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Ratings of Perceived Exertion and Muscle Activity During the Bench Press Exercise in Recreational and Novice Lifters

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Abstract. Lagally, K.M., S.T. McCaw, G.T. Young, H.C. Medema, and D.Q. Thomas. Ratings of perceived exertion and muscle activity during the bench press exercise in recreational and novice lifters. *J. Strength Cond. Res. 18(2):359–364. 2004.*—This study examined ratings of perceived exertion (RPE) and electromyography (EMG) during resistance exercise in recreational and novice lifters. Fourteen novice (age = 21.5 ± 1.5 years) and 14 recreationally trained (age = 21.9 ± 2.2 years) women volunteered to perform the bench press exercise at 60 and 80% of their 1 repetition maximum (1RM). RPE and EMG were measured during both intensities. Statistical analyses revealed that active muscle RPE increased as resistance exercise intensity increased from 60% 1RM to 80% 1RM (12.32 ± 1.81 vs. 15.14 ± 1.74). Integrated EMG also increased as resistance exercise intensity increased from 60% 1RM to 80% 1RM (in the pectoralis major; 98.62 ± 17.54 vs. 127.98 ± 29.02). No significant differences in RPE or EMG were found between novice and recreational lifters. These results indicate that RPE is related to the relative exercise intensity lifted as well as muscle activity during resistance exercise for both recreational and novice lifters. These results support the use of RPE as a method of resistance exercise intensity estimation for both types of lifters.

Key Words. active muscle exertion, electromyography, overall body exertion

Introduction

Recent evidence suggests that during resistance exercise, ratings of perceived exertion (RPE) are related to relative exercise intensity (i.e., percentage of the 1 repetition maximum lifted [% 1RM]) (11, 12, 20). This has been demonstrated using an experimental design in which the number of repetitions performed at each % 1RM varied in order to hold total work constant (11, 12). The investigations using this design have found that both active muscle and overall body RPE increased as the % 1RM increased despite a similar total work. This finding suggests that RPE during resistance exercise is related to systematic increases in relative exercise intensity rather than total work performed. The importance of this finding is that it provides evidence that RPE can be used to accurately describe differences in relative lifting intensities (19). It has been suggested that RPE as a method of estimating resistance exercise intensity may be particularly useful for novice lifters whose primary resistance training concern is the selection of safe and appropriate resistances to improve muscular strength and endurance (19). For these individuals, RPE would serve as a straightforward, subjective guide for estimating intensity during a resistance exercise session. In addition, because RPE is commonly used to regulate aerobic exercise intensity, it would be convenient to also use it during resistance exercise. However, it is unknown whether RPE is a valid method of monitoring resistance exercise intensity for novice lifters.

Previous research has shown that RPE is also related to certain physiological indices of resistance exercise intensity. These physiological measures are thought to mediate the intensity of exertional perceptions and include such variables as blood lactic acid concentration (6, 10, 12, 16, 20) and muscle activity (7, 9, 12, 17, 18). Muscle activity (quantified using electromyography, or EMG) has been a focus of recent investigations in this area. The majority of these investigations have examined RPE and EMG during isometric exercise (9, 17, 18). Information regarding the relation between these 2 variables during dynamic resistance exercise is limited (7, 12). It has been suggested that the relation between EMG and RPE may involve a feed-forward neurophysiological mechanism (3, 4, 14). This mechanism holds that muscle activity increases as a result of increased central feed-forward commands (4). Corollary signals of these central efferent commands are sent to the sensory cortex, which regulates the perception of exertion. When central feed-forward commands increase in order to increase motor unit recruitment and firing frequency, corollary signals to the sensory cortex would also increase and intensify exertional sensations (3, 14). Thus, it is hypothesized that increases in perceived exertion will parallel increases in muscle activity, which are directly related to increases in central motor feed-forward commands (4). During resistance exercise, it would be expected that central feed-forward commands and, by extension, muscle activity and RPE would be relatively high when the % 1RM lifted is high and low when the % 1RM lifted is low. In a recent investigation, EMG activity and RPE were examined during the biceps curl exercise performed at 30, 60, and 90% 1RM (12). It was found that RPE and EMG increased in a corresponding manner with increasing resistance exercise intensity, which is consistent with the aforementioned expectation.

The simultaneous increase in RPE and EMG is an encouraging first step in the attempt to establish a physiological basis for using perceived exertion to measure and prescribe resistance exercise intensity. A demonstrated relation between RPE and physiological markers of resistance exercise intensity (e.g., muscle activity) is consistent with Borg's model of the Effort Continua (2). This model postulates a link between perceptual and physiological responses and exercise performance during dynamic exercise and suggests that perceptual responses

Table 1. Subject characteristics.†

	Novice (n = 14)	Recreational (n = 14)
Age (y)	21.5 ± 1.5	21.9 ± 2.2
Weight (kg)	58.8 ± 6.9	60.6 ± 6.4
1RM‡ (kg)	31.3 ± 5.7	44.3 ± 11.2*

* Significantly different ($p < 0.01$) from novice.
† Values are mean ± *SD*.
‡ 1RM = 1 repetition maximum.

provide similar information regarding exercise performance, as do physiological responses. Perceptual-physiological links that have been established during dynamic aerobic exercise (e.g., between % $\dot{V}O_2$max and RPE) have provided the foundation for the examination of RPE as a method of prescribing *aerobic* exercise intensity (15). Similarly, establishing a link between RPE and physiological indices of resistance exercise intensity and expanding the knowledge base regarding these perceptual-physiological links are important if RPE is to be examined as a prescriptive tool for *resistance* exercise intensity.

The purposes of the present investigation were to examine the relation between RPE, EMG, and % 1RM during dynamic resistance exercise by using a multijoint resistance exercise and both novice and recreational lifters and to examine whether RPE is a valid method of estimating resistance exercise intensity for novice lifters. It was hypothesized that in both novice and recreational lifters, RPE and EMG would demonstrate corresponding increases with increasing resistance exercise intensity.

Methods

Experimental Approach to the Problem

To examine the relation between RPE and % 1RM, we collected perceived exertion data following the bench press exercise performed for 8 repetitions at 60% 1RM and 6 repetitions at 80% 1RM. By varying the number of repetitions performed at each percentage of the 1RM, total work remained constant between intensities. This was done to eliminate the possibility that perceived exertion responses were dependent on the work performed. We also collected EMG data as a measure of muscle activity, which may play a role as a mediator of perceived exertion responses during resistance exercise. EMG data were collected during both intensities from the 4 muscle groups involved in the bench press exercise.

Subjects

Fourteen novice and 14 recreationally trained women between the ages of 18 and 35 years participated in this cross-sectional, counterbalanced investigation. Subject characteristics are provided in Table 1. Subjects were defined as novice (N) if they had not performed the bench press exercise for at least 2 years and as recreational (R) if they regularly performed the bench press exercise for at least 1 year. Subjects reported that they were not taking performance-enhancing drugs at the time of the experiment, had no skeletal muscle or endocrine disorders that contraindicate exercise testing, and were nonsmokers. During the course of the testing, subjects were instructed to refrain from any nonexperimental anaerobic or resistance exercise; maintain normal dietary habits; abstain from alcohol, caffeine, and nicotine for at least 24 hours prior to the testing session; and present for testing in a 3-hour postprandial state. Each participant completed a medical history questionnaire and provided their written consent to participate. The Biomedical Institutional Review Board of Illinois State University approved all procedures used in this investigation.

Orientation Session

The experiment required 2 testing sessions, the first of which served as an orientation session. During the orientation session, height, weight, and biacromial breadth were measured. Biacromial breadth was measured using an anthropometric caliper. The grip width for the bench press exercise was set at 130% of biacromial breadth during the orientation and experimental sessions. A bench press 1RM was determined using the methods of Mayhew et al. (13). Standard York brand, free-weight bench press equipment was used during all test sessions. Proper lifting technique (see "Experimental Session") was demonstrated for the subjects prior to the 1RM assessment. The 1RM value was used to determine the 60 and 80% 1RM intensities that were used during the experimental session.

Scaling and anchoring procedures for resistance exercise as detailed by Gearhart et al. (8) for the 15-category Borg Perceived Exertion Scale were administered prior to the 1RM procedures in the orientation session. The rating scale anchors were established by having each subject perform an unweighted repetition and a 1RM using the bench press exercise. The feelings of exertion in the active muscles (chest, triceps, shoulders) and overall body during the unweighted repetition were assigned a 7 on the Borg scale. The feelings of exertion in the active muscles (chest, triceps, shoulders) and overall body during the 1RM were assigned a 19 on the Borg scale. Subjects were instructed to assign a rating of 6 to any perceptions of exertion that were less than those experienced during the unweighted repetition and a rating of 20 to any perceptions of exertion that were greater than those experienced during the 1RM.

Experimental Session

The experimental session took place 1 week following the orientation session. Athletic tape was used to mark the appropriate hand placement on the bar in order to standardize grip width at 130% biacromial breadth during each intensity. A warm-up consisting of 8 repetitions at 40% 1RM was performed immediately prior to the experimental intensities. Subjects were randomly assigned to perform either a 60 or an 80% 1RM intensity first. During the experimental session, each subject performed 8 repetitions of the bench press exercise at 60% 1RM and 6 repetitions of the bench press exercise at 80% 1RM. By varying the number of repetitions performed, total work remained the same across the 2 intensities. Subjects were instructed to perform each lift to a 2-count up, 2-count down cadence set by a metronome at 70 beats·min^{-1}. Cadence was controlled in order to allow RPE and EMG comparisons between the 60 and 80% 1RM intensities. An experienced spotter was available at all times to stabilize the bar before and after each intensity and to ensure that proper form was maintained throughout each intensity. Subjects were closely monitored to ensure that their backs remained flat on the bench, their feet remained flat on the floor, and full range of motion was completed for each repetition of the bench press.

Perceived Exertion Assessment Procedures

Prior to the warm-up in the experimental session, each subject was asked to reread the scaling instructions for the Borg RPE scale. Both an active muscle and an overall body RPE were assessed immediately following each of the 2 resistance exercise intensities. Active muscle RPE (RPE-AM) was defined as the feelings of exertion in the chest, shoulders, and triceps. Overall body RPE (RPE-O) was defined as the feelings of exertion in the whole body.

EMG Assessment Procedures

Muscle activity was assessed using the MP100 EMG System (Biopac Systems, Inc., Santa Barbara, CA). The EMG signals were monitored using EL 500 Series disposable surface electrodes. Two disposable surface electrodes (EL 500 Series) were placed 2 cm apart over the belly of the pectoralis major, anterior deltoid, medial deltoid, and triceps brachii. Electrode sites were lightly sanded with fine sandpaper and cleaned with alcohol prior to electrode placement. All electrodes remained in place until data were collected in both intensities. The EMG signals were differentially amplified using gains between 500 and 5,000, with an EMG 100B electromyogram amplifier module (Biopac). The amplifiers had a differential input impedance of 2 megaohms and a common mode input impedance of 1,000 megaohms, with a common mode rejection ratio of 110 dB. Amplifiers were set with a low-frequency cutoff of 3 Hz and a high-frequency cutoff of 10 Hz, each with single-pole roll-off filters to minimize the effects of noise (MP100, Biopac). To identify the descent and ascent phases of each repetition, a TSD130B series goniometer (Biopac) was placed on the lateral surface of the elbow to monitor joint flexion and extension. Only data from the ascent phase of the lifts were used in our analyses. Eccentric data were not included because of differences in the neural recruitment strategies between concentric and eccentric muscle contractions (21).

An isometric reference position (IRP) was used in order to normalize the EMG data. To perform the IRP, the spotter assisted the subject in lowering her 80% 1RM load until the elbows reached 90° of flexion. The spotter released the bar, and the subject held the bar steady for 5 seconds while EMG data were collected. The IRP data were collected before the first intensity, between the 2 intensities, and after the second intensity. The mean value of the third second of the 3 IRP trials was calculated for use in normalizing the data collected during the 60 and 80% 1RM intensities. All EMG data collected from the 60 and 80% 1RM repetitions were subsequently expressed as a percentage of isometric reference position (% IRP). The mean % IRP across the 6 repetitions at 80% 1RM and across the 8 repetitions at 60% 1RM was used in the analyses.

Statistical Analyses

A p value of $\leq$0.05 was used to establish statistical significance. All analyses were performed using the Statistical Package for the Social Sciences (SPSS). Perceived exertion responses were analyzed using a 3-factor (group $\times$ RPE [region] $\times$ intensity) ANOVA with repeated measures on the RPE and Intensity factors. In this analysis, each factor had 2 levels. To identify the source of a significant interaction, the appropriate t-test was applied with the alpha level adjusted using the Bonferroni procedure (0.05/2 = 0.025).

EMG data were analyzed using a 2-factor (group $\times$ intensity) ANOVA with repeated measures on the Intensity factor. Each muscle group was analyzed separately. To measure the degree of association, the Pearson product moment correlation coefficient was calculated between the RPE and EMG measures.

Table 2. Mean ± *SD* for RPE-AM and RPE-O responses to 2 resistance exercise intensities in novice and recreational lifters.‡

	60% 1RM	80% 1RM*
RPE-AM†		
Recreational (n = 14)	12.14 ± 1.61	15.14 ± 1.51
Novice (n = 14)	12.5 ± 2.03	15.14 ± 1.99
Total (n = 28)	12.32 ± 1.81	15.14 ± 1.74
RPE-O		
Recreational (n = 14)	11.07 ± 1.69	13.14 ± 2.03
Novice (n = 14)	11.5 ± 1.65	13.64 ± 1.78
Total (n = 28)	11.29 ± 1.65	13.39 ± 1.89

* All values significantly ($p < 0.01$) different than the corresponding 60% 1RM values.

† All values significantly ($p < 0.01$) different than the corresponding RPE-O values.

‡ 1RM = 1 repetition maximum; RPE-AM = active muscle rating of perceived exertion; RPE-O = overall body rating of perceived exertion.

RESULTS

Mean ± standard deviations for RPE-AM and RPE-O are shown in Table 2. The results indicate that RPE and EMG increased for both novice and recreationally trained women as resistance exercise intensity increased from 60–80% 1RM. Results of the 3-factor (group $\times$ RPE [region] $\times$ intensity) ANOVA revealed a significant RPE $\times$ intensity interaction ($F[1,26] = 7.37$, $p = 0.012$). Both RPE-AM and RPE-O increased as resistance exercise intensity increased from 60–80% 1RM. RPE-AM was significantly higher than RPE-O at both intensities; however, the magnitude of the difference between RPE-AM and RPE-O was greater at 80% 1RM than at 60% 1RM. No other significant 3- or 2-way interactions were found, nor was there a significant Group main effect ($F[1,26] = 0.340$, $p > 0.05$).

Complete EMG data were available for 20 (10 novice, 10 recreational) of the 28 subjects. EMG means and standard deviations are shown in Table 3. There were no group $\times$ intensity interactions, nor was there a significant main effect for Group for any of the muscles. However, there was a significant main effect for Intensity on each of the muscles (pectoralis major: $F[1,18] = 51.36$, $p < 0.01$; anterior deltoid: $F[1,18] = 58.77$, $p < 0.01$; medial deltoid: $F[1,18] = 28.28$, $p < 0.01$; triceps brachii: $F[1,18] = 16.13$, $p < 0.01$). No significant correlations were found between RPE and EMG.

Table 3. Mean ± *SD* for integrated electromyography responses to 2 resistance exercise intensities in novice and recreational lifters.†

	60% 1RM				80% 1RM			
	PM	AD	MD	TR	PM	AD	MD	TR
Recreational ($n = 10$)	105.3 ± 18.5	90.9 ± 31.9	88.9 ± 30.4	117.2 ± 31.9	137.2 ± 32.5*	109.7 ± 31.1*	118.0 ± 42.9*	168.4 ± 68.2*
Novice ($n = 10$)	91.9 ± 14.4	89.5 ± 18.9	97.8 ± 31.9	121.6 ± 41.4	118.7 ± 23.1*	112.9 ± 25.5*	130.8 ± 40.1*	153.1 ± 32.2*
Total ($n = 20$)	98.6 ± 17.5	90.2 ± 25.6	93.4 ± 30.7	119.4 ± 36.1	127.9 ± 29.0*	111.3 ± 27.7*	124.4 ± 40.9*	160.7 ± 52.5*

* Within a given muscle group, significantly ($p < 0.01$) different from the 60% 1RM intensity.
† 1RM = 1 repetition maximum; PM = pectoralis major; AD = anterior deltoid; MD = medial deltoid; TR = triceps brachii.

DISCUSSION

This study examined perceptual responses and muscle activity during the bench press exercise performed at 2 different resistance exercise intensities in novice and recreationally trained women. The results indicate that RPE and EMG increased as resistance exercise intensity increased from 60–80% 1RM in both groups. These results provide support for a link between relative exercise intensity and RPE in both novice and recreational lifters and suggest that muscle activity mediates the perception of exertion during resistance exercise.

In novice and recreational lifters, active muscle and overall body RPE increased as resistance exercise intensity increased from 60–80% 1RM. Because total work was held constant between the intensities, the possibility that RPE was dependent on the work performed was eliminated. Previous studies have demonstrated similar findings with recreational lifters (11, 12, 20). The present findings indicate that RPE is a valid method of monitoring resistance exercise intensity for novice lifters as well as recreational lifters.

RPE-AM was significantly higher than RPE-O at both intensities for both groups, suggesting that the sensations of strain and discomfort were more intense in the active muscles than in the overall body at a given exercise intensity. This result could be attributed to the types of physiological events that may mediate the perception of exertion during resistance exercise. For instance, the present and previous investigations suggest that muscle activity may mediate RPE during resistance exercise. Muscle activity is specific to the active muscle, and so it is plausible that a lifter would perceive active muscle exertion to be greater than overall body exertion. Other potential mediators of perceived exertion during resistance exercise, such as lactic acid accumulation, might also result in higher active muscle RPE when compared to overall body RPE. The implication of the observed difference between reported RPE values is that RPE-AM likely provides a better indication of resistance exercise intensity than RPE-O.

Examination of the RPE × intensity interaction revealed that RPE-AM was disproportionately higher than RPE-O at 80% 1RM than at 60% 1RM. The “breaking away” of RPE-AM from RPE-O at higher resistance exercise intensities has been demonstrated in previous studies (11, 12) and may be an amplification of the events hypothesized to result in a higher RPE-AM than RPE-O at a given intensity. For instance, at very high exercise intensities (i.e., ≥80% 1RM), lactic acid production may be disproportionately higher than at lower exercise intensities. In addition, there may be other factors that are most likely to occur at high exercise intensities, such as phosphocreatine depletion or reductions in blood pH, which may act to intensify active muscle perceived exertion to a greater extent than overall body perceived exertion as exercise intensity increases.

EMG was collected during each resistance exercise intensity to assess muscle activity during the bench press exercise. Results indicate that muscle activity increased significantly in the pectoralis major, anterior deltoid, medial deltoid, and triceps brachii muscles as resistance exercise intensity increased from 60–80% 1RM for both novice and recreationally trained women. The increases in EMG paralleled the increases in perceived exertion, as previously reported by Lagally et al. (12). In the present study, the hypothesized increase in muscle activity with increasing resistance exercise intensity was observed in novice as well as recreational lifters. This finding suggests that a similar mechanism may mediate perceived exertion across experience levels. A feed-forward neuromuscular mechanism has been proposed to link muscle activity and perceived exertion (3, 4, 14). As the relative load lifted increases, motor unit recruitment and firing frequency must increase in order to achieve the necessary muscular tension. An increase in muscle activity is a direct result of increases in motor efferent commands (4). As the motor efferent commands increase, so too do the number of corollary copies sent to the sensory cortex. This in turn is hypothesized to intensify perceived exertion. The corresponding increases between RPE and EMG seen in the present and previous studies suggest that such a feed-forward neuromuscular mechanism does play a role in the perception of exertion during resistance exercise.

The corresponding increases in RPE and EMG seen with greater resistance exercise intensity are consistent with Borg's model of the Effort Continua. The model suggests that perceived exertion during exercise performance is functionally linked to select physiological variables (2). A link between perceptual (RPE) and physiological (EMG) responses suggests that both responses provide similar information about exercise performance (2). RPE is an established method for the regulation of exercise intensity during dynamic aerobic exercise because physiological (e.g., oxygen uptake, heart rate) and perceptual responses are functionally related (15). A target RPE can be used like a target heart rate to achieve and maintain a specific aerobic metabolic rate (15). Similarly, the link identified between perceptual (RPE) and physiological (EMG) responses during resistance exercise in this study suggests that RPE may be used to attain a given resistance exercise intensity.

A unique feature of this study was the comparison of perceived exertion responses between novice and recreational lifters. Subjects were classified as novice or recreational based on bench press experience in the past 2 years. The expectation that recent experience with the bench press exercise would be related to upper-body muscular strength was supported by results indicating the mean 1RM was significantly higher in the recreational group compared to the novice group ($R = 44.3 \pm 11.2$ kg; $N = 31.3 \pm 5.7$ kg). Using the upper-body strength classifications (bench press weight ratio = weight pushed/body weight) from the ACSM guidelines (1), the novice group fell into approximately the 23rd percentile with a mean ratio of 0.53 (well below average), whereas the recreational group fell into approximately the 69th percentile with a mean ratio of 0.73 (average). Despite the differences in upper-body strength and bench press experience, we found no differences in the mean perceived exertion rating between the groups at either 60 or 80% 1RM. Felts et al. (5) reported a similar finding of no significant difference in RPE between women of above-average, average, and below-average aerobic fitness when cycle ergometer exercise was performed at 30 and 60% of heart rate reserve. The similar results suggest that relative exercise intensity plays an important role in the perception of exertion regardless of fitness level during both aerobic and resistance exercise. In general, perceived exertion is similar at a given relative exercise intensity regardless of exercise mode or participant fitness level. The practical implication of this is that the Borg RPE scale may be applied during estimation of resistance exercise intensity without concern for strength or lifting experience.

Although previous investigations have demonstrated significant correlations between RPE and EMG (7, 9), the present investigation did not. The correlation coefficients between EMG and RPE-AM ranged from 0.063–0.254. The relatively low correlation coefficients may be attributed to the limited intensities and total work performed, which restricted the response range for both RPE and EMG. In addition, as measured by the standard deviations, variability was considerably lower for the RPE data compared to the EMG data, further impacting the correlation analysis. Future studies should incorporate a wider range of exercise intensities to further investigate the relationship between RPE and EMG.

In summary, the results of this investigation suggest that a link exists between perceived exertion and % 1RM in both novice and recreational lifters. Thus, it may be concluded that relative exercise intensity plays an important role in the estimation of perceived exertion during resistance exercise regardless of fitness level. The results also provide evidence that RPE is a valid method of monitoring resistance exercise intensity for both novice and recreational lifters. RPE and EMG increased correspondingly as resistance exercise intensity increased from 60–80% 1RM, suggesting that muscle activity acts as a mediator of RPE during resistance exercise. These results provide a justification for using RPE to monitor resistance exercise intensity with healthy novice and recreational lifters. In combination with previous results demonstrating links among perceived exertion, 1RM, and various physiological markers of intensity, these results provide the foundation for further investigation of perceived exertion during resistance exercise. Research employing estimation-production protocols would be particularly useful in more clearly defining the role of RPE in resistance exercise intensity prescription.

Practical Applications

The present results indicate that RPE from the Borg RPE scale is a valid method of assessing resistance exercise intensity for healthy novice and recreational lifters. Using RPE as a method of intensity estimation may be particularly applicable to these types of lifters, whose primary goal is to improve muscular strength and endurance for health-related purposes. An RPE reported at a given % 1RM during a testing session could be used as a target RPE to estimate safe and appropriate resistance exercise training intensities during a training session. This would provide exercisers with a quick and easy method of determining resistance exercise intensity that is consistent with a widely accepted and commonly used method of determining aerobic exercise intensity (i.e., RPE).

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