ORIGINAL RESEARCH ARTICLE

Acute and session RPE responses during resistance training: Bouts to failure at 60% and 90% of 1RM

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Abstract

Objective. To compare resistance bouts performed to failure at low (60% 1RM) and high (90% 1RM) workloads for acute rate of perceived exertion (RPE) (per exercise), session RPE (S-RPE) (30 min post), HR (per exercise) and total work (per session, and per exercise).

Background. RPE is a convenient method for quantifying intensity in aerobic exercise. However, RPE has recently been extended to exercise modalities dominated by anaerobic pathways such as resistance training (RT).

Method. Subjects (*N*=12) were assessed using an exercise-specific 1 repetition maximum (1RM) for 6 exercises. On separate days in a counterbalanced order, subjects performed 3 sets of each exercise to volitional failure at a low intensity (LI) and a high intensity (HI) with 2 minutes rest between sets and exercises. At the end of each set, subjects estimated acute RPE for that set using a 10-point numerical scale. Thirty minutes after the end of the exercise session subjects estimated their S-RPE for the entire workout. HR, total work, and acute RPE were compared (HI v. LI) using repeated measures ANOVA.

Results. A paired samples *t*-test showed LI was significantly higher (p=0.039) than HI for session RPE (LI=8.8±0.8, HI=6.3±1.2) and total work (LI=17461±4419, HI=8659±2256) (p=0.043). Per exercise, total work and acute RPE were significantly greater (p=0.01) for LI for all exercises. Peak HR was significantly higher per exercise during LI for leg press (p=0.041), bench press (p=0.031), lat pull-down (p=0.037) and shoulder press (p=0.046).

Conclusion. In resistance exercise performed to failure, total work influences acute and session RPE more so than percentage 1RM.

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Introduction

The lack of agreement between subjective and objective measures of intensity led Borg to develop the ratings of perceived exertion (RPE) scale.[1] Perceived exertion has been widely used as a subjective measure of aerobic exercise intensity. While correlating well with objective physiological measures such as heart rate (HR)[1-4] and VO_2,[1-3] it is generally agreed that perceptual responses are attributed to numerous physiological and psychological variables rather than any a single mediator.[4-6] RPE is supported by the American College of Sports Medicine as a convenient and practical method for quantifying intensity in aerobic-type exercise.[7] The application of RPE has recently been extended to exercise modalities dominated by oxygen-independent metabolic pathways such as resistance training (RT), with results suggesting it is a valid measure of effort.[8-10] RT studies show that acute RPE systematically increases with percentage of 1 repetition maximum (1RM) lifted when exercise is terminated at a predetermined number of repetitions (reps).[9,11-13] For example, Sweet *et al*.[10] observed this trend as the percentage of 1RM increased from 50% to 70% to 90%, despite a decreased number of repetitions (15, 10 and 4 respectively).

While original work dealt with RPE during an exercise bout, Foster *et al*.[14,15] developed the concept of session RPE. This RPE paradigm relative to the entire workout is estimated in the post-exercise period and is not associated with any specific time point in the bout. This permits a subjective estimation for an entire training session. Session RPE has been used to quantify RT sessions. A study comparing session RPE across 3 different workouts involving 5 exercises (1 set each) at 50% (15 reps), 70% (10 reps), and 90% (5 reps) of 1-RM,[8] found session RPE to be reliable for quantifying intensity during RT and concluded that session RPE values increased concurrently with percentage of 1RM. However, participants only completed one set and stopped upon completing the predetermined number of repetitions, and therefore total work between varying intensities was not equated. Sweet *et al*.[10] made similar conclusions; however, previous studies identified an association between perceptual measures and intensity, with minimal consideration for effects of total work, for each set of exercise or for the entire bout.

Previous studies indicate that acute RPE increases concomitantly with intensity (i.e. percentage of 1-RM) [8-10] electromyography activity, and blood lactate.[12] However, a greater RPE might result from the knowledge that the resistance is greater, which could be independent of the exercise-associated fatigue and pain to which RPE is typically attributed. This could disrupt correspondence between physiological overload and a subjective rating that might be particularly problematic when exercise is terminated prior to volitional exhaustion, a common end-point in RT. The lack of substantial research taking individuals to volitional exhaustion during RT magnifies the belief that perceptual responses to exhaustive RT are not well understood. Therefore the purpose of this study was to investigate acute and session RPE between HI (90% 1RM) and LI (60% 1RM) RT sessions when subjects were required to perform repetitions to volitional failure.

Methods

Subjects

Twelve recreationally strength trained (minimum 6 weeks) males served as participants. Prior to data collection, subjects completed and signed a written informed consent outlining requirements for participation. All procedures were approved by the university review board for protection of human subjects. Each subject was given instructions to arrive for testing well hydrated, at least 3 hours post-prandial, and having abstained from caffeine and alcohol for a minimum of 24 hours. Age (years), height (cm) (Medart: St Louis, Mo) and mass (kg) (Detecto-Medic: Detecto Scales Inc. Brooklyn, NY USA) were measured and body fat percentage was estimated using Lange skinfold calipers (Cambridge, MD, USA) and a three-site method (chest, abdomen, and thigh).[16]

Design

Each subject completed a HI (90% of 1RM) and a LI trial (60% of 1RM) performed in a counterbalanced order, between the 2 intensity trials. Subjects were first assessed for their 1RM and then on separate days were called back to perform the HI and LI trials. Each session include 3 sets of 6 exercises performed to volitional fatigue. Exercises were performed in a specific order: leg press, bench press, lat pull down, shoulder press, triceps press, and biceps curl.

1RM determination

Following descriptive data, each participant completed a 1RM for all exercises in the order mentioned previously. All exercises were performed on Cybex weight equipment (Lumax, Ronkonkoma, NY). Each 1 RM was defined as the heaviest weight that could be lifted for 1 complete repetition.[17,18] Each subject performed three sets of each exercise at sub-maximal resistance with stepwise increases (based on participant feedback) in resistance until the participant could perform the lift for only 1 repetition. In order to enhance recovery, 2 - 3 minutes between attempts and 5 minutes between exercises was provided.[19]

Low-intensity trial – 60% 1RM

Subjects completed a warm-up prior to the first lower body exercise (leg press) and the first upper body exercise (bench press) consisting of 8 reps at 30% of 1RM. Following the warm-up set, each subject performed 3 sets to failure at 60% of 1RM for each exercise. The inability to complete a full repetition was considered 'failure'. Resistance for each exercise was set to the weight corresponding to the appropriate percentage of each individual 1RM (within 0.5 kg). The orders of the exercises were kept the same throughout the exercise regimen. Subjects were asked to estimate their acute RPE within 10 seconds of completing each set, utilising a category ratio (CR) 10-point RPE scale specific to strength training.[4] Subjects were held to a 2-minute recovery between sets and 2 minutes between exercises throughout the work-out session. Subjects were asked to sit quietly for the next 30 minutes. Acute RPE was recorded upon completion of each set. Session RPE was also recorded 30 minutes after each session. Peak HR for each set (highest HR response observed) was recorded, using a polar HR monitor (Stamford, CT, USA).

Thirty minutes following each exercise session subjects estimated their session RPE relative to the entire work-out session using the same scale by answering the question 'How do you rate the entire workout?'.[15] Session RPE was recorded following the 30-minute period to prevent the perceptual feelings at the immediate termination of exercise from dominating this measure as it is intended to reflect feelings for the entire bout.[15]

High-intensity trial – 90% of 1RM

The HI trial was conducted in the same manner as the LI trial except that resistance was set at 90% of 1RM.

Statistical analysis

HI and LI were compared using a 2 (trials) x 3 (sets) repeated measures ANOVA for each variable (reps, acute RPE, and HR) within each exercise. RPE per exercise was calculated using the average of three sets. Total work for the exercise session was calculated by adding the sum of each exercise. A Bonferroni *post-hoc* procedure was applied to locate differences when ANOVA revealed a significant interaction. Session RPE and total work (LI v. HI) were compared using a paired samples t-test. Statistical significance was set at $p<0.05$. A Pearson's product – moment coefficient of correlation was used for both session RPE and volume (HI and LI). All data are reported as means ± standard deviations.

Results

Means and standard deviations for descriptive data were: age (23.8± 3.1 yrs), mass (78.8±14.5 kg), height (175.1±5.6 cm), body fat (13.1±6.6 %). Fig. 1A shows LI was significantly higher ($p=0.039$) for session RPE (8.8±0.8) compared with HI (6.3±1.2). Fig. 1B shows total work for the entire session was also significantly higher ($p=0.043$) for LI (17 461±4 419) compared with HI (8 658±2 255). Total work per exercise for LI (Fig. 2) was significantly higher ($p=0.021$) than for HI. Peak HR for triceps press and biceps curl was not significantly different LI v. HI ($p=0.075$). Peak HR (Fig. 3) was however significantly higher during LI for leg press ($p=0.041$), bench press ($p=0.031$), lat pulldown ($p=0.037$) and shoulder press ($p=0.046$) respectively. Fig. 4 depicts acute RPE, which was significantly higher ($p=0.029$) for LI v. HI per each exercise. A strong relationship between total work and session RPE is depicted in Fig. 5, which is evident by the positive correlation for both LI and HI ($R^2=0.85$, $p=0.029$).

Discussion

RPE is a convenient method for quantifying training effort. Typically, subjects perceive exercise to be more strenuous with an increase in intensity.[8,11] However, few studies have assessed subjective measures when resistance training bouts are completed to failure. This study compared acute and session RPE (S-RPE) throughout an entire resistance training exercise session when participants completed 3 sets of 6 exercises at low and high intensities to volitional failure.

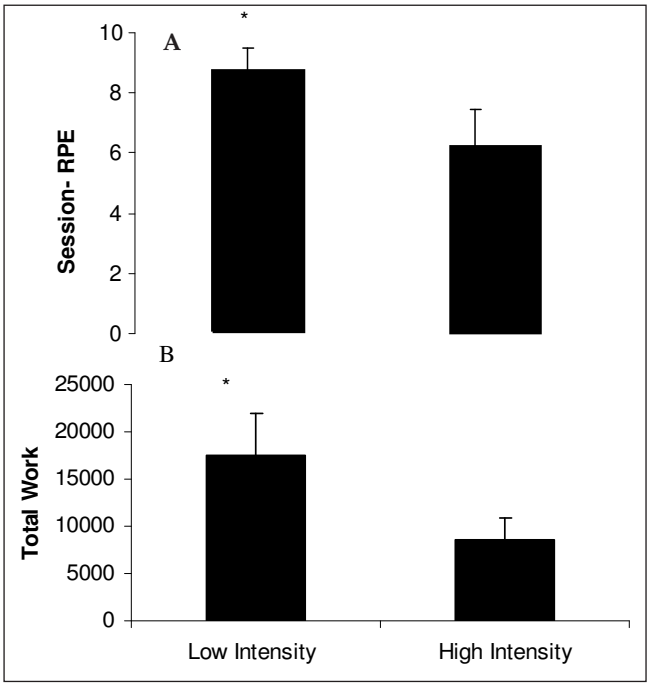

Fig. 1 A and B. Session RPE values, 30 min post-exercise bout (*p<0.039) (B). Total work (weight X reps) for entire exercise bout * LI v. HI. (p<0.043). Each exercise bout consisted of 6 exercises: leg press, bench press, lat pull-down, shoulder press, triceps press, and biceps curl. Values are means and SD; N=12.

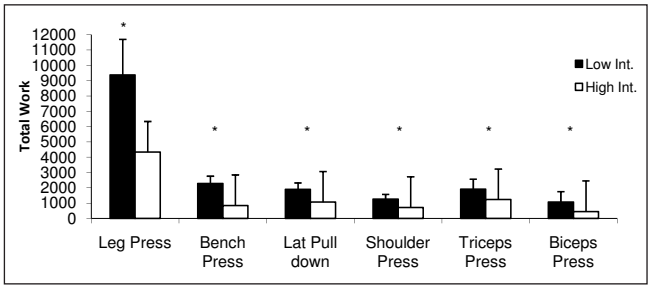

Fig. 2. Total work (weight X reps) for each exercises LI v. HI. LI was significantly higher than HI (*p< 0.021). Values are means and SD; N=12.

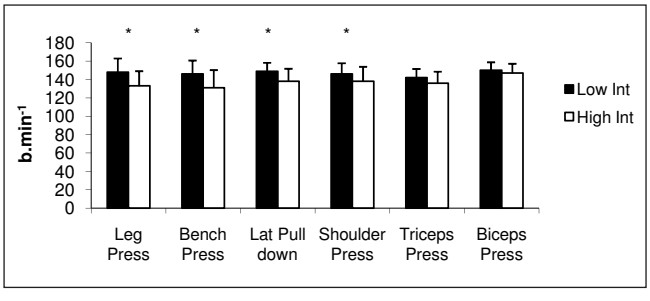

Fig. 3. Peak HR for individual exercises LI v. HI. Peak HR was significantly higher during LI for leg press (*p< 0.041), bench press (p=0.031), lat pull-down (p=0.037) and shoulder press (p=0.046). Values are means and SD; N=12.

S-RPE responses

Results indicate that at a LI trial (60% 1RM) S-RPE was greater compared with the HI trial (Fig. 1A). This may be attributed to the significantly (p=0.043) greater total work for the LI exercise session (Fig. 1B). Furthermore, this suggests that S-RPE within the current

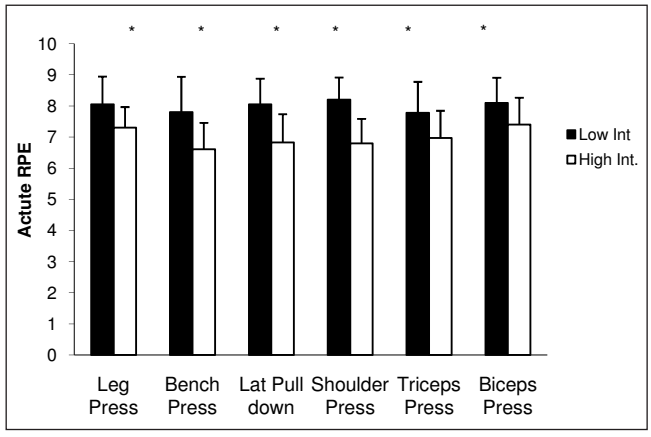

Fig. 4. Acute RPE for individual exercises. RPE was significantly higher (*p< 0.029) for LI v. HI. Values are means and SD; N=12.

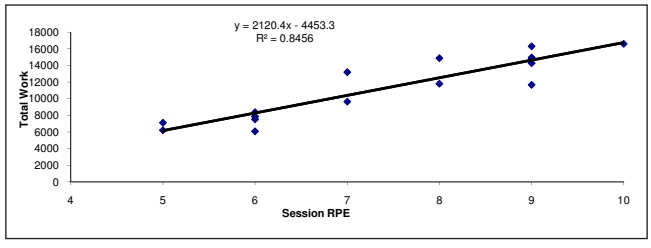

Fig. 5. Correlation between total work and S-RPE for both LI and HI. Total work and S-RPE positive linear relationship (R^2=0.85, p=0.029).

paradigm (multiple sets to volitional exhaustion) is affected by the total work of an entire exercise bout more so than the intensity (resistance) of the bout. This supports recent work by Sigh *et al*.,[20] but it is contrary to prior research reporting acute RPE is primarily influenced by exercise intensity,[8,10,11] and not total work being performed. Previous studies, utilised RT sets at sub-maximal intensities, and have terminated the exercise protocol prior to subjects' volitional failure.[8] Results from these particular studies have reported mean RPE values taken throughout the exercise bout correspond well with the S-RPE. Consequently, authors concluded that S-RPE is a valid method of quantifying entire bouts of resistance training.[8] Day *et al*.[8] differentiated between high (90% of 1RM 4 - 5 reps), moderate (70% of 1RM 10 reps) and low (50% of 1RM 15 reps) with subjects completing only 1 set. RPE was higher for the HI bout, where subjects were asked to complete a maximum of 5 repetitions. Some subjects reached volitional failure upon completion of the fourth repetition whereas the moderate and LI bouts prompted none of the subjects to failure.[8] The experimental protocol used by Day *et al*.[8] was such that the training intensities and corresponding repetitions allowed for variation in the total amount of work performed between testing sessions. However, the unique aspect of the current study is that subjects exercised to volitional exhaustion at both HI and LI intensities. American College of Sports Medicine guidelines for resistance exercise prescription state that 'high intensity can be achieved either by performing a few repetitions (e.g. 3 - 6) with heavy resistance or by several repetitions (e.g. 8 - 12) with a lighter resistance'.[7] Because of the significantly (p=0.043) greater total work (achieved via higher repetitions) during the LI trials, it is plausible that subjects in the current study achieved greater disruption to their internal physiological environment which may have contributed to elevated RPEs.

Because of the amount of total work in LI trial, S-RPE was significantly higher. Also, LI generated a significantly (p=0.041) higher peak HR, but only for the first 4 exercises with peak HR response

converging (between LI and HI) in the latter bouts. Even with a strong link between RPE and HR[14,15,21] in the current study, there was a stronger association between session RPE and total volume (R^2= 0.85) (Fig. 5). Lagally *et al*.[9] found electromyographic (EMG) activity increased significantly as the intensity of exercise increased from 30% to 90% 1RM. Furthermore, post-exercise blood lactate was significantly greater at 90% 1-RM than 30% 1-RM. Greater RPE at 90%1RM between trials in which total volume was equated led Lagally [9] to conclude that RPE is coupled with intensity more tightly than with volume. Conversely, current results indicate RPE is more closely linked with work than %1RM as higher acute and session RPE were found with lower intensity bouts in which a greater volume was completed. Because the principal difference between studies (current study and Lagally[12]) is termination of exercise at a predetermined number of reps 12 and volitional failure (current study), it could be concluded that the factor dominating RPE is dependent on the RT end-point. An additional possibility exists regarding perceptual measures. According to Lagally *et al*.[9] and Gearhart *et al*.[11] it is possible that participants were immediately capable of detecting the considerable resistance variation between trials. Greater RPE estimations could have been based on perceptions of resistance rather than physiological changes and associated feelings of fatigue. Continuing to volitional exhaustion in the current study helped to ensure subjects were fatigued as indicated by failure to complete an additional repetition even when verbally encouraged.

It is therefore proposed that session RPE for LI was greater due to the cumulative fatigue associated with a greater amount of total volume performed. This again suggests that when RT exercises are completed to volitional failure, associated perceptual measures are more sensitive to total work than to resistance.

Acute RPE and HR responses

The peak HR responses for each exercise, was significantly (p<0.05) higher for LI for leg press, bench press and lat pull-down and shoulder press. However, for triceps press and biceps curl there was no significant difference in HR response. This may be related to the short recovery time (2 minutes) between exercises, and the cumulative effects of physiological fatigue that presumably increased concurrently as total work volume diverged (LI v. HI) with each exercise set. During LI, the greater volume (per set, per exercise) may have resulted in a greater disruption of the internal environment (as speculated earlier) and consequently successive sets may have been initiated with less relative recovery (v. HI).

Viewing acute RPE estimations concurrently with peak HR responses, and differences in work volume per exercise, leads to similar conclusions for acute RPE as for S-RPE. That is, when sets are completed to volitional failure, total volume weighs more heavily on perceptual responses than does percentage 1RM.

Practical application

S-RPE is responsive to multiple factors, many of which have yet to be clearly defined. The current study indicates that the volume of work is an important determinant in strength training when comparing repeated bouts of lighter and heavier resistances completed to failure. While further investigation is warranted, it is plausible that S-RPE would provide an effective gauge of overall difficulty of a given training session with potential for also identifying overtraining.

Conclusion

S-RPE is shown to be affected by total work rather than just exercise intensity alone (% 1RM). These results extend the knowledge regarding perceived exertion during resistance training. More specifically, when using RPE to quantify resistance training the amount of total work must be taken into consideration when bouts are completed to failure. This suggests that S-RPE is a valuable quantification tool of work performed throughout the exercise bout in that paradigm. In consideration of the current study and previous research, RPE relationship with %1RM and total work seems to be dependent on the end-point of the exercise bout with a stronger relationship with total work, than exercise intensity during exhaustive bouts. Subsequently S-RPE may be considered a safe and reliable method for monitoring strength training gains and a valid tool for monitoring training programmes, which would offer a quick and subjective method of quantifying RT exercise bouts.

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