threshold, and three resistance training trials consisted of 15 reps of 50% of 1RM, 10 reps of 70% of 1 RM, and 4 reps of 90% of 1RM. In both aerobic and resistance tests, RPE increased as the intensity (e.g % 1RM) increased supporting the concept that RPE can be used in resistance training as it is in aerobic training (Sweet et al., 2004).

Day et al. (2004) compared RPE and session RPE of different intensities during resistance training. They tested 9 men and 10 women on 1 set of 5 different exercises at 4-5 reps of 90% 1RM, 10 reps of 70% 1RM, and 15 reps of 50% 1RM. RPE was measured at the completion of each set and session RPE. Each intensity showed similar slopes just at different RPE values; 90% of 1RM showed the highest RPE, 70% of 1RM showed the moderate RPE, and 50% as the lowest RPE (Day et al., 2004). This supports the concept that a greater weight with less reps corresponds with a higher RPE; likewise, a lighter weight with more reps corresponds with a lower RPE.

Singh et al. (2007) compared intensities during resistance training using session RPE. They tested 15 men on three sets of five different exercises with three different protocols: 5 reps of 50% of 1RM, 10 reps of 70% of 1RM, and 5 reps of 90% of 1RM. These were designed to measure sessions designed to improve power, hypertrophy and strength respectively. The results concluded that RPE with hypertrophy and strength training sessions had similar RPE ratings with power being very much lower (Singh et al., 2007). These results also support the concept that subjects will have a higher RPE with greater weight rather than lower weight.

Studies have also compared session RPE to the RPE at the completion of a set. Overweight and obese children performed three resistance training sessions a week (McGuigan et al., 2008). During each session, they completed three sets of 3-15 repetitions of eight different resistance exercises. RPE was measured after the completion of each set and for the session. Results showed that the RPE at the end of end of each set was lower (1.68 ± 061) than that of RPE at the end of the session (3.10±1.18) (McGuigan et al., 2008). It is important to recognize that there is a difference in RPE over the entire session when compared with the average RPE. For example, an individual may not feel as though they are working very hard during their workout but could feel exhausted afterwards.

Foster et al. (2001) used both momentary RPE and session RPE during a cycle ergometry test to compare subjects' RPE and objective heart rate. Subjects measured RPE at rest and every 10 minute interval of the exercise bout, as well as 30 minutes after completing the exercise bout, either 30, 60, or 90 minutes at a given power output. RPE was shown to be substantially different depending on the momentary activity pattern compared to the session RPE in which subjects were instructed to give a global rating of the entire training bout. Foster et al. (2001) also used this study to show that RPE is applicable to different modes of exercise. In the second part of the study, they compared session RPE and HR during non steady-state high-intensity basketball. Results showed that the absolute score for session RPE was greater than heart rate for both the cycle tests and basketball (Foster et al., 2001). However, following a regression analysis, RPE and heart rate nearly overlapped in both the exercises. This supports that concept that using session RPE is an equivalent way to measure intensity and can be used for a wide variety of exercises (Foster et al., 2001).

In order to study RPE and teleoanticipation, Joseph et al. (2008) studied RPE during cycling trials of three different distances. Ten subjects completed three separate cycling time trials of 2.5km, 5km, and 10km, while RPE was measured every 10% of the trial distance. Results showed that the RPE at 20% of the distance was typically 5 (e.g.

hard), regardless of which distance was being completed. Similarly, RPE at 80% of the distance was typically 8 (e.g. very very hard), regardless of which distance was being completed. This study suggests that RPE has scalar properties and increases in relation to relative distance rather than total distance performed (Joseph, 2008). Because of teleoanticipation, the brain was apparently anticipating the body's pace for that particular distance.

Faulkner et al., (2008) studied the relationship between RPE and %time of running. Subjects completed a 7 mile road race and half marathon and recorded their RPE score at each mile point among other measures. When Faulkner et al. (2008), compared RPE to %time of the two runs, the regression lines nearly overlapped regardless that one run was nearly twice the distance of the other. This again shows that RPE has scalar properties and increases by relative distance rather than total distance performed.

Eston et al., (2007) showed that RPE increases in relation to relative time rather than actual time performed during cycling. Ten participants completed a graded exercise test on a cycle ergometer to find their VO_2max. After 15 minutes of rest, the participants cycled at 75% of their VO_2max until exhaustion. The investigators measured RPE before and after the test and randomly throughout so participants were unaware of their time. The average time until exhaustion was 21.06 minutes. Between 48-72 hours of rest, two trials (separated by 48-72 hours of rest) were performed at 75% of VO_2max until exhaustion. These "nonfatiguing" trials lasted much longer (35.32 and 34.43 minutes) than the fatiguing trial. RPE was again measured randomly throughout the tests. Results showed that the slope of RPE in both the fatiguing trial and rest trial showed no differences when compared to relative time, regardless of total time completed. The start and end RPE were also the same for both the fatigued condition and nonfatigued conditions. This supports the concept that RPE has scalar properties and will act in an anticipatory manner when compared to relative time.

Although many other studies have been done relating RPE to resistance training, there has been a lack of research on RPE between repetitions during resistance training. Gearhart et al. (2002) tested 10 men and 7 women at a high-intensity workout and a low-intensity workout. During the high-intensity, subjects lifted 5 reps of 90% of 1RM, and during the low-intensity workout, subjects lifted 15 reps of 30% of 1RM, with RPE measured after every third repetition. The results of this study support the concept that a greater weight, less reps will result in a higher RPE while a lower weight, with more reps will result in a lower RPE. Although Gearhart et al. studied RPE between every repetition of a high intensity resistance program and every third repetition of a low intensity resistance program, there is no research published on finding RPE between *every* repetition.

RPE has been shown to be a valid and reliable method to measure intensity during a variety of aerobic and resistance exercises. It has been shown to correspond with % maximal HR, %VO_2 max, and blood and muscles lactate concentrations. With resistance training, RPE has been a consistent method for measuring intensity especially because of the rest in between exercises. In many different studies, session RPE has been shown to be a reliable way of describing the intensity for the overall workout. RPE can also be measured after the completion of a set or exercise to quantify intensity of that specific exercise. It is also understood that during resistance training, the greater weight, less reps performed will result in a greater RPE.

In addition, studies have shown that RPE has scalar properties and will increase as a relative distance or relative time regardless of overall distance or duration because of teleoanticipation. While this is true during aerobic training, it is unknown how RPE acts during high muscle force exercise. Since RPE can be used in relation to relative time or distance, it seems reasonable that the same concept can be applied to resistance training. It is hypothesized that regardless of the total amount of maximum repetitions, RPE will be dependent on the relative number of repetitions completed.

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