The relationship between session rate of perceived exertion measures and the volume load of resistance training

Mirza Abdul Latif

Edith Cowan University

Recommended Citation
Edith Cowan University

Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study.

The University does not authorize you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following:

- Copyright owners are entitled to take legal action against persons who infringe their copyright.

- A reproduction of material that is protected by copyright may be a copyright infringement. Where the reproduction of such material is done without attribution of authorship, with false attribution of authorship or the authorship is treated in a derogatory manner, this may be a breach of the author’s moral rights contained in Part IX of the Copyright Act 1968 (Cth).

- Courts have the power to impose a wide range of civil and criminal sanctions for infringement of copyright, infringement of moral rights and other offences under the Copyright Act 1968 (Cth). Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.
The Relationship between Session Rate of Perceived Exertion Measures and the Volume Load of Resistance Training

BY

Mirza Abdul Latif

A Thesis Submitted in Partial Fulfilment of the Requirements for the Award of Bachelor of Science (Sports Science) with Honours

At the School of Exercise, Biomedical and Health Sciences

Edith Cowan University

Western Australia

Date of Submission: 28th of November 2008
EDITH COWAN UNIVERSITY

USE OF THIS THESIS

This copy is the property of Edith Cowan University. However, the literary rights of the author must also be respected. If any passage from this thesis is quoted or closely paraphrased in a paper or written work prepared by the user, the source of the passage must be acknowledged in the work. If the user desires to publish a paper or written work containing passages copied or closely paraphrased from this thesis, which passages would in total constitute an infringing copy for the purpose of Copyright Act, he or she must first obtain written permission of the author to do so.

Signature: __________________________

Date: 28 November 2008
ABSTRACT

The purpose of the study was to investigate the relationship between session rate of perceived exertion (RPE) measures and the volume load (VL) during resistance training (RT). Twelve male and eight female participants (24.3 ± 4.2 years) performed three RT sessions per week for a period of four weeks. The RT sessions during the week consisted of strength, hypertrophy and power protocols that included the same four resistance exercises (bench press, squat, shoulder press and bench row). The participants performed 3 sets of 3 repetitions per exercise at a load of 75-90% of their 1-RM with a rest period of five minutes between each set for the strength sessions, 3 sets of 10 repetitions per exercise at a load of 65-75% of their 1-RM with a one minute rest period between each set for the hypertrophy sessions and 3 sets of 5 repetitions per exercise at a load of 25-40% of their 1-RM at a fast lifting speed with a three minute rest period, for the power sessions. Session RPE was collected within thirty minutes following the completion of each session using the Borg’s CR-10 RPE scale. Session load (SL), monotony and strain were derived from the session RPE values. The training volume for each session was determined by calculating VL (total repetitions and amount of weight lifted). Pearson’s product moment correlations revealed significant relationships between VL and session RPE (r = 0.737), as well as VL and SL (r = 0.258). However, there were no significant relationships between the average weekly VL and training monotony, and average weekly VL and training strain. There were significant differences between the strength, hypertrophy and power protocols for session RPE, SL and session duration. It was concluded that the session RPE method is a simple way of monitoring VL during undulated periodised RT program. It was also demonstrated that the SL did not provide the same information as volume load during RT possibly due to the dependence on session duration.
DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education;

(ii) contain any material previously published or written by another person except where due reference is made in the text; or

(iii) contain any defamatory material.

Signature: ____________________________

Date: 28 November 2008
ACKNOWLEDGEMENTS

I would like to take this opportunity to thank the people who have made this honours journey possible and enjoyable. I could not have done it without the continual support and encouragement given to me by all of you. No amount of words could totally express my gratitude.

Firstly, to my supervisors, Dr Michael McGuigan and Dr Michael Newton, I am very grateful for your excellent guidance and supervision during the past few years, particularly this past year. Your contributions and commitment to me and my thesis will not be forgotten. Thank you for believing in me and giving me the opportunity to work along side you both during my research.

Also, I would like to express my appreciation to all those who volunteered to partake in my study. Thank you for donating your time and effort to make this research a success. I hope you had as much fun working out as I had making you work out. It was a pleasure to work with all of you.

Special mention goes out to all my fellow post-graduates and staff in the Sports Science department. I have benefited greatly by being in your presence and thank you for your assistance at some point of time during the year. In particular I would like to thank Joe, Weipeng, Cesar and Travis for all your help. You guys have helped me get through the tough times and made me persevere. I cannot fully express my appreciation and will forever be indebted.

Last but definitely not least, I would like to express my heartfelt gratitude to all of my family members, in particular Bak, Mak, Kakak, Uncle Sar and Aunty Aisha, for all their faith and encouragement throughout my university education. This thesis is dedicated to all of you. I could not have done it without your love and prayers. Thank you.

Mirza Abdul Latif
LIST OF TABLES AND FIGURES

Table 3.1  Borg’s CR-10 RPE scale  28

Table 3.2  Exercise protocol  29

Table 3.3  Volume load calculations  30

Table 4.1  Participants characteristics  33

Table 4.2  Participants one-repetition maximum for four resistance exercises  33

Table 4.3  Relationship between volume load, session load, session RPE, monotony and strain  34

Table 4.4  Relationship between variables during different protocols  34

Figure 3.1  Volume load over the four week training period  31

Figure 4.1  Volume load values for the different resistance training protocols  35

Figure 4.2  Session RPE values for the different resistance training protocols  36

Figure 4.3  Session load values for the different resistance training protocols  37

Figure 4.4  Session duration for the different resistance training protocols  38
# TABLE OF CONTENTS

**USE OF THIS THESIS** 2  
**ABSTRACT** 3  
**DECLARATION** 4  
**ACKNOWLEDGEMENTS** 5  
**LIST OF TABLES AND FIGURES** 6  
**TABLE OF CONTENTS** 7  

## CHAPTER 1 Introduction  
1.1 Background to the Study 9  
1.2 Significance of the Study 10  
1.3 Purpose of the Study 11  
1.4 Hypothesis 11  

## CHAPTER 2 Review of Literature  
2.1 Introduction 12  
2.2 The Reliability and Validity of the RPE Scale during Aerobic Exercise 12  
2.3 The Reliability and Validity of the RPE Scale during Resistance Exercise 13  
2.4 RPE with Different Independent Variables 17  
2.5 The Reliability and Validity of the Session RPE during Aerobic Exercise 19  
2.6 Monitoring Resistance Training using Session RPE 21  
2.7 Summary 25  

## CHAPTER 3 Methodologies  
3.1 Participants 26  
3.2 Experimental Approach to Problem 26  
3.3 Exercise Protocol 27  
3.4 RPE Measures 29  
3.5 Volume Load Measures 30  
3.6 Training Program 30  
3.7 Statistical Analysis 31
3.8 Limitations
3.9 Delimitations

CHAPTER 4 Results
4.1 Descriptive Characteristics
4.2 Relationship between Variables
4.3 Relationship between Variables during Different Protocols
4.4 Differences between Protocols

CHAPTER 5 Discussions
5.1 Main Findings
5.2 Relationship between Variables
5.3 Volume Load and Session RPE across Different Protocols
5.4 Session Load across Different Protocols
5.5 Practical Applications
5.6 Conclusions

REFERENCES

APPENDICES

Appendix A – Information Letter to Participants
Appendix B – Informed Consent Form
Appendix C – Information Flyer
Appendix D – Medical Questionnaire
CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Resistance training (RT) has been shown to be an effective form of exercise for improving athletic performance and overall quality of life (Egan, Winchester, Foster, & McGuigan, 2006; Singh, Foster, Tod, & McGuigan, 2007; Sweet, Foster, McGuigan, & Brice, 2004). It is also known to play an important role in the preparation of athletes for the specific strength and conditioning demands of their sports (Egan et al., 2006). Furthermore, periodised programs have been shown to result in decreased injuries and enhanced strength and power gains (Fleck, 1999; Foster, 1998; Gamble, 2006; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). The primary goals of periodisation are to reduce the potential for overtraining and maximise training adaptations (Buford, Rossi, Smith, & Warren, 2007; Stone et al., 1999). These goals can be achieved through the manipulation of training variables such as the number of sets or repetitions performed; the amount or type of resistance used; or the training frequency (Rhea et al., 2003). The ability to monitor training volume and intensity is crucial to the process of quantifying training and can assist with the periodisation process (Foster et al., 2001).

Previous studies have found that the rate of perceived exertion (RPE) during exercise is related to relative exercise intensity (Gearhart et al., 2002; Lagally, Robertson, Gallagher, Gearhart, & Goss, 2002a). Perceived exertion is the feeling of how heavy and strenuous a physical task is (Borg, 1998) whereas the intensity of RT has been defined as the magnitude of the load used in a training session or the rate of work performed (McGuigan & Foster, 2004). The Borg category-ratio 10 (CR-10) RPE scale was developed to rate exertion associated with nonlinear physiological responses (Borg, 1998).

Studies have shown session RPE to be a valid and reliable method of quantifying exercise intensity during RT (Day, McGuigan, Brice, & Foster, 2004; McGuigan, Egan, & Foster, 2004; Singh et al., 2007). These studies found that there were no significant differences between the session RPE and the average RPE values that were taken after the
completion of every set. Therefore, session RPE seems to provide coaches and sport scientists with the same information about perceived exertion as the average RPE measures (Egan et al., 2006). The session RPE is a simple modification in which the global intensity of the entire RT session is rated (Foster, 1998). It allows athletes to provide the global RPE for the whole session instead of reporting a series of RPE measures throughout the session thus simplifying the myriad of exercise cues (McGuigan & Foster, 2004).

However, exercise intensity is not the only factor important in RT. The training volume of the session also has an important role in periodisation plans (Stone, Stone, & Sands, 2007) and has been reported to exert an effect on athlete’s performance and success (Foster, Daines, Hector, Snyder, & Welsh, 1996). Training volume is a measure of the total work performed and total amount of energy expended (Stone et al., 2007). A high volume, periodised RT program has been reported to produce significant increases in muscular strength and power (Stone, Johnson, & Carter, 1979). In addition, studies have shown that athletes who employed undulating periodised programs had significantly greater increases in strength, motor performance and local muscular endurance compared to athletes who utilised a single set model (Kraemer et al., 2000; Marx et al., 2001)

According to Stone et al. (2007), the best estimate to measure the amount of work performed during RT is volume load (VL). It is a product of the total number of repetitions performed, and the amount of mass lifted by the athlete (Stone et al., 2007). Haff et al. (2008) found that the VL can have a distinct impact on the ability to generate maximal force and peak rate of force development. They found that alterations in VL of more than 30% could have a significant impact on performance. It was suggested that individual fluctuations in VL should be noted when designing periodised training programs (Haff et al., 2008). No previous research has investigated the relationship between VL and other measures commonly used to monitor RT such as session RPE.

1.2 SIGNIFICANCE OF THE STUDY

Studies have demonstrated a relationship between intensity of exercise (expressed as a percentage of one repetition maximum) and session RPE (McGuigan & Foster, 2004; Singh et al., 2007; Sweet et al., 2004). They found that a single session RPE rating
correlates well with the intensity of RT session (Egan et al., 2006; Lagally et al., 2002b; McGuigan et al., 2004; Singh et al., 2007). Foster et al. (1996) suggested that heavy VLs were needed to achieve successful athletic performance, yet the appropriate periodisation of VL during the training week is essential to prevent overtraining while maximising training adaptations (Impellizzeri et al., 2004). The use of session RPE to monitor VL during RT could be useful in detecting fatigue in athletes and preventing overtraining. Session RPE can be used to calculate training measures such as session load (SL), monotony and strain (Foster, 1998). Careful manipulation of the VL could produce a successful design and implementation of a periodised training program (Fleck & Kraemer, 2004; Haff et al., 2008). Therefore, it is important for the relationship between session RPE measures and VL to be investigated further to provide valuable information to coaches and sport scientists regarding the efficacy of session RPE in monitoring the VL of training, and hence the utility of employing session RPE for this purpose.

1.3 PURPOSE OF THE STUDY

The purpose of the study was to investigate the relationship between session RPE measures (load, monotony and strain) and the VL during RT.

1.4 HYPOTHESIS

It was hypothesised that:

- There would be a significant relationship between each session RPE measure and VL during RT.
CHAPTER TWO

REVIEW OF LITERATURE

2.1 INTRODUCTION

This chapter will review the current literature associated with the use of the RPE and in particular, session RPE methods to monitor RT. The session RPE is a simple modification of the standard RPE in which the global intensity of an entire RT session is rated and allows athletes to provide a global RPE for the whole session instead of reporting a series of RPE measures throughout the session (McGuigan & Foster, 2004). In the first part of this review, the reliability and validity of the Borg’s 15-category and category-ratio 10 (CR-10) RPE scales to monitor exercise intensity during aerobic exercise and resistance exercise will be introduced. Next, the influence of different independent variables on RPE will be discussed. The final part of the review will concentrate on the reliability and validity of the session RPE method and its efficacy in monitoring RT.

2.2 THE RELIABILITY AND VALIDITY OF THE RPE SCALE DURING AEROBIC EXERCISE

Several studies have investigated the reliability and validity of the RPE scale in monitoring intensity of aerobic exercise (Borg, Hassmen, & Lagerstrom, 1987; Borg, Ljunggren, & Ceci, 1985; Noble, Borg, Jacobs, Ceci, & Kaiser, 1983). Noble et al. (1983) studied the relationship between perceptual ratings from Borg’s CR-10 RPE scale and physiological variables during exercise. Ten male participants performed a cycle ergometer test until voluntary exhaustion. The test began with no load and increased progressively by 50 watts (W) for every four minute stage. Heart rate and RPE were recorded during the last thirty seconds of each stage while blood lactate was obtained at the end of each stage. The results showed that the RPE values had significant relationships with exercise intensity, blood lactate and heart rate. These findings suggest that the RPE measure is a valid and reliable method in monitoring exercise intensity in a similar manner to both heart rate and blood lactate.
Borg et al. (1985) investigated the relationship between perceived exertion and perception of pain or aches in the legs to heart rate and blood lactate. Twenty-eight male participants performed a cycle ergometer test up to a voluntary maximum. The test included a forty watts increase for every five minute stage. Perceived exertion and perception of pain were collected using the CR-10 RPE scale during the last minute of each stage. The results found that heart rate increased linearly with power while the RPE and blood lactate increased in a positively accelerating function. The findings suggest that the combination of heart rate and blood lactate is a good predictor of RPE and supports the validity of the RPE measure in quantifying exercise intensity.

Further work by Borg et al. (1987) examined the reliability and validity of the Borg’s 15-category and CR-10 RPE scales in monitoring exercise intensity across different types of exercises. Eight male participants performed cycle and arm ergometer tests. The cycle and arm ergometer workloads increased every four minutes by 40, 70, 100, 150 and 200 W and 20, 35, 50, 70 and 100 W respectively. Heart rate, blood lactate and RPE ratings using both RPE scales were recorded thirty seconds before the end of each stage. The results showed that all the variables increased with workload. The responses obtained from the arm ergometer tests were all higher compared to responses from the cycle ergometer tests. Further analysis found that RPE had a linear relationship with the combination of heart rate and blood lactate during both types of exercise. The authors concluded that both sets of RPE scales were reliable and valid in monitoring intensity during steady state exercises.

The findings from the above studies have shown that the RPE ratings obtained from both the Borg’s 15-category scale and CR-10 scale are valid and reliable in monitoring exercise intensity during different types of aerobic exercises.

2.3 THE RELIABILITY AND VALIDITY OF THE RPE SCALE DURING RESISTANCE EXERCISE

Other studies have confirmed the reliability and validity in the use of the RPE scale in quantifying the intensity of resistance exercise (Gearhart et al., 2002; Lagally, McCaw, Young, Medema, & Thomas, 2004; Lagally et al., 2002a; Lagally et al., 2002b; Pierce,
Rozenek, & Stone, 1993; Suminski et al., 1997). Pierce et al. (1993) examined the effects of high volume weight training on lactate, heart rate and perceived exertion. The purpose of the study was to investigate the response of the above variables following an eight week high volume weight training program that emphasised on large muscle-mass exercises. Twenty-three untrained male participants were divided into experimental and control groups. A pre-test protocol, consisting of seven sets of ten repetitions of full squats at different intensities of each participant’s 1-RM, was performed on all the participants prior to the commencement of the training program. Measures of RPE were collected after each set. After eight week of weights training by the experimental group, all participants were retested using the same protocol. Results showed that there were significant decreases in the blood lactate and heart rate values for the experimental group compared to the control group. It also showed that RPE increased as the exercise intensity increased, with lower values for the experimental group after the training program. The authors concluded that an eight week high volume weight training program could reduce the physiological and perceived stress associated with RT. In addition, the findings of this study suggested that RPE is a valid and reliable method in monitoring exercise intensity.

In addition, Suminski et al. (1997) examined the perception of effort during resistance exercise using overall body RPE (RPE-O). The RPE-O measures the perceived exertion for the whole body instead of specific anatomical regions or physiological functions (Borg, 1998). Eight male participants completed two trials in a counter-balanced design: a single bout of seven resistance exercises at 70% of 1-RM and the same exercises at 50% of 1-RM. Blood lactate, heart rate and systolic blood pressure were measured before each trial, immediately after each exercise, and at thirty and sixty minutes post trial. The RPE-O ratings were collected immediately after each exercise using the CR-10 RPE scale. The results found that the increase in exercise intensity corresponded with a significant increase in RPE-O and blood lactate, but not heart rate or systolic blood pressure. The authors concluded that RPE-O is related to exercise intensity and that blood lactate may act as a mediator between RPE-O and exercise intensity. However, heart rate and systolic blood pressure appeared not to be related to RPE-O during RT. These findings suggest that the RPE measure is a valid method in monitoring exercise intensity during RT.
In a study by Lagally et al. (2002a), the RPE during low and high intensity resistance exercise by young adults was investigated. The purposes of the study were to obtain RPE during two different intensities of RT while holding total work constant and to compare active muscle RPE (RPE-AM) with RPE-O during RT. Nineteen participants performed seven resistance exercises for two different intensities. The two experimental trials were conducted on separate days and RPE-AM and RPE-O were collected immediately at the completion of each of the seven exercises during both intensities. The high intensity trial consisted of one set of five repetitions at 90% of 1-RM while the low intensity trial consisted of one set of fifteen repetitions at 30% of 1-RM. The results found that both the RPE-AM and RPE-O were significantly higher for the high intensity trial than for the low intensity trial. They also found that RPE-AM were significantly higher than RPE-O for all exercises during both exercise intensity. These findings suggested that RPE can provide information regarding the intensity of resistance exercise and that RPE values in the active muscles are greater than RPE values for the overall body.

Later work by Lagally et al. (2002b) investigated the response of perceived exertion, electromyography (EMG) and blood lactate during acute bouts of RT. The main purpose of the study was to examine the RPE during RT in women. In addition, changes in blood lactate and biceps muscle activity assessed using EMG were investigated as potential mediators of RPE during RT. Twenty female participants performed one set of biceps curl exercise at three different percentages of their 1-RM. The total work was held constant during each of the three intensities by varying the number of repetitions performed. RPE responses were assessed for both the active muscle (RPE-AM) and the overall body (RPE-O) following each intensity. EMG data was collected from the biceps brachii muscle during each exercise intensity while blood samples were taken before and following the intensities. The results found that RPE-AM, RPE-O and the EMG activity in the biceps increased as the intensity of exercise increased. Furthermore, the post-exercise blood lactate was significantly greater at 90% 1-RM than at 30% 1-RM. The authors concluded that monitoring RPE might be a useful technique for regulating exercise intensity and that blood lactate and the activity of the active muscle might mediate the relation between RPE and resistance exercise intensity.
Gearhart et al. (2002) examined the RPE-AM during high intensity and low intensity resistance exercise. Twenty participants performed two trials (high intensity and low intensity) consisting of seven resistance exercises. Participants had to perform five repetitions of their 90% 1-RM and fifteen repetitions of their 30% 1-RM for each resistance exercise during the high intensity and low intensity protocols respectively. During the high intensity trial, RPE-AM was collected after each repetition while RPE-AM was collected after every third repetition during the low intensity trial. The results found that RPE-AM were significantly greater for the high intensity protocol than the low intensity protocol for all the seven resistance exercises. It was concluded that RPE-AM could be used to regulate exercise intensity during both strength and endurance weight lifting protocols.

Lagally et al. (2004) examined RPE and electromyography (EMG) during resistance exercise in recreational and novice lifters. Fourteen novice and fourteen recreationally trained female participants performed the bench press exercise for eight and six repetitions at 60 and 80% of their 1-RM respectively. The numbers of repetitions performed were varied to maintain a constant total work between intensities. RPE-AM, RPE-O and EMG were measured during both intensities. The EMG data were collected from the four muscle groups (pectoralis major, anterior deltoid, medial deltoid and triceps brachii) involved in the bench press exercise. The results indicated that RPE and EMG increased for both novice and recreationally trained females as resistance exercise intensity increased from 60 to 80% of 1-RM. In addition, they found that RPE-AM values were significantly higher than RPE-O at both intensities. However, no significant correlation was found between RPE and EMG. These findings provide support for a link between relative exercise intensity and RPE in both novice and recreationally trained lifters and suggest that muscle activity mediates the perception of exertion during resistance exercise. Furthermore, these findings support the reliability and validity of the RPE method in monitoring resistance exercise intensity for both types of lifters.

Duncan et al. (2006) studied the relationship between RPE and muscle activity during dynamic leg extension exercise. Ten male and ten female participants performed one set of twelve, six and four repetitions at 30%, 60% and 90% of 1-RM respectively. RPE-AM and RPE-O were recorded at the end of each intensity while EMG data were collected from the rectus femoris, vastus lateralis and vastus medialis muscles. The results showed
that both the RPE measures and EMG activity in the muscles significantly increased as the exercise intensity increased and that the RPE-AM was higher than RPE-O at all intensities. Significant relationships were found between RPE-AM and RPE-O with the muscle activities of the three muscles. These findings suggest that RPE is a valid and reliable method in monitoring exercise intensity.

The findings from the above studies have provided further evidence that the RPE measure is a valid and reliable method in quantifying intensity during RT.

2.4 RPE WITH DIFFERENT INDEPENDENT VARIABLES

Robertson et al. (2000) examined the gender comparison of RPE at absolute and relative physiological criteria using various exercise models. The purpose of the study was to investigate the effect of gender on RPE for the overall body (RPE-O), chest (RPE-C), legs (RPE-L) and arms (RPE-A) during exercise. Nine male and ten female participants were compared using a perceptual estimation paradigm for treadmill (weight bearing), simulated skiing (partial weight bearing) and cycle (non-weight bearing) exercises. All of the RPE values were determined at the end of each test using a Borg 15-category scale. These values were compared between genders at absolute oxygen uptake and heart rate, and relative maximal oxygen uptake (%\( \text{VO}_2 \text{ max} \)) and maximal heart rate (%HR\(_{\text{max}}\)) reference criteria. The results found that there were no significant differences in all the RPE values between male and female participants when comparisons were made at both absolute and relative heart rate for the three exercise modes. Furthermore, no significant differences were found in RPE values between genders when compared at mode specific relative oxygen uptake criteria. The authors concluded that RPE did not differ between genders at exercise intensities between 70 and 90% of mode specific maximal values.

Nethery (2002) examined the influence of different exercise settings (control, sensory deprived, video and music) on RPE during cycling exercise. Thirteen male participants completed four sessions of fifteen minutes cycling at 50% and 80% of their maximal oxygen uptake (\( \text{VO}_2 \text{ max} \)) under each of the conditions. RPE and heart rate were collected every five minute interval during all the sessions. The results found that RPE increased with exercise duration at both intensities and that the RPE was significantly
higher during the higher exercise intensity. Further analysis showed that the RPE values during the exercise setting with music were significantly lower during both exercise intensity than that of the other conditions while exercising in the sensory deprived setting produced the highest RPE compared to the other conditions. Heart rate increased with exercise duration as the intensity of exercise increased and was higher for the harder intensity. However, the heart rate values were not different among the four conditions at either intensity. The authors concluded that the type of exercise conditions influences the RPE on an exercising individual, with the degree of influence dependent on the intensity and duration of exercise.

Woods et al. (2004) investigated the effects of rest interval length on RPE during dynamic knee extension exercise. Thirty participants performed three sets of ten repetition of inertial knee extension exercise at 70% of their 1-RM. They were randomly assigned into one of three groups following the establishment of their 1-RM. Each group had a different rest interval length (1, 2 and 3 minutes) between sets. RPE was collected after each repetition of each set using the CR-10 scale. The results found that there were no significant differences in RPE when performing knee extension exercise between rest interval lengths of one to three minutes. The results also found that there was a significant increase in RPE across the repetitions performed within each set and that the increases in RPE values were greater in set 3 than in sets 1 and 2. The authors concluded that rest interval lengths that were 3 minutes or less were not sufficient for the muscles to recover fully.

Simao et al. (2005) investigated the influence of exercise order on the number of repetitions performed and perceived exertion during resistance exercises. Eighteen participants with at least six months RT experience completed two training sessions that were separated by 48 hours in a counterbalanced crossover design. They performed a total of five upper-body resistance exercises in each session. One session began with exercises of the large muscle group and progressed to exercises of the small muscle group, whereas the other session was performed with the opposite sequence. During both sequences, three sets of each exercise were performed to concentric failure, with a two minute recovery intervals between sets and exercises. The results found that comparisons between the sequences showed no significant differences for RPE. This suggested that exercise order did not influence RPE.
From these studies, it was demonstrated that gender, rest interval and exercise order does not significantly affect the RPE ratings during exercise. However, the type of exercise setting made available could influence the RPE on the athlete. Also, more research needs to be done to examine the effects of longer rest interval lengths with different types of exercises on RPE measures to get more information on muscle recovery.

2.5 THE RELIABILITY AND VALIDITY OF THE SESSION RPE DURING AEROBIC EXERCISE

The session RPE method is a simple modification in which the global intensity of an entire training session could be rated, allowing athletes to provide a global RPE for the whole session instead of reporting a series of RPE measures throughout the session (McGuigan & Foster, 2004). It allows researchers and coaches to evaluate trends in training, injury and illness in relation to the session RPE and global exercise intensity (McGuigan & Foster, 2004). Foster et al. (1996) investigated the relationship between athletic performance and SL. They monitored fifty-six competitive athletes from various sports (running, cycling and speed skating) during twelve weeks of training. The first six weeks included baseline training while the second weeks included a self-selected increased in SL. Session RPE values were taken thirty minutes following the completion of each training session. SL was quantitated as the product of session RPE and the duration of each training session. The athletes’ performances were assessed at the sixth and twelfth week using either unpaced time trials. The results found that their performances improved from week six to week twelve. The average time to complete the time trials decreased. Training duration and intensity did not change significantly although session RPE and SL increase significantly. The findings suggest that improved performance in response to intensified training is primarily dependent on increases in total load and session RPE during training.

In another study, Foster (1998) observed the relationship of illnesses and injuries (overtraining syndrome) to SL and training monotony in twenty-five competitive athletes. Each athlete was instructed to rate their global intensity for their training sessions over a period of six months to three years. The session RPE were collected thirty minutes post-exercise and the duration of training sessions were also recorded. The daily SL (session RPE multiplied by session duration) was summated to create a weekly SL. Training
monotony was derived from the daily mean SL divided by standard deviation while training strain was the product of training monotony and weekly SL. The incidence of illnesses and injuries were also noted during this period of time. The results found that 84, 77 and 89% of illnesses or injuries could be explained by spikes in SL, monotony and strain respectively. These findings suggest that training programs designed to minimise training monotony and strain decreases the chances of athletes overtraining.

In addition, Foster et al. (2001) evaluated the ability of session RPE method to monitor training during non-steady state and prolonged exercise compared with an objective standard based on heart rate (HR). The study was conducted in two separated but related parts. The exercise bouts were quantititated using both the session RPE method and an objective HR method. In the first part of the study, twelve well-trained, recreational cyclists performed eight cycle ergometer trials after completing a preliminary VO$_2$ max test on a cycle ergometer. The individual anaerobic threshold (AT) was calculated during the VO$_2$ max test. The eight cycle ergometer trials included a reference thirty minute steady state bout at a power output equivalent to 90% of AT, two additional steady state exercise bouts at the same power output but of sixty and ninety minutes duration, and five interval bouts at the same mean power output. HR and blood lactate were collected during each trial while session RPE was obtained thirty minutes following the completion of exercise using Borg’s CR-10 RPE scale. An exercise score for each bout was computed by multiplying the exercise duration by the session RPE for that bout. In the second part, fourteen male collegiate basketball players performed a VO$_2$ max test. They were then monitored during basketball practices sessions and competitive matches. HR responses were recorded during these sessions while session RPE was measured thirty minutes following the completion of each session. The results from both parts revealed a consistent relationship between both the session RPE and objective HR method although the absolute score for session RPE was significantly greater due to the differences in scale. These findings suggested that the session RPE method is a valid method of monitoring exercise training during different types of exercise.

Impellizzeri et al. (2004) studied the use of RPE-based SL in soccer. The purpose of the study was to apply the session RPE method to quantify internal load and to assess its correlation with various heart rate-based methods that are used to determine internal SL.
During exercise. Nineteen male soccer players were tracked for seven training weeks. They performed an incremental treadmill test before and after the training period during which their lactate threshold was established. Their SL during the training period was calculated from the product of their session RPE and session duration. At the same time, their heart rate were collected during these training sessions and were used to calculated SL based on three different heart rate-based methods. The results found that there were significant relationship between the session RPE-based SL and all three of the heart rate-based SL ($r = 0.50-0.85$, $p \leq 0.01$). The findings suggested that session RPE gives similar information about SL during soccer as heart rate-based methods, and is a valid method in quantifying exercise intensity.

Additionally, Alexiou et al. (2008) investigated the relationship between the session RPE-based method and three heart rate-based methods of quantifying SL during different types of training. Fifteen female soccer players were tracked for a period of sixteen weeks. Their session RPE, heart rate and session duration were recorded during this period. The types of training were broken down into conditioning, speed, technical, resistance and matches. The results found that the correlations between the session RPE-based SL and the three heart rate-based SL during different training types were all significant ($r = 0.25-0.82$, $p \leq 0.05$). These findings offer further evidence that session RPE provides similar information as heart rate-based methods in quantifying SL during soccer.

### 2.6 Monitoring Resistance Training Using Session RPE

In further studies, researchers had investigated the reliability and validity of the session RPE method in monitoring exercise intensity during RT (Day et al., 2004; Egan et al., 2006; McGuigan et al., 2008; McGuigan et al., 2004; Singh et al., 2007; Sweet et al., 2004). Day et al. (2004) investigated the reliability of the session RPE method in monitoring exercise intensity during high, moderate and low intensity RT. Nine male and ten female participants performed each intensity twice to establish the reliability of RPE measurements. Each protocol consisted of one set of five resistance exercises. The high, moderate and low intensity protocols consisted of, four to five repetitions at 90%, ten repetitions at 70% and fifteen repetitions at 50%, of a participant’s 1-RM respectively. RPE was collected using the CR-10 RPE scale following the completion of each exercise while
session RPE was measured thirty minutes post exercise. The results found that RPE increased significantly as exercise intensity increased and that average RPE and session RPE did not differ significantly during each intensity. The intraclass correlation coefficient (ICC) for the session RPE was 0.88. These findings suggest that performing fewer repetitions at a higher intensity was perceived to be more difficult than performing more repetitions at a lower intensity. In addition, the session RPE is found to be a valid and reliable method to quantify RT intensity.

In another study, McGuigan et al. (2004) investigated the salivary cortisol responses and perceived exertion during high and low intensity bouts of resistance exercise. Eight male and nine female participants performed two trials of acute RT bouts in a counterbalanced design. Each session consisted of the squat and bench press exercise, and was performed twice to test for reliability of the measures. The high and low intensity protocol consisted of six sets of ten repetitions at 75% of 1-RM and three sets of ten repetitions at 30% of 1-RM respectively. Saliva samples were collected immediately before, immediately after and thirty minutes following the completion of the session. Standard and session RPE values were determined after each set and thirty minutes post-exercise respectively using a CR-10 RPE scale. The results found that there was significant difference between the average RPE values for each exercise intensity. There was also a significant difference between the session RPE values for each exercise intensity. Both the average and session RPE increased as the intensity of exercise increased. The results also revealed that there was no significant difference between the average and session RPE values for the squat exercise during each intensity. However, there was a significant difference between average and session RPE for the bench press exercise. The study also found that there was no significant difference for session RPE values between male and female participants. In addition, the ICC for the session RPE measure was 0.95. The authors concluded that the session RPE measure was a valid and reliable method of quantifying RT.

A study done by Sweet et al. (2004) investigated the validity of session RPE method in quantifying RT. Ten men and ten women performed three aerobic training bouts on a cycle ergometer at intensities of 56%, 71% and 83% of VO₂ max and three RT sessions with two sets of six exercises at 50% (15 repetitions), 70% (10 repetitions) and 90% (4 repetitions) of 1-RM. The order and intensity of the RT and cycling sessions were
randomised. Three different RPE measurements were recorded. During the RT sessions, participants rated their RPE after each set using the Borg CR-10 RPE scale. The session RPE and session RPE lifting-only (RPE-LO) were determined thirty minutes post-exercise. The session RPE values were determined thirty minutes following the completion of exercise during the cycling sessions. The results found that the average RPE, session RPE and session RPE-LO values increased as percentage of 1-RM increased, despite a decrease in total repetitions and total workload. A general correspondence was observed between comparable intensities of RT and cycling using the session RPE method. The results also observed that as the intensity of each session increased on the cycle ergometer, the session RPE increased comparably with heart rate. The reliability of the session RPE method was determined to be high (ICC = 0.88). Thus, the session RPE method was demonstrated to be a reliable and valid method for quantifying the intensity of RT, generally comparable to aerobic training.

Additionally, Egan et al. (2006) studied the validity of the session RPE method to monitor different types of RT. The purpose of the study was to compare session RPE for different RT techniques (traditional, super slow and maximal power) in the squat exercise. Fourteen female participants performed three RT sessions in a randomised crossover design. The traditional, super slow and maximal power protocols consisted of six sets of six repetitions at 80%, 55% and 30% of 1-RM respectively. Standard and session RPE measures were collected after each set and thirty minutes following each training session respectively, using Borg’s CR-10 RPE scale. The results found that there was no significant difference between average RPE and session RPE across all the three protocols. In addition, power training had significantly lower average and session RPE compared to both super slow and traditional trainings. These findings suggest that session RPE provides the same information about perceived exertion as the standard RPE measures. The lack of significant difference between the average RPE and session RPE values confirms the findings from previous studies (Day et al., 2004; McGuigan et al., 2004; Sweet et al., 2004).

Singh et al. (2007) studied the effectiveness of session RPE in measuring effort during different models of RT. Fifteen male participants performed three different protocols that consisted of the same five resistance exercises. The strength, hypertrophy and power protocols included three sets of five repetitions at 90% of 1-RM with three minutes of rest,
three sets of ten repetitions at 70% of 1-RM with one minute of rest and three sets of five repetitions at 50% of 1-RM with three minutes of rest respectively. Standard and session RPE values were collected following the completion of each set and at five minute time interval within thirty minutes post-exercise, respectively with a CR-10 RPE scale. The results found that there was a significant relationship between the average and session RPEs (r = 0.74). There was no significant difference between mean and session RPE values for the power protocols. However, the results showed a difference between the mean and session RPE values for both the strength and hypertrophy protocols. The average session RPE values at five and ten minutes post-exercise were significantly different whereas all other session RPE values (15, 20, 25 mins) had no significant difference when compared with the session RPE at thirty minutes post-exercise. The authors concluded that the session RPE method was effective in monitoring different types of RT, and session RPE was a better indicator of the overall RT sessions than average RPE.

McGuigan et al. (2008) investigated the use of session RPE for monitoring RT in overweight or obese children. Sixty-one children performed three RT sessions every week for four weeks. The strength, hypertrophy and power protocols consisted of three sets of three to fifteens repetitions of eight different resistance exercises. The RPE and session RPE measures were obtained after each set and fifteen minutes following the end of each session respectively. The results found that there was a significant difference between the average RPE and session RPE values during the training period. However, they found that a significant relationship between average RPE and session RPE existed (r = 0.88). The ICC for session RPE was 0.94. These findings suggest that session RPE provides different information to average RPE in children. The authors concluded that the session RPE is a valid measure in monitoring RT in obese or overweight children.

The studies above provided further evidence to support the validity and reliability of the session RPE method in quantifying RT intensity. They also found that session RPE was effective in monitoring RT across different training protocols.

2.7 SUMMARY
This literature review has shown the standard RPE measure is a valid and reliable method in monitoring intensity during different types of exercises. RPE has also been shown to relate well with objective measures such as heart rate and blood lactate. RPE was found not to be significantly influenced by gender, rest interval or exercise order. The session RPE method was introduced to allow athletes to provide a global rating for an entire session and was first used to monitor training intensity and load during aerobic exercises. Also, it was found to be a valid and reliable method in quantifying the intensity and SL during aerobic exercises. The findings from these studies indicated that session RPE provides the same information as heart rate-based method and was simple to administer. These studies also found that session RPE method allows the calculation of other measures (SL, monotony and strain) that were useful in preventing illnesses and injuries associated with overtraining. Furthermore, studies have also indicated that session RPE method can be used to quantify RT validly and reliably and is sensitive to changes within exercise intensity across different types of resistance exercises and training protocols.
CHAPTER THREE
METHODOLOGY

3.1 PARTICIPANTS

Following ethical approval from the Faculty Ethics Committee, twelve male and eight female volunteers (n=20) age 18 to 35 years were recruited from the student population at Edith Cowan University to complete the study. The participants were required to have at least six months of experience in RT. Participants were provided with a letter of information outlining the possible risks, requirements and benefits of participating in the study. They were asked to complete a physical activity and medical questionnaire to determine the correct training history for inclusion in the study and to screen for any medical contraindications. Each participant completed an informed consent form prior to beginning the study. Participants were required to refrain from any other forms of RT during the course of the study and were allowed to withdraw from the study at any stage without prejudice.

3.2 EXPERIMENTAL APPROACH TO PROBLEM

Each participant performed three RT sessions per week for a period of four weeks. The three RT sessions during the week consisted of strength, hypertrophy and power protocols and were performed at least 48 hours apart. All participants underwent two familiarisation sessions prior to the start of the study. The first familiarisation session included informed consent and medical questionnaire procedures, height and weight measurements, instructions on how to use the CR-10 RPE scale to rate session RPE and its perceptual anchors (high and low), demonstration of each of the four exercises (bench press, squats, shoulder press and bench rows) and the determination of 1-RM for squats and bench press while the second familiarisation session included the determination of 1-RM for shoulder press and bench rows. The 1-RM of an exercise was defined as the heaviest resistance that could be lifted with proper technique for one complete repetition of an exercise (Fleck & Kraemer, 2004).
3.3 EXERCISE PROTOCOL

All participants completed fourteen sessions in this study. The sessions were conducted in the strength and conditioning laboratory at Edith Cowan University. The first two sessions involved the familiarisation sessions during which the participants’ 1-RM for the four resistance exercises were determined. The determination of 1-RM for two exercises was determined during each session. These exercises were performed using free weights. The 1-RM for these exercises were determined according to the method of Kraemer and Fry (1995). Each participant was instructed to begin with a light warm-up of 5 to 10 repetitions at 40 – 60% of his perceived 1-RM weight. After a 1 minute rest period, the participant performed 3 to 5 repetitions at 60 – 80% of his perceived 1-RM weight. This previous set took the participant close to his 1-RM. After a 2 minute rest period, a conservative increase in the weight was made and the participant attempted his first 1-RM lift. If the lift was successful, the participant was given a 3 to 5 minute rest period. A small increase in weight was made and the participant attempted another 1-RM lift. This process continued until a failed attempt occurred. The weight of the last successfully completed lift by the participant was the reported 1-RM. The 1-RM was determined within 3 to 5 maximal efforts. The session RPE was also collected during this session to familiarise the participants with the use of the CR-10 RPE scale (Table 3.1).

The 1-RM results for the four resistance exercises were used to set the training intensities of each session. VLs were then calculated from the weights that the participants used in each session. Each participant was required to perform three RT sessions, consisting of strength, hypertrophy and power protocols, per week for a period of four weeks. Participants performed the same four resistance exercises (bench press, squats, shoulder press and bench rows) for all the sessions. The study utilised an undulating periodised RT program which had 3 loading weeks followed by an unloading week.
Table 3.1  
*Borg's CR-10 RPE Scale*

<table>
<thead>
<tr>
<th>Ratings</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Rest</td>
</tr>
<tr>
<td>1</td>
<td>Very, Very Easy</td>
</tr>
<tr>
<td>2</td>
<td>Easy</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat Hard</td>
</tr>
<tr>
<td>5</td>
<td>Hard</td>
</tr>
<tr>
<td>6</td>
<td>*</td>
</tr>
<tr>
<td>7</td>
<td>Very Hard</td>
</tr>
<tr>
<td>8</td>
<td>*</td>
</tr>
<tr>
<td>9</td>
<td>*</td>
</tr>
<tr>
<td>10</td>
<td>Maximal</td>
</tr>
</tbody>
</table>

For the strength sessions, participants performed 3 sets of 3 repetitions per exercise at a load of 75-90% of their 1-RM with a rest period of five minutes between each set. The hypertrophy session required participants to perform 3 sets of 10 repetitions per exercise at a load of 65-75% of their 1-RM. A one minute rest period between each set was established for this protocol. The strength and hypertrophy sessions were representative of protocols that were used to develop maximal strength and increased muscle size, respectively (Fleck & Kraemer, 2004). The power sessions required the participants to perform 3 sets of 5 repetitions per exercise at a load of 25-40% of their 1-RM at a fast lifting speed. The rest period between each set was three minutes. The lifting velocity was rapid during this protocol to maximise muscular power (Fleck & Kraemer, 2004). The sets and repetitions for each protocol were fixed for all the four weeks for control purposes. Table 3.2 summarises all the protocols for the four weeks.
Table 3.2

*Exercise Protocol*

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Week</th>
<th>Load (% of 1-RM)</th>
<th>Sets</th>
<th>Repetition</th>
<th>Rest Interval (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength</td>
<td>1</td>
<td>80</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>85</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>90</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>75</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Hypertrophy</td>
<td>1</td>
<td>70</td>
<td>3</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>72.5</td>
<td>3</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>75</td>
<td>3</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>65</td>
<td>3</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Power</td>
<td>1</td>
<td>30</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>35</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>40</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>25</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

Participants were required to perform stretching exercises for selected muscle groups prior to the commencement of each session. Their body positions (hand grips and leg position) and range of motion was standardised for each exercise.

### 3.4 RPE MEASURES

Each participant was provided instructions on the use of the CR-10 RPE scale during the familiarisation session. Standard instructions and anchoring procedures for assessing session RPE during the RT sessions was explained during this session (Borg, 1998; Foster et al., 2001; Gearhart et al., 2001; Noble & Robertson, 1996). The rating scale anchors were established by having each participant resting and later performing 1-RM’s of the four exercises. Participants were instructed to associate the rest (no effort) with the rating of 0 and 1-RM (maximal effort) with the rating of 10. During the study, session RPE was determined within thirty minutes following the RT session in order to avoid particularly easy or difficult elements toward the end of the session from skewing the
overall rating of the session (Day et al., 2004). The participants was asked to rate their session RPE by answering the question “How hard was your entire workout?” (Gearhart et al., 2001). The product of the session RPE and session duration had been defined as the SL (Foster, 1998). “Training monotony” was calculated from the mean SL divided by the standard deviation of the SL over a 1-week period. Training monotony had been defined as the variability of training for the training period (McGuigan & Foster, 2004). The product of SL and training monotony was then used to calculate “training strain” (Foster, 1998). Training strain had been defined as the overall stress imposed on the athlete (McGuigan & Foster, 2004).

3.5 VOLUME LOAD MEASURES

The volume of training for each session was determined by calculating the VL. VL is the product of the total number of repetitions performed and the amount of load lifted by the participant (Stone et al., 2007). Weekly average VL is the mean VL performed during one week. Table 3.3 below shows an example of the calculation of VL for a single session.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Load/ kg</th>
<th>Total Repetitions</th>
<th>Volume Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench Press</td>
<td>90</td>
<td>9</td>
<td>810</td>
</tr>
<tr>
<td>Squats</td>
<td>135</td>
<td>9</td>
<td>1215</td>
</tr>
<tr>
<td>Shoulder Press</td>
<td>54</td>
<td>9</td>
<td>486</td>
</tr>
<tr>
<td>Bench Rows</td>
<td>72</td>
<td>9</td>
<td>648</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>3159</td>
</tr>
</tbody>
</table>

3.6 TRAINING PROGRAM

Figure 3.1 depicts the range of VL variations for sessions over the four week training period. The highest VL values were attained during the third week (session 7-9) while the lowest were attained during the fourth week (session 10-12).
3.7 STATISTICAL ANALYSIS

Data was presented as Mean ± Standard Deviation (SD). Pearson's product correlation was used to assess the strength of relationship between the different variables determined from session RPE (SL, monotony and strain) and VL. A one-way between-groups analysis of variance (ANOVA) was used to test for differences in VL, session RPE and SL among the different RT protocols. Significant main differences were further analysed using Tukey post-hoc comparisons. Statistical significance was set at an alpha level of 0.05.

3.8 LIMITATIONS

Limitations of this study included the measurement of 1-RM for the different RT exercises during the familiarisation sessions. The 1-RM testing of two different exercises in one session might had caused fatigue and provided inaccurate 1-RM measurements for the subsequent exercise sessions.
3.9 DELIMITATIONS

Delimitations of the study were imposed through the selection of participants. This study was restricted to male and female volunteers aged between 18 and 35 years with a RT background of at least six months. All participants were also required to refrain from any other form of RT during the course of the study.
CHAPTER FOUR
RESULTS

4.1 DESCRIPTIVE CHARACTERISTICS

Descriptive characteristics and 1-RM of the participants are presented in Table 4.1 and Table 4.2 respectively.

Table 4.1
Participants’ Characteristics (mean ± SD)

<table>
<thead>
<tr>
<th>Participants</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (n = 10)</td>
<td>24.7 ± 4.7</td>
<td>175 ± 5.5</td>
<td>79.3 ± 13.5</td>
</tr>
<tr>
<td>Female (n = 10)</td>
<td>23.6 ± 4.0</td>
<td>166.0 ± 3.2</td>
<td>64.1 ± 7.2</td>
</tr>
</tbody>
</table>

Table 4.2
Participants’ one repetition maximum (1-RM) for four resistance exercises (mean ± SD)

<table>
<thead>
<tr>
<th>Participants</th>
<th>Bench Press (kg)</th>
<th>Squat (kg)</th>
<th>Shoulder Press (kg)</th>
<th>Bench Rows (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (n = 10)</td>
<td>84.6 ± 18.4</td>
<td>123.8 ± 32.1</td>
<td>68.5 ± 16.0</td>
<td>81.3 ± 13.8</td>
</tr>
<tr>
<td>Female (n = 10)</td>
<td>37.5 ± 3.0</td>
<td>75.0 ± 13.6</td>
<td>33.8 ± 5.0</td>
<td>43.4 ± 4.4</td>
</tr>
</tbody>
</table>

4.2 RELATIONSHIPS BETWEEN VARIABLES

The VL and session RPE values were collected from 240 RT sessions. Pearson’s product moment correlations revealed significant positive relationships between VL and session RPE ($r = 0.737$), as well as VL and SL ($r = 0.258$) (Table 4.3). However, there were no significant relationships between the average weekly VL and training monotony, and average weekly VL and training strain (Table 4.3).
Table 4.3

Relationships between variables volume load (VL), session load (SL), session RPE (SRPE), monotony and strain

<table>
<thead>
<tr>
<th>Relationship between variables</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall (N=240)</td>
<td></td>
</tr>
<tr>
<td>VL vs SL</td>
<td>0.258*</td>
</tr>
<tr>
<td>VL vs SRPE</td>
<td>0.737*</td>
</tr>
<tr>
<td>Average weekly VL vs monotony</td>
<td>0.061</td>
</tr>
<tr>
<td>Average weekly VL vs strain</td>
<td>0.178</td>
</tr>
</tbody>
</table>

Note. * p ≤ 0.01;

4.3 RELATIONSHIPS BETWEEN VARIABLES DURING DIFFERENT PROTOCOLS

There were moderate significant relationships between VL and session RPE (r = 0.230), as well as VL and SL (r = 0.223) during the power protocol (Table 4.4). However, no significant relationships were found between these variables during the other protocols.

Table 4.4

Relationships between variables during different protocols

<table>
<thead>
<tr>
<th>Protocol (N=80)</th>
<th>Relationship between variables</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength</td>
<td>VL vs SL</td>
<td>0.063</td>
</tr>
<tr>
<td></td>
<td>VL vs SRPE</td>
<td>0.075</td>
</tr>
<tr>
<td>Hypertrophy</td>
<td>VL vs SL</td>
<td>0.193</td>
</tr>
<tr>
<td></td>
<td>VL vs SRPE</td>
<td>0.102</td>
</tr>
<tr>
<td>Power</td>
<td>VL vs SL</td>
<td>0.223*</td>
</tr>
<tr>
<td></td>
<td>VL vs SRPE</td>
<td>0.230*</td>
</tr>
</tbody>
</table>

Note. * p ≤ 0.05
4.4 DIFFERENCES BETWEEN PROTOCOLS

The average VL performed for the three different protocols of RT are shown in Figure 4.1. The average VL values for strength, hypertrophy and power protocols were 2152.7 ± 760.0, 6065.3 ± 2057.4 and 1411.4 ± 551.7 respectively. Significant differences were found between the strength, hypertrophy and power protocols for this measure.

*Figure 4.1. Volume load values for the different resistance training protocols; * $P \leq 0.001$. 


The mean session RPE collected during the three different RT protocols are shown in Figure 4.2. The session RPE values for the strength, hypertrophy and power protocols were 3.69 ± 1.51, 7.19 ± 1.64 and 1.65 ± 0.68 respectively. There were significant differences between the strength, hypertrophy and power protocols for session RPE.

*Figure 4.2. Session rate of perceived exertion (RPE) values for the different resistance training protocols; * $P \leq 0.001$. 
The mean SL obtained from the different exercise protocols are presented in Figure 4.3. The SL values for the strength, hypertrophy and power protocols were 224.4 ± 94.4, 172.6 ± 47.0 and 60.0 ± 24.9 respectively. There were significant differences between the strength, hypertrophy and power protocols for this measure.

![Session Load Values](image)

*Figure 4.3. Session load values for the different resistance training protocols; * $P \leq 0.001$. 


The mean session duration obtained from the different exercise protocols are presented in Figure 4.4. The session duration for the strength, hypertrophy and power protocols were 60.7 ± 2.2, 23.9 ± 3.0 and 36.3 ± 1.9 minutes respectively. There were significant differences between the strength, hypertrophy and power protocols for session duration.

![Figure 4.4. Session duration for the different resistance training protocols; * P ≤ 0.001.](image-url)
CHAPTER FIVE
DISCUSSION

5.1 MAIN FINDINGS

The purpose of this study was to investigate the relationships between session RPE measures (SL, monotony and strain) and the VL during RT. It was hypothesised that there would be a significant relationship between each session RPE measure and VL of RT. As some of the session RPE measures did not significantly correlate with VL the main hypothesis was rejected, however, importantly the results of the study did show that there were significant relationships between session RPE and VL, as well as SL and VL (Table 4.3). The relationships were positive in nature showing that an increase in session RPE and SL values were reflected by corresponding increases in VL of the training sessions. There were, however, no significant relationships evident between the average weekly VL and training monotony, and average weekly VL and training strain (Table 4.3).

The results of this study indicated that the participants perceived the hypertrophy training sessions to be the most difficult, followed by the strength and power training sessions, respectively (Figure 4.2). The results also revealed that SL during the strength training sessions was the highest, followed by the hypertrophy and power training sessions, respectively (Figure 4.3).

5.2 RELATIONSHIPS BETWEEN VARIABLES

Previously, it has been shown that session RPE is a valid and reliable method in quantifying exercise intensity during RT (Day et al., 2004; Egan et al., 2006; McGuigan et al., 2008; Singh et al., 2007). However, no other studies had specifically examined the efficacy of session RPE in monitoring VL during RT. The results in the present study found that session RPE was significantly correlated (r = 0.737) with VL during RT. The findings suggest that as the training volume during RT increases, the perception of exertion of the participants also increased. A feed-forward neuromuscular mechanism has previously been proposed to link muscle activity with perceived exertion (Lagally et al., 2004; McCloskey,
Gandevia, Porter, & Colebatch, 1983). It has also been previously found that there is greater tension development, which requires an increase in motor unit recruitment and firing frequency, when muscles are under heavy load (Gearhart et al., 2001; Noble & Robertson, 1996). The increase in muscle activity causes the motor cortex to send stronger signals to the sensory cortex, which may increase the perception of exertion (Egan et al., 2006). Kraemer et al. (1993) demonstrated that as volume of RT increased, there were significant increases in plasma β-endorphin and serum cortisol. They also observed that the larger increases in blood lactate occurred during high volume RT. Taken together, these findings suggest that there is increased perceptual load with increased volume of RT. The current findings add support for use of session RPE in monitoring VL during RT.

The results also indicated that SL had a significant relationship with VL during RT, although the correlation was only moderate (r = 0.258). This could be due to the SL being dependent on the session duration while VL does not take time into account in its calculation. A study conducted by Alexiou and Coutts (2008) also found that the correlation between SL and heart rate based SL to be low (r = 0.25-0.52) during RT sessions. The results of the present study also revealed that there were no significant relationships between the average weekly VL and training monotony, and average weekly VL and training strain. Previous studies by Alexiou and Coutts (2008), Impellizzeri et al. (2004) and Foster (1998) had suggested that the session RPE measures could be a simple method of monitoring aerobic training as well as minimising undesired training outcome. No previous study has attempted to investigate the effectiveness of the session RPE measures in quantifying VL during RT. The findings of this study suggest that the session RPE measures of SL, monotony and strain can not be applied to monitor VL during RT as previous studies by Alexiou and Coutts (2008), Impellizzeri et al. (2004) and Foster (1998) had found for aerobic training.

From these results, it appears that session RPE provides an indication of training volume during RT, however, the measures that can be derived from session RPE, such as SL, monotony and strain, seem to be more limited in quantifying VL during this type of training (i.e., RT).
5.3 VOLUME LOAD AND SESSION RPE ACROSS DIFFERENT PROTOCOLS

In the present study, participants performed three sessions per week for four weeks of an undulating periodised RT program that consisted of strength, hypertrophy and power protocols. The strength sessions incorporated the longest rest period (5 minutes) and lower total repetitions per exercise (9 repetitions) while the hypertrophy sessions employed the shortest rest period (1 minute) and highest total repetitions per exercise (30 repetitions). The power sessions employed a three minute rest period and a total of 15 repetitions per exercise. As such, the VL during the hypertrophy sessions were the highest followed by the strength and power sessions, respectively (Figure 4.1). As indicated by the results, the protocol with the lowest VL (power protocol) produced the lowest session RPE while the hypertrophy protocol which had the highest VL, produced the highest session RPE, despite the higher exercise intensities used during the strength sessions (75-90% of 1-RM) compared to the hypertrophy sessions (65-75% of 1-RM). This suggests that session RPE could be a sensitive method of monitoring VL during different types of exercise protocols.

The findings of this study are in contrast to the findings of previous studies by Day et al. (2004), Lagally et al. (2004), Lagally et al. (2002b), McGuigan et al. (2004), Suminski et al. (1997) and Sweet et al. (2004). These studies had found that standard Borg and session RPE values increased as resistance exercise intensity (expressed as a percentage of 1-RM) increased, despite a decrease in repetitions and total workload. These studies had concluded that exercise intensity, and not training volume, was the overriding factor in determining RPE. Singh et al. (2007) also demonstrated that there were no significant differences between the session RPE values of strength and hypertrophy protocols even though the hypertrophy protocol had a higher VL.

Several factors could have influenced these differences. Most of these studies employed different training designs and did not utilise an undulating periodised training program. The different rest periods between sets during the different protocols could have effected the session RPE. Day et al. (2004) and Sweet et al. (2004) employed a training design that consisted of high, moderate and low intensity sessions which included only five resistance exercises with 2 minutes rest between sets and two sets of six resistance exercises with 60 to 90 seconds rest between sets, respectively. The rest interval lengths were kept
constant for all the protocols in these studies whereas in the present study, the rest periods across the protocols were varied. In the study conducted by Singh et al. (2007), the rest period during the strength protocol was only 3 minutes compared to the 5 minutes rest period during the present study, while the rest period for the hypertrophy protocols was the same (1 minute). This suggests that the reason for higher session RPE values during the hypertrophy sessions could be due to the minimal rest period between sets.

Miranda et al. (2007) investigated the effect of different rest period interval lengths on the number of repetitions performed during RT. They found that 1 minute rest intervals resulted in a decreased number of repetitions performed compared with 3 minutes rest intervals between sets and exercises. Matuszak, Fry, Weiss, Ireland, & McKnight (2003) and Weir, Wagner, & Housh (1994) demonstrated that rest intervals of 1-2 minutes were sufficient between repeated sets when training with maximal weights. The current investigation incorporated a 5 minute rest period during the strength sessions which could explain why the participants perceived these sessions to be easier than the hypertrophy sessions. During hypertrophy sessions, the body relies increasingly upon anaerobic glycolysis to supply energy required for muscle contraction (Mirzaei, Arazi, & Saberi, 2008). During low to moderate intensity exercise, fast-twitch muscle fibers rely heavily on anaerobic glycolysis for energy production and accumulate high levels of hydrogen ions which in turn lower the intracellular pH, resulting in muscle fatigue (Larson & Potteiger, 1997).

In addition, the participants required more time to complete a set during the hypertrophy (10 repetitions) compared to the strength (3 repetitions) and power (5 repetitions) sessions. The participants in the present study perceived lifting 10 repetitions of 65-75% of 1-RM to be harder than 3 repetitions of 75-90% of 1-RM. However, lifting 5 repetitions of 25-40% of 1-RM at a fast velocity during the power sessions was perceived as the easiest. The current findings were similar in this respect to the previous study by Singh et al. (2007). The combination of time under tension and rest periods were reported by the participants to influence their perceived exertion for the overall session.
5.4 SESSION LOAD ACROSS DIFFERENT PROTOCOLS

The results revealed that there were significant differences between the strength, hypertrophy and power protocols for SL (Figure 4.3). The SL for the strength protocol was the highest (224.4 ± 94.4), followed by hypertrophy (172.6 ± 47.0) and power (60.0 ± 24.9). These findings do not reflect the session RPE values, as the hypertrophy protocol was perceived to be harder than the strength protocol. Recovery time between sets may also be an important consideration when attempting to reconcile the disparity between exercise protocols in terms of SL. Hypertrophy training produced individual session VL (Figure 4.1) and session RPE (Figure 4.2) values which were greater than the strength protocol, however the situation was reversed when SL was considered. When compared to hypertrophy training, the recovery period between sets was five times the duration in the strength sessions. This contributes appreciably to the overall SL values and may explain to some extent why the correlation between SL and VL is weaker than that between session RPE and VL. Even when time under tension is considered the session duration (including work and rest time) for the strength training (60.7 ± 2.2 mins) was approximately 2.5 times the length of hypertrophy (23.9 ± 3.0 mins) and just under twice as long as power (36.3 ± 1.9 mins). McGuigan and Foster’s (2004) suggestion that SL does not provide an accurate reflection of the quantification of RT may well be due to SL’s reliance on rest periods in its determination. Investigating relationships between the total time under tension (by excluding rest intervals between sets) and session RPE and VL may reveal useful training related information and warrants future research. A modified calculation of SL during RT by excluding the above mentioned rest periods may be more reflective of session RPE and VL.

5.5 PRACTICAL APPLICATIONS

The present study indicates that session RPE seems to be a reasonable method to monitor VL during an undulating periodised RT program. Coaches and sports scientists could utilise this method to gather valuable information that would allow them to manipulate the training program. By carefully monitoring the athletes’ session RPE response to their training, preventative measures can be undertaken to avoid overtraining symptoms, such as illnesses or injuries.
5.6 CONCLUSIONS

In conclusion, the session RPE method seems to be a simple way to monitor VL during an undulated periodised RT program. The results of this study have shown that there is a significant positive relationship between both session RPE and VL, and SL and VL. However, there were no significant relationships between the average weekly VL and training monotony, and average weekly VL and training strain. A significant relationship between VL and session RPE, as well as VL and SL was identified only for the power protocol. It was also demonstrated that increases in the VL and session RPE occurred concomitantly. Differences were observed for session RPE values between the three protocols with hypertrophy displaying the highest, followed by strength and power protocols, respectively. The SL was found not to provide the same information as VL during RT and is probably due to its dependence on session duration.
REFERENCES


APPENDICES

Appendix A

INFORMATION LETTER TO PARTICIPANTS


Chief Investigators: Mirza Abdul Latif, Dr Mike McGuigan and Dr Mike Newton
19.126 Joondalup Campus
Tel: (08)   
Email:  

Thank you for expressing interest in this research project. The reason for providing you with the following information is to fully inform you of the purpose and the nature of this study.

You are invited to participate in a research project that will investigate the relationship between session rate of perceived exertion (RPE) measures and the volume load during resistance training.

If you agree to participate in this study, you will be asked to report to the strength and conditioning laboratory in Room 19.139, Joondalup campus on fourteen separate occasions. The first two visits to the laboratory will be used to familiarise you with 1) the testing and exercise apparatus, 2) the testing and exercise procedures that will be employed in the study, 3) the measurement of the one repetition maximum (1-RM) for each of the four different exercises and 4) the measurement of session RPE within thirty minutes of the completion of the entire workout. The 1-RM is defined as the most amount of weight you can lift maximally in one lift. The actual exercises and testing for the main components of the study will be conducted over twelve separate occasions with each session performed at least 48 hours apart. These sessions will be conducted three times a week, for a period of four weeks. RPE measurements will be taken within thirty minutes following the end of the entire workout. You will be required to perform three different resistance training workout sessions: Strength, hypertrophy and power protocol sessions. You will perform four different exercises (bench press, squat, shoulder press and bench rows) during each session.

The principle outcome measure will be the session RPE measured within thirty minutes after the completion of the entire workout. The measurement will be done using a Borg category ratio 10 (CR-10) RPE scale. A rating of 0 is associated with the least effort and the highest rating of 10 refers to maximal effort.

You will be required to perform four basic resistance exercises for three different resistance training protocol sessions. For the strength protocol sessions, you will be required to perform 3 repetitions for 3 sets per exercise at a load of 75-90% of your 1-RM with a 5 minute rest period between each set. The hypertrophy protocol sessions will require you to
perform 10 repetitions for 3 sets per exercise at 65-75% of your 1-RM with a shorter rest period of 1 minute between each set. The power protocol sessions require each exercise to be performed at a fast lifting velocity for 5 repetitions for 3 sets per exercise at 25-40% of your 1-RM with a 3 minute rest period between sets.

All information collected in this study will be confidential. Only the primary investigators will have access to any information collected and all written documents will be coded so that individual identification of your data will not be possible for anyone else.

The risks associated with this study are minimal. You may experience some fatigue and tiredness during the workout sessions. Some muscle soreness may develop 24-72 hrs following each workout. However, careful considerations will be taken to ensure that this does not take place. Adequate recovery time will be provided between sets, exercises and different workout sessions. Moreover, warm up stretching will be implemented to facilitate additional recovery and further reduce the chances of muscle soreness. However, there are no other associated risks as the exercises and recovery sessions will be closely supervised by qualified staff and you will be continuously monitored throughout.

Benefits of this procedure include obtaining information about your maximum lifting capacity for all four resistance exercises and it will provide assistance with the present research study. You should be assured that results that may be presented at conferences or in scientific publications will not include any information that may identify individual participants.

Participation is voluntary and no explanation or justification is needed if you choose not to participate. You are also free to withdraw your consent to further involvement in the research project at any time. If you are interested in participating in this study, you will need to complete an informed consent and return it to the principle investigator. You will receive a payment of fifty dollars at the successful completion of the study.

This research project has been approved by the Faculty Human Ethics Subcommittee.

If you have any questions or require further information about the research project, please contact Mirza Abdul Latif at 0424659822, email mmirzaab@student.ecu.edu.au, Dr Mike McGuigan at (08) 6304 2118, email m.mcguigan@ecu.edu.au or Dr Mike Newton at (08) 6304 5961, email m.newton@ecu.edu.au.

If you have any concerns or complaints about the research project and wish to talk to an independent person, you may contact:

Research Ethics Officer
Human Research Ethics Officer
Edith Cowan University
100 Joondalup Drive
Joondalup WA 6027
Phone: (08) back number redacted
INFORMED CONSENT FORM

Project Title
The Relationship between Session Rate of Perceived Exertion Measures and Volume Load during Resistance Training

I have read the information sheet and the consent form. I agree to participate in the study entitled ‘The relationship between session rate of perceived exertion measures and volume load during resistance training’ and give my consent freely. I understand that the study will be carried out as described in the information sheet, a copy of which I have retained. I realise that whether or not I decide to participate is my decision. I also realise that I can withdraw from the study at any time and that I do not have to give any reasons for withdrawing. I have had all questions answered to my satisfaction.

Participant: ___________________________ Date: ___________________________
MALE AND FEMALE VOLUNTEERS WITH AT LEAST 6 MONTHS RESISTANCE TRAINING EXPERIENCE REQUIRED
Age: 18 to 35 years

Research Project: The Relationship between Session Rate of Perceived Exertion Measures and Volume Load during Resistance Training.

You are invited to participate in a research project that will investigate the relationship between session RPE measures and volume load during resistance training. Participants will be required to perform three resistance training sessions per week for a period of four weeks. Participants will acquire information on their maximal strength for four different resistance training exercises. At the end of the study, participants will be familiar with rating their perceived exertion for a session using the RPE scale. Each participant will receive 50 dollars at the completion of the study.

For more information, please contact
Latif Mirza

Telephone: [REDACTED]
Email: [REDACTED]
Appendix D

Familiarisation Session
Medical Questionnaire

Name: ________________________________

Age: ________

Height: ________ (cm)

Weight: ________ (kg)

Gender: ________

Number of months of resistance training experience: ________

Do you have any injuries? (Please list)

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Do you have any medical problems? (Please list)

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________