The Influence of Muscle Action on Heart Rate, RPE, and Affective Responses After Upper-Body Resistance Exercise

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Abstract

Miller, PC, Hall, EE, Chmelo, EA, Morrison, JM, DeWitt, RE, and Kostura, CM. The influence of muscle action on heart rate, RPE, and affective responses after upper-body resistance exercise. J Strength Cond Res 23(2): 366–372, 2009—Ratings of perceived exertion (RPE) are routinely used to monitor, assess, and prescribe aerobic exercise. Heart rate (HR) is another measure used to evaluate exercise intensity. Additionally, affective responses to aerobic exercise have been studied and seem to be influenced by the intensity of the exercise. The perceptual, HR, and affective responses to resistance exercise have not been effectively established. The purpose of this study was to examine whether differences in affect, RPE, and HR exist among college-aged women (n = 31) performing three different modes of resistance training: concentric (CE), eccentric (EE), and traditional concentric/eccentric (TE) performed at varying resistances. The women were asked to complete four sessions of resistance training on variable resistance machines: chest press, seated row, overhead press, and biceps curl. The first session was used to establish the 10-repetition maximum (RM) load for each station. Subsequent sessions involved the execution of training in one of the three test conditions: CE, EE, or TE. The participants performed three sets of each lift at 80% 10-RM, 100% 10-RM, and 120% 10-RM. The data revealed lower RPE during EE than the other test conditions. Similarly, EE elicited more mild HR response than either CE or TE. This finding is potentially important for the establishment of training programs, especially for those individuals recovering from an illness, who had been previously sedentary, and who are involved in rehabilitation of an injury.

Key Words eccentric, concentric, exercise intensity, perceived exertion

Introduction

Investigation of the benefit of different types of resistance training has been of ongoing interest to clinicians, coaches, and scientists. Most are in agreement that specificity of training is important for eliciting the desired exercise responses and/or adaptations. Whereas the concept of specificity is widely accepted for both athletes and nonathletes, exercise adherence and compliance are major obstacles in the establishment of exercise regimes. Development of an appropriate exercise prescription should not only be rooted within the concept of specificity, but both the physiological responses and affective feelings of the exerciser should also be considered (4). This may be especially relevant when an individual’s training goals are directed to general fitness rather than athletic competition. Careful consideration of a variety of techniques closely matching an individual’s exercise comfort level with resistance exercise may make the experience more pleasant and potentially increase both adherence and compliance.

It has been suggested that eccentric exercise may be an advantageous exercise technique for several scenarios including injury prevention, strength gains, hypertrophy, preservation of cortical bone, fatigue resistance, and several clinical populations (8,12,15,16,21–23). Although traditional concentric/eccentric regimes have been shown to elicit greater training responses, individuals may actually tolerate eccentric resistance exercise better (11,25). Consequently, eccentric resistance exercise may be a desirable method of resistance exercise, especially for the nonathlete, where regular participation may be less than desired. Eccentric resistance exercise may enhance an individual’s effort, adherence, and compliance.

Exercise outcomes elucidated by examining musculoskeletal adaptations are important in identifying the effectiveness of resistance training programs. Several studies have compared the strength and hypertrophy gains after participation in eccentric vs. concentric resistance training. Eccentric training does seem to elicit a superior training response (i.e., enhanced hypertrophy and strength gains) when compared with concentric training. This phenomenon also seems to be influenced by training intensity (21).
Additionally, prevention of injury is a primary concern when creating exercise prescriptions. Mjolsnes et al. (16) investigated the use of eccentric hamstring training in soccer players. Working on the assumption that hamstring strains occur more during the eccentric phase of a movement, they felt that pursuing training programs that focus specifically on eccentric contractions may result in injury prevention. The results of their study did describe superior eccentric strength gains after eccentric training. These investigators report improved hamstring to quadriceps ratios among the participants even though they were already highly trained. These same results were seen when the methods were repeated in an untrained, college-aged sample. The results of this study support the use of eccentric-only training for athletes and also for those exercising for general fitness.

In addition to the proposed physiological benefit of eccentric resistance training, positive affective responses may also be seen after participation in this type of exercise. Acute bouts of aerobic exercise have consistently been found to improve affect (6,19). Previous research has found that there is an enhanced affect usually indicated by an increase in pleasantness and activation after aerobic exercise (5,9). However, few studies have examined the affective responses after acute bouts of resistance exercise.

In an early meta-analysis, Petruzello et al. (18) reported an increase in state anxiety after resistance exercise. However, it should be noted that this meta-analysis was limited to only a few studies that had been conducted at that time.

More recent studies have found improvements in affect and emotion after acute bouts of resistance training (1,3,7). Arent et al. (1) reported a curvilinear dose-response relationship between exercise intensity and affective responses, with the greatest improvements in affect occurring at moderate-intensity exercise (i.e., 70% of 10-repetition maximum [RM]) compared with low- and high-intensity exercise (i.e., 40% 10-RM and 100% 10-RM, respectively). There has been some research providing evidence that resistance exercise can play a role in improving affect (3,19,23).

One aspect of resistance training that may be of interest when examining affective responses is the type of muscle action used. Research has shown that eccentric muscle actions may be a more effective way to enhance muscle size and strength while requiring smaller amounts of energy than traditional concentric-eccentric methods (13,14). These findings, along with others, suggest that the type of muscle action may warrant consideration when selecting exercise intensity for exercise programs. Such consideration may be particularly important for the development of exercise programs that address the physical needs of individuals who are recovering from injuries or illness or who have been previously sedentary. If eccentric muscle actions can produce optimal strength gains with less effort, it may be hypothesized that this may contribute to more positive affective responses and, hopefully, better exercise adherence. The purpose of this study was to examine the affective, perceptual, and heart rate (HR) responses that female exercisers experience after acute bouts of resistance exercise using three different patterns of muscle action: eccentric only (EE), concentric only (CE), and concentric-eccentric (TE).

**Methods**

**Experimental Approach to the Problem**

A repeated-measures design was used to assess differences in HR, ratings of perceived exertion (RPE), and affective measures (Feeling Scale [FS], Felt Arousal Scale [FAS], and Activation Deactivation Adjective Check List [AD ACL]) between lifting conditions and exercise intensity for the bench press, overhead press, rows, and biceps curl. The use of only upper-body exercise was based solely on issues of practicality for this initial investigation. Loads for upper-body lifts tended to be lighter than those seen for lower-body lifts, therefore making execution of the protocol less strenuous for the investigator. The independent variables were the muscle action (EE, CE, and TE) and intensity (80, 100, and 120% 10-RM). Affective and perceptual responses to exercise are regarded as being related to intensity; therefore, the percentages of the 10-RM were used to vary the intensity (1). The dependent variables were HR, RPE, and affective responses to the task. Within each testing session, both muscle action and exercise intensity were counterbalanced to safeguard against an order effect.

**Subjects**

Thirty-one 18- to 22-year-old females (mean age $\pm SD = 20.6 \pm 1.3$ years, mean height $\pm SD = 161.0 \pm 5.8$ cm, mean weight $\pm SD = 75.8 \pm 3.9$ kg) agreed to participate in this investigation. All participants completed a physical activity readiness questionnaire and a brief health history questionnaire. All participants seemed to be healthy and free of musculoskeletal concerns. Before participating in this investigation, all subjects read and signed an informed consent approved by Elon University’s institutional review board for human subjects.

**Measures**

All participants were given standardized written instructions for the Borg CR-10, FS, FAS, and AD ACL before each administration. These instructions were made available for the participants at every testing session. Heart rate was measured using a Polar HR monitor. Heart rate was assessed on completion of each set.

Perceived exertion was assessed using the Borg CR-10 scale. This scale measures how hard an individual feels he or she is working during a given task. Responses range from 0 to 10, where 0 is indicative of no perceived exertion and 10 represents maximal exertion (17).

The circumplex model of affect (20) was measured by two single-item scales: the FS (10) and the FAS (24). The AD ACL (26) was also used to assess dimensions of the circumplex model. The FS is an 11-point, single-item, bipolar
rating scale commonly used for the assessment of affective responses during exercise. The scale ranges from −5 to +5. Anchors are provided at zero (“neutral”) and at all odd integers, ranging from “very good” (+5) to “very bad” (−5). The FAS is a six-point, single-item rating scale, ranging from 1 to 6, with anchors at 1 (“low arousal”) and 6 (“high arousal”). The AD ACL is a 20-item measure of the bipolar dimensions of EA and TA. The EA dimension ranges from Energy to Tiredness, whereas the TA dimension ranges from Tension to Calmness. These dimensions are consistent with the circumplex model of affect.

Procedures
All participants completed four exercise sessions. On the initial visit, each participant was introduced to the four exercises used in this study. They were the biceps curl, chest press, overhead press, and the seated row. The exercises were performed using variable resistance machines (Body Masters Sports Industries Inc., Rayne, Louisiana). These machines were selected for practical considerations: they are easier to spot the lift, they are less dependent on technique than free weights, and they were readily available for the purposes of protocol standardization. Baechle et al. (2) have recommended the use of a 10-RM test instead of a 1-RM test for individuals with limited resistance training experience and for unijoint, small muscle lifts (e.g., triceps extension and biceps curl) where a 1-RM is contraindicated. Consequently, the determination of the 10-RM was established using the recommendations of Baechle et al. (2).

Each participant was asked to estimate her 10-RM for each lift. Using their input, initial load was established and then modified via the testing procedures (2). A 2-minute rest interval was given between attempts to allow for recovery. Each 10-RM was determined within three attempts. To reduce the risk of injury and/or error during the establishment of the 10-RM, each participant was given instruction in proper lifting technique. Spotting and monitoring during each lift was done by the investigators. Participants returned to the testing center three more times with a 48- to 72-hour rest interval between visits. On each test day, a different experimental condition was employed. The experimental conditions used were EE, CE, and TE. Traditional resistance training consisted of both a lengthening and shortening phase, CE consisted of only a shortening phase, and EE consisted of only a lengthening phase. For both the CE and EE conditions, the phase of the lift that was not under direct observation was performed by the investigator. During the testing sessions, the participants were asked to perform three sets of each lift at varying resistances: one set at 80% 10-RM, one set at 100% 10-RM, and one set at 120% 10-RM. Again, a 2-minute rest was given between sets to minimize the effects of fatigue. A counterbalance technique was used to minimize the risk of an order effect.

After each set, HR was measured using a Polar HR monitor and recorded. Ratings of perceived exertion were assessed and recorded using Borg’s CR-10 RPE scale. Before the beginning of each exercise trial, the participant completed the affect questionnaires (e.g., FS, FAS, and AD ACL). Additionally, the affect questionnaires were completed immediately after and 1 hour after the completion of the exercise trial. The participants were told to refrain from performing resistance training between sessions to insure proper recovery from the exercise session and to avoid carryover or training effects to the next session.

Statistical Analyses
Comparisons between experimental condition and relative intensity for all lifts were made using a repeated-measures general linear model. A significance level of $p \leq 0.05$ was selected a priori. Standard contrast procedures were performed when main effects were found.

Results
A 3 (condition: EE, CE, and TE) by 3 (intensities: 80, 100, and 120% 10-RM) repeated-measures general linear model on RPE scores showed a significant main effect for condition (chest press: $p = 0.0001$; rows: $p = 0.0001$; overhead press: $p = 0.0001$; biceps curl: $p = 0.0001$) and for intensity (chest press: $p = 0.0001$; rows: $p = 0.0001$; overhead press: $p = 0.0001$; biceps curl: $p = 0.0001$) for each lift. A condition-by-intensity interaction was also seen for each lift (chest press: $p = 0.014$; rows: $p = 0.004$; overhead press: $p = 0.014$; biceps curl: $p = 0.029$). A pictorial depiction of the differences in RPE across the exercise intensities and muscle actions is provided in Figure 1.

A 3 (condition: EE, CE, and TE) by 3 (intensities: 80, 100, and 120% 10-RM) repeated-measures general linear model on HR showed a significant main effect for condition (chest press: $p = 0.0001$; rows: $p = 0.0001$; overhead press: $p = 0.0001$; biceps curl: $p = 0.0001$) and for intensity (chest press: $p = 0.0001$; rows: $p = 0.0001$; overhead press: $p = 0.0001$) for each lift except for the biceps curl. A condition-by-intensity interaction was also seen for each lift except for the biceps curl (chest press: $p = 0.003$; rows: $p = 0.006$; overhead press: $p = 0.007$). A pictorial depiction of the differences in HR across the exercise intensities and muscle actions is provided in Figure 2.

A 3 (condition: EE, CE, and TE) by 3 (time points: preexercise, post 0 minutes, and post 60 minutes) repeated-measures general linear model on AD ACL (EA and TA) scores showed a significant main effect of time ($p = 0.001$) and a condition-by-time interaction ($p = 0.026$). Univariate analyses for time revealed that this was attributable to changes in both EA ($p < 0.001$) and TA ($p = 0.003$). Univariate analyses for the condition-by-time interaction revealed that this was attributable to changes in TA only ($p = 0.003$). Mean scores for all measures are shown in Table 1. A pictorial depiction of the temporal dynamics of the affective responses to resistance training is provided in Figure 3.

A 3 (condition: EE, CE, and TE) by 3 (time points: preexercise, post 0 minutes, and post 60 minutes) repeated-measures general linear model on FS and FAS scores showed...
standardization across conditions for the rate at which the motion was performed. Moving the weight at a constant rate, ensuring that each contraction occurs in a set interval, may allow for a more accurate testing procedure throughout the sample and, thus, facilitate greater consistency of the movement between subjects.

Heart rate response was also significantly lower in the EE condition. One could theorize that this, again, resulted from differences in the relative loading of the muscle for each lifting condition. So, one may theorize that when the muscles were used to perform EE, less work was done and less energy was expended than when the CE or TE conditions were completed. Because of the varying exercise conditions, if muscles are under less stress, the energy, blood, and oxygen requirements are not as great as they would be if a muscle were under greater stress, and, thus, the cardiac response would not be as great. This finding is in agreement with those of LaStayo et al. (14), in which the oxygen demand of muscles during EE training was less than the oxygen requirements during CE training.

The attenuated HR response seen during the EE training may be attributed to the lower relative load used in that condition. The relative intensity for EE training is certainly less than those seen in the other conditions because the loads were established using TE techniques (8,22). This is in agreement with the findings of a study by LaStayo et al. (13), which elaborated on the notion that EE muscle contractions may be a more effective way to enhance muscle size and strength while requiring smaller amounts of energy than CE methods. This is potentially important for prescribing exercise for those individuals who are either returning to exercise after prolonged absence or recovering from illness or injury.

An additional goal of this study was to examine the influence of different muscle actions on the affective responses to resistance training. The results of this investigation support the notion that resistance training can provide affective benefits to the exerciser. Specifically, resistance exercise resulted in increased pleasantness and activation immediately after exercise in all exercise conditions. At 60 minutes post-exercise, pleasantness was still elevated; however, activation had decreased toward preexercise levels. This is consistent with what has previously been demonstrated with aerobic
The present investigation did not show that one type of muscle action was more beneficial than any other. Although the EE condition did not elicit greater improvements in affect than the CE or TE conditions, the results may still suggest that it might be a more beneficial training protocol for those who are unfit, injured, or suffering from illness because it will require less effort and provide affective benefits. Such outcomes are expected to be closely associated with greater exercise adherence.

Two major limitations should be taken into consideration when interpreting these results. First, in the present study, only college-aged females were examined, most of whom were already regularly physically active. Because of the narrow segment of the population sampled, caution should be used in generalizing these results. Second, only the upper body was tested on four different lifts using resistance machines. Therefore, it may be beneficial to conduct research regarding lower-body resistance training exercises in addition to more upper-body exercises.

There exists a gap in the literature on the effects of resistance exercise on affective responses to exercise, and thus future studies investigating these relationships are warranted. Additionally, future investigations need to determine how varying the components of the exercise prescription will influence affective responses to exercise. In resistance exercise, some of the variables that may be of interest to manipulate may include the intensity of exercise, number of sets, rest between sets, and exercises prescribed (e.g., upper body vs. lower body). Arent et al. (1) was one of the first to attempt to equate volume (reps × sets) of exercise between different intensities and found that moderate-intensity resistance exercise (70% 10-RM) was superior to low- (40% 10-RM) and high-intensity (100% 10-RM) resistance exercise for improving positive affective responses. Additionally, future studies may be needed to examine the psychological and physiological mechanisms responsible for the affective responses that occur with exercise.

**Practical Applications**

The findings of this study may have important implications in regard to exercise prescription. These findings support the idea that differing types of muscle contractions may elicit

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**TABLE 1.** Descriptive statistics (mean ± SD) for responses to the Energetic Arousal (EA) and Tense Arousal (TA) scales of the Activation Deactivation Adjective Check List (AD ACL) for the three exercise conditions.

<table>
<thead>
<tr>
<th></th>
<th>Eccentric</th>
<th>Concentric</th>
<th>Concentric – eccentric</th>
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<tbody>
<tr>
<td></td>
<td>EA</td>
<td>TA</td>
<td>EA</td>
</tr>
<tr>
<td>Preexercise</td>
<td>23.1 ± 6.5</td>
<td>21.0 ± 3.0</td>
<td>21.9 ± 6.7</td>
</tr>
<tr>
<td>Post 0 min</td>
<td>26.9 ± 6.9</td>
<td>22.1 ± 1.4</td>
<td>28.7 ± 5.4</td>
</tr>
<tr>
<td>Post 60 min</td>
<td>24.3 ± 4.2</td>
<td>21.7 ± 1.9</td>
<td>25.1 ± 5.1</td>
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</table>
somewhat distinct physiological, perceptual, and affective responses. Although previous research has demonstrated superior training responses for those participating in combined concentric/eccentric programs, an EE program may be more palatable and lead to better affective responses (25). Therefore, the application of these findings may become very meaningful when applied to individuals who are commencing new exercise programs, when dropout rates are highest. Furthermore, when considered with the findings of LaStayo et al. (13), which describe eccentric contractions as a very efficient method to enhance muscle function, the use of eccentric techniques may have profound applications across several clinical and subclinical populations; however, this remains to be demonstrated.

REFERENCES


### Table 2. Descriptive statistics (mean ± SD) for responses to the Feeling Scale (FS) and Felt Arousal Scale (FAS) for the three exercise conditions.

<table>
<thead>
<tr>
<th></th>
<th>Eccentric</th>
<th></th>
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<th>Concentric – eccentric</th>
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<tbody>
<tr>
<td></td>
<td>FS</td>
<td>FAS</td>
<td>FS</td>
<td>FAS</td>
<td>FS</td>
<td>FAS</td>
</tr>
<tr>
<td>Preexercise</td>
<td>1.78 ± 1.5</td>
<td>2.78 ± 1.0</td>
<td>2.52 ± 1.2</td>
<td>3.04 ± 1.2</td>
<td>1.81 ± 1.3</td>
<td>2.93 ± 1.0</td>
</tr>
<tr>
<td>Post 0 min</td>
<td>2.96 ± 0.9</td>
<td>3.56 ± 1.1</td>
<td>2.96 ± 1.2</td>
<td>3.96 ± 1.0</td>
<td>2.89 ± 1.2</td>
<td>3.78 ± 1.1</td>
</tr>
<tr>
<td>Post 60 min</td>
<td>2.78 ± 1.2</td>
<td>3.44 ± 1.1</td>
<td>2.78 ± 1.3</td>
<td>3.41 ± 1.2</td>
<td>3.00 ± 1.1</td>
<td>3.41 ± 1.1</td>
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