RPE, Pain, and Physiological Adjustment to Concentric and Eccentric Contractions

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ABSTRACT

HOLLANDER, D. B., R. J. DURAND, J. L. TRYNICKI, D. LAROCK, V. D. CASTRACANE, E. P. HEBERT, and R. R. KRAEMER. RPE, Pain, and Physiological Adjustment to Concentric and Eccentric Contractions. *Med. Sci. Sports Exerc.*, Vol. 35, No. 6, pp. 1017–1025, 2003. **Purpose:** The purpose of the study was to compare perceptual (RPE and pain), cardiac (heart rate), lactate, and endocrine (cortisol) responses with concentric (CON) and eccentric (ECC) resistance exercise protocols using the same absolute workload. **Methods:** Eight healthy men with resistance-training experience participated in the study. Subjects completed two experimental trials consisting of either CON contractions or ECC contractions at the same absolute workload for each of four exercises: bench press, leg extension, military press, and leg curl. Subjects performed four sets of 12 repetitions at 80% of 10-RM with 90-s rest periods. Blood samples were taken before, immediately after, and 15-min postexercise. **Results:** There was a significant trial effect for RPE, with CON exercise eliciting a higher RPE than ECC exercise (6.71 $\pm$ 0.51 and 4.10 $\pm$ 0.27, respectively). A significant trial effect was also demonstrated for pain, with CON exercise producing a higher pain rating than ECC exercise (5.59 $\pm$ 0.41 and 3.23 $\pm$ 0.27, respectively). Significantly higher heart rates and lactates were also demonstrated during the CON trial. For cortisol, a significant interaction was revealed between the pre- and immediate posttrial measures but not an overall trial effect. Correlational analyses revealed a significant relationship between RPE and pain for both trials. **Conclusions:** CON exercise elicits greater perceptual (higher RPE and pain rating), cardiac, lactate and cortisol response than ECC exercise at the same absolute workload. Data demonstrate that relative to absolute load, RPE and pain respond to resistance exercise in a similar fashion. Additionally, physiological cues are consistent with these perceptual data. **Key Words:** RESISTANCE EXERCISE, CORTISOL, LACTATE, HEART RATE

Resistance exercise typically includes concentric (CON) and eccentric (ECC) muscle contractions. Moreover, strenuous resistance exercise is commonly associated with intense effort and pain. However, few studies have investigated the link between rating of perceived exertion (RPE) and pain, and we are unaware of any studies investigating RPE and pain perceptions to resistance exercise involving CON and ECC muscle actions. Perceived exertion can be conceptualized as a sense of effort experienced while performing physical or mental work. Borg has referred to this rating as a psychosomatic interaction to assess changes in work, effort, and breathlessness to produce an effort sense (5,23). Pain is typically defined as an unpleasant sensation that is a result of injury, disease, emotional trauma, or distress (5).

The relationship between RPE and intensity of resistance exercise appears to follow both a linear and quadratic model (27). Gearhart et al. (10) demonstrated that when comparing seven exercises at either five repetitions at a 90% of a 1-RM or 15 repetitions at a 30% of a 1-RM, the higher intensity protocol was perceived as more difficult despite requiring a similar amount of relative work. Another investigation revealed that at intensities of 30, 60, and 90% of a 1-RM for a biceps curl, RPE for both overall body and active muscle increased as workload increased (21). These findings were further validated by Lagally and colleagues (21), who demonstrated that EMG increases paralleled the perception of effort changes during resistance exercise. Collectively, these data suggest that RPE is an effective measure of the intensity of resistance exercise.

A consistent finding has been that lactate concentrations are related to RPE during resistance exercise both in single and multi-joint exercise protocols (17,21). Kraemer et al. (17) demonstrated a clear progressive increase in RPE in a multiple set resistance exercise protocol utilizing three sets of 10 repetitions for bench press, latissimus dorsi pull downs, leg extensions, and leg curls with concomitant in-

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crease in lactate. Another study reported significant correlations between lactate and RPE in which subjects completed resistance exercise at 50 or 70% of a 1-RM (30). Additionally, training may alter RPE and subsequent lactate levels at a standard workload (25). Thus, the pattern of increases in RPE with increases in intensity of resistance exercise appears to be related to lactate concentrations and these values can be attenuated after resistance exercise training.

Recently it was suggested that RPE and pain are distinct markers of perceptual change because RPE is related to sense of effort whereas pain may be related to damage and distress (5). Supporting this contention, a study that compared RPE and leg pain in response to cycling suggested that RPE is greater than leg pain on the same scale (CR-10) at the same workload (6). Although previous research indicates the absolute scores for RPE are higher than pain, there is evidence that the pattern of change in RPE and pain to increased workload is similar (6). The rationale for why RPE and pain may be related can be seen in the physiological marker of lactate. Several studies have been conducted demonstrating the relationship between increased lactate levels with higher workload and increased ratings for RPE and pain (5,26,30). Additionally, when examining resistance exercise, CON muscle actions in an absolute loading scheme represent greater muscular stress than ECC actions, thus potentially eliciting higher lactate concentrations. Support for greater RPE and pain during CON muscle actions is inferred from research demonstrating that maximal ECC strength is roughly 20–60% more than maximal CON strength; thus, if identical absolute loads are used for CON and ECC actions, ECC actions are performed at a lower relative intensity and may have less motor unit recruitment (2).

Cook et al. (7) compared the effects of progressive isometric resistance exercise to fatigue on RPE and pain using category ratio and standardized scales. A low correlation was observed between RPE and pain. Perhaps the type of muscle contraction (e.g., dynamic vs isometric) affects the relationships between RPE and pain, as Borg et al. (6) found that RPE and pain were related during cycle ergometry. Exploration of the effects of contraction type on the relationship between RPE and pain could illuminate subtle distinctions that may exist and are linked to physiological changes (8,12,13,16,31). O'Connor et al. (25) examined the relationship between RPE and pain responses to three different ECC resistance exercise protocols (80% of maximum for 45 repetitions, 100% of maximum for 36 repetitions, and 120% of maximum for 30 repetitions of CON maximal voluntary contraction). Findings revealed a moderate relationship between RPE (during exercise) and pain (12–72 h postexercise) that was probably due to the intensity of ECC muscle work on skeletal muscle damage. The relationship between RPE and pain has yet to be examined during both ECC and CON dynamic resistance exercise.

With regard to RPE and pain during resistance exercise, if afferent feedback from the muscle or cognitive alterations occurs, then it is plausible that cortisol, a neuroendocrine marker of stress, would be altered (2). Additionally, if the stressor of resistance exercise is perceived to be greater in one muscular action versus another, then activity of the hypothalamic-pituitary-adrenal (HPA) axis (as indicated by cortisol levels) should mirror the perceptual changes. Traditionally, psychophysiological studies using cortisol as a neuroendocrine marker have operated under the assumption that perception of increased stress leads to a hormonal cascade that results in increased cortisol bioavailability (32). However, the relationship between cortisol, RPE and pain in response to different muscle actions has not been clearly defined.

Therefore, the purpose of this investigation was to examine perceptual (RPE and pain), cardiac (heart rate), lactate, and cortisol responses to CON and ECC resistance exercise protocols using the same absolute workload. Additionally, we sought to examine the relationship between RPE and pain during resistance exercise. Our hypotheses were that CON muscle actions would produce higher RPE and pain ratings on the CR-10 scale than ECC muscle actions; HR, lactate, and cortisol responses would also be higher in response to CON muscle actions; and RPE and pain would be related. The expectation that RPE and pain would be related was predicated on the previous work of Borg and colleagues demonstrating at moderate intensities of work, RPE, and pain ratings were moderately related and became more correlated as maximum workloads were approached (5). Understanding the relationship between RPE and pain as well as physiological markers related to these perceptual changes for standard, absolute load resistance exercise could aid in the development of resistance exercise prescriptions to improve the exercise experience while capitalizing on the psychophysiological benefits of exercise.

METHODS

Subjects. Eight healthy men with resistance-training experience were recruited and gave written consent for participation in the investigation. Subjects were determined to be eligible if they engaged in recreational weight lifting for a minimum of 1 yr and were between 18 and 30 yr of age. The subjects were well-trained recreational athletes who were not involved in sport but whose normal training regimen consisted of bodybuilding type workouts (i.e., multiple sets, high-repetition training). A health history questionnaire was administered to rule out 1) participation in competitive body building or weight lifting for the previous year; 2) smoking; 3) taking medications that could alter test results (e.g., anabolic steroids, sympathoadrenal drugs, etc.); 4) history of pituitary, renal, hepatic, cardiovascular, or metabolic disease; 5) adherence to a reduced calorie or low fat diet, or ketogenic diet that could affect hormone levels; and 6) use of commercial ergogenic aids in the past 6 months such as creatine monohydrate, androstenedione, DHEA, or ephedra. The mean $\pm$ SE for age, height, weight, and body composition were 24.88 $\pm$ 1.36 yr, 178.28 $\pm$ 2.49 cm, 84.72 $\pm$ 6.27 kg, and 17.00 $\pm$ 1.78%, respectively. The study was approved by the Southeastern Louisiana University Institutional Review Board and was conducted in accordance with the policies of the American College of Sports Medicine.

Experimental design. Subjects completed three testing trials: 1) a preexperimental trial, 2) a CON-only exercise trial, and 3) an ECC-only exercise trial. The CON and ECC trials were conducted in a counterbalanced fashion. Most resistance training protocols investigating CON and ECC contractions and RPE have used either the same relative load or did not employ both muscular actions (14,25). We employed conventional resistance exercise that involved the performance of dynamic, full range-of-motion contractions against a constant external load.

Preexperimental trial (session 1). Subjects completed a preexperimental session to obtain anthropometric and muscular strength measurements. First, height and weight were determined. Next, body composition was assessed with a skinfold caliper using a four-site equation (15) (abdomen, suprailiac, triceps, and thigh) (Lange, Beta Technology Inc., Santa Cruz, CA). Subjects were then tested to determine the 10-RM for each of the four exercises: bench press (BP), leg extension (LE), military press (MP), and leg curl (LC). Before each subject was tested, two 48-inch (10 lb each) steel pipes were bolted on top of the machine bench and military press. The steel rods were placed on the machine before the 10-RM to simulate the conditions of the CON and ECC trials. The 10-RM was a modification of a 1-RM protocol by Kraemer et al. (20). Briefly, a 2–3 set warm-up was performed with 5–10 repetitions that represented 40–60% of a perceived maximal exertion. Each warm-up set was performed in a linear progression. Subjects were instructed to perform the next 1–2 sets for 5 repetitions at a weight that was approximately 80% of perceived 10-RM. Immediately after these sets, subjects were instructed to perform a 10-RM; if the 10-RM was not achieved, a heavier weight was chosen. Rest periods between all sets were 3–5 min. After determining the 10-RM on each exercise, the validity of this measurement was tested by having each subject perform as many repetitions as possible with the determined 10-RM weight after a 10-min rest period. All subjects reached their 10-RM within three trials after their warm-up sets were performed. Ten-repetition maximum strength measurements have been accepted as a suitable secondary choice for determining appropriate training loads when maximal strength testing is not possible (2). The position of all benches, seats, bars, and subject handgrip alignment were recorded and kept constant for each exercise. For each exercise, the distance the weight was displaced was determined with a metal meter stick and pointers mounted to the resistance exercise equipment in an effort to maintain constant work per repetition in subsequent sessions. The maximal lifts determined for the BP, LE, MP, and LC used in the ECC and CON trials were (mean $\pm$ SE) 116.48 $\pm$ 8.6 kg, 42.05 $\pm$ 3.1kg, 68.75 $\pm$ 7.4 kg, and 21.02 $\pm$ 2.5 kg, respectively.

Sessions 2 and 3 (CON and ECC trials). Seven and 14 d after the preexperimental trial, the subjects returned to the weight room for session 2 or 3 after an 8-h fast. For both sessions, the same procedures were followed except one session was CON-only and the other session was ECC-only resistance exercise. At 8:00 a.m., the subject was seated quietly for 20 min. A baseline blood sample was collected from an antecubital vein via venipuncture. During this rest period, subjects filled out a state anxiety questionnaire. Subjects then performed four sets of 12 repetitions of the four exercises at 80% of the previously determined 10-RM in the following order: BP, LE, MP, and LC. During piloting of the study, we determined that four sets of 10 repetitions at 80% of a 1-RM load was too strenuous for researchers positioning the weight (in a timely manner) and for some subjects to complete the CON protocol. Four sets of 12 repetitions at 80% of the 10-RM load (approximately 60–65% of 1-RM, see reference 2) were found to be optimal to produce a substantial stimulus and ensure completion of the protocol. After each set, the subject's heart rate, RPE, and pain level were recorded. During the CON trial, subjects lifted the weight for each repetition, whereas technicians using a pulley or steel bar extensions performed the lowering of the weight. During the ECC trial, technicians lifted the weight stack with a pulley or steel bar extensions, and then the subject lowered the weight. All repetitions were performed to the rhythm of a metronome; the weight was lifted in 2 s and lowered in 2 s. Subjects rested 90 s between all sets and exercises. A rest period of 90 s was chosen because this interval is indicative of high-intensity weight-training sessions commonly performed (19). After completion of the fourth set of LC, a blood sample was immediately collected, and another blood sample was taken 15-min postexercise. For each blood sample, blood was collected into a 10-mL whole-blood tube for hormone analysis and a 3-mL tube with sodium fluoride and potassium oxalate for lactate determination. The 10-mL tubes were allowed to sit at room temperature for 10 min for clot formation and refrigerated for 25 min before centrifugation (500 $\times$ g). Serum was aliquotted and samples were stored at -80°C until hormone assays were performed.

State anxiety inventory. A state anxiety questionnaire that is a measure of how anxious a subject is at the moment (the state portion from Spielberger's State-Trait Anxiety Inventory (STAI)) was employed as a control variable to ensure that anxiety did not disrupt perceptions of exertion or pain (29). Previous research has demonstrated a relationship between state anxiety and RPE during exercise (9,24). Our goal was to control for potential effects of state anxiety on RPE and pain during resistance exercise. The state portion of the STAI asks individuals to respond to a series of questions regarding their thoughts and feeling "at this moment" to examine context and current levels of anxiety.

RPE and pain instruments. For instructing the subjects to rate perceived exertion during CON and ECC trials, we quoted the exact instructions recommended by Borg (5). The instructions included a paragraph of basic instruction and separate scaling instructions for RPE and pain. The instructions to the subjects for rating RPE were: "We want you to rate your perception of exertion, that is, how heavy and strenuous the exercise feels to you. The perception of

TABLE 1. Borg CRIO scale 1998 (5).

0	Nothing at all	"No P"
0.3		
0.5	Extremely weak	Just noticeable
1	Very weak	
1.5		
2	Weak	Light
2.5		
3.0	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	"Max P"
11		
●	Absolute maximum	Highest possible

exertion depends mainly on the strain and fatigue in your muscles and on your feeling of breathlessness or aches in the chest. We want you to use this scale from 0 to 10 and "●, where 0 means 'no exertion at all' and 10 means 'extremely strong—max P,' that is, the maximal exertion you have previously experienced" (Table 1).

For instructing the subjects to rate pain during CON and ECC trials, we quoted the exact instructions recommended by Borg (5). The instructions to the subjects for rating pain were "What are your worst experiences of pain? If you use 10 as the strongest exertion you have ever experienced or can think of, how strong would you say that your three worst pain experiences have been (5)?"

"10 'Extremely strong—max P,' is your main point of reference. It is anchored in your previously experienced worst pain, which you just described, the 'max P'."

"●The worst pain that you have experienced, the 'max P' may not be the highest possible level of pain. There may be a level of pain that is still stronger than your 10, you will say 11 or 12. If it is much stronger, e.g., 1.5. times, 'Max P,' you will say 15! Any questions (5)?" Then subjects were asked to scale their pain using the CR-10 scale as shown above.

Additionally, subjects were told that RPE and pain were different sensations in that RPE should relate to fatigue and strain, whereas pain should be considered as unpleasant feelings related to muscle damage or potential muscle damage. Subjects were asked to confirm that they recognized the differences in the ratings. These directions enabled subjects to have perceptions anchored by the worst pain they had ever experienced and compare the pain with the type and quality of pain they were experiencing during the resistance exercise trial. The rationale for employing the CR-10 scales for overall body RPE and pain was to remain consistent with past research that had employed overall body RPE ratings when using multiple joint movements such as those employed in the bench press and military press for the present study (3,17,30). In addition, because a specific muscle action was not targeted in the present study, overall body RPE and pain ratings were deemed most appropriate. Moreover, although active muscle RPE has been employed in past research, it was important for our experiment to employ whole-body RPE to match whole-body ratings of pain. Then, instructions were given that followed Borg's recommendations on pain scaling (4). Category-ratio scales (CR-10) for both rating of perceived exertion and pain were selected based on high concurrent and predictive validity. Specifically, category-ratio scales for RPE and pain employed during multiple workloads of cycle ergometry revealed high correlation coefficients (correlation coefficients between pain and exertion and workload magnitude estimations $r = 0.66$ (5) as well as perception of exertion and pain and maximal workload capacity ($r = 0.56$) (5)). Furthermore, reliability coefficients using split-half analyses have demonstrated high coefficients with both types of scales during bicycle ergometry testing (Spearman-Brown correlations were r_e (exertion) = 0.96, r_p (pain) = 0.96, heart rate $r = 0.97$, and blood lactate $r = 0.98$ (5)). These scales were also consistent with recommendations related to psychophysiological scaling (5).

Heart rate and blood analyses. All blood samples were analyzed for lactate and cortisol. Lactate was determined using an enzymatic method (Sigma Chemical, St. Louis, MO). Cortisol concentrations were determined using a sensitive chemiluminescent enzymatic immunoassay (Immulite: Diagnostic Products Corp., Los Angeles, CA). The interassay coefficient of variation was 5.44%, and the intra-assay coefficients of variation were < 5.0%.

Statistical analysis. A preliminary *t*-test was run on state anxiety measures for each trial to ensure that anxiety was similar in each protocol. If the *t*-tests were significant, anxiety would be entered as a covariate in subsequent analyses. RPE, pain, and heart rate were analyzed using 2 (Trial: CON and ECC) × 16 (Time of measurement) ANOVA with repeated measures. For lactate and cortisol, 2 (Trial: CON and ECC) × 3 (Time: pre, immediately post, and 15 min postexercise) ANOVA with repeated measures were performed. Finally, Pearson product moment correlation coefficients were computed to examine relationships between RPE and pain as well as these perceptual variables and HR, lactate, and cortisol. All comparisons were considered statistically significant at $P < 0.05$. *Post hoc* tests were applied where appropriate. ANOVA analyses were followed by the calculation of eta-squared and *post hoc* power analysis to determine the statistical probability of detecting differences of the observed sizes as significant given the design characteristics and number of subjects in the study.

RESULTS

The *t*-test comparing anxiety before CON and ECC trials revealed no significant difference. Therefore, anxiety was not entered as a covariate in the ANOVA analyses.

RPE. Analysis of RPE data revealed a significant trial effect ($P < 0.01$) with CON exercise eliciting a higher RPE than ECC exercise (6.71 ± 0.51 and 4.10 ± 0.27, respectively). A main effect for time was also demonstrated ($P < 0.001$). This factor was further investigated using *post hoc* analyses that compared each exercise time point to the previous time point. Significant differences were demonstrated between bp1-bp2, bp2-bp3, bp4-le1, le2-le3, mp1-mp2, mp2-mp3, mp4-lc1, lc1-lc2, lc2-lc3, and lc3-lc4 ($P <$

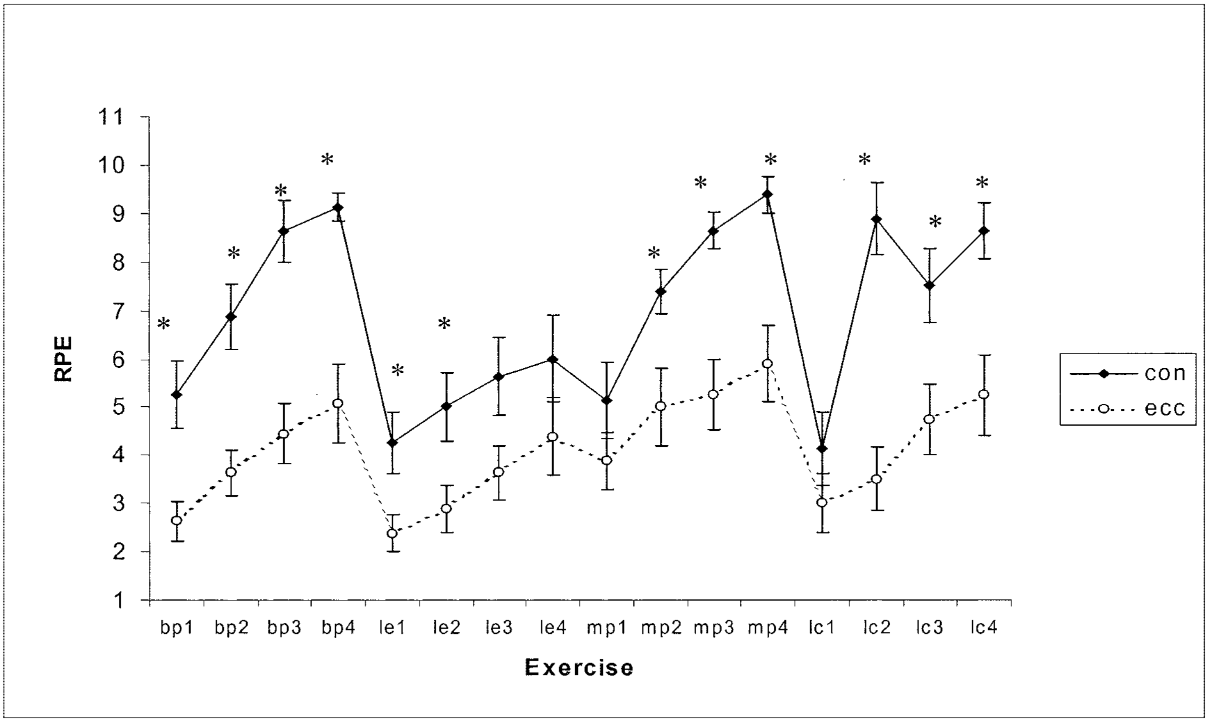

FIGURE 1—Data represent mean ± SE RPE values for the concentric (CON) and eccentric (ECC) trials. * Represents a significantly different (*P* < 0.05) value of CON trial when compared with the same time point in the ECC trial. For sets 1–4: bp, bench press; le, leg extension; mp, military press; lc, leg curl.

0.01) time points. As shown in Figure 1, RPE increased on each subsequent set of each exercise then decreased at the start of each new exercise. A significant trial × time interaction effect was demonstrated as well for RPE ($P < 0.01$). *Post hoc* contrasts indicated significant differences existed between CON and ECC trials for all but the following time points, le3, le4, mp1, and lc1, suggesting that RPE changed at a different rate for CON as compared with ECC muscle actions (see Fig. 1). Eta-squared values indicated most of the variance in RPE was due to the time factor (0.60) and trial factor (0.48). Power to detect differences for these two factors as significant were greater than 0.90. The interaction eta-squared value was substantially smaller (0.15) and power to detect differences for this interaction was 0.64.

Pain. The pattern of changes in pain across trials was similar to RPE. Pain increased with each subsequent set of an exercise and decreased between exercises (see Fig. 2). Analysis of pain between CON and ECC trials demonstrated a significant trial effect ($P < 0.01$) with CON contractions eliciting a higher pain rating than ECC contractions (5.59 ± 0.56 and 3.26 ± 0.56, respectively). Additionally, a significant time effect was demonstrated ($P < 0.0001$); *post hoc* comparisons revealed significant time differences between sets bp1-bp2, bp2-bp3, bp4-le1, le1-le2, le2-le3, mp1-mp2, mp2-mp3, mp4-lc1, lc1-lc2, lc2-lc3, and lc3-lc4 ($P < 0.01$). The interaction failed to reach significance. Eta-squared and observed power for trial, time, and the interaction respectively were 0.38/0.77, 0.55/1.00, and 0.09/0.40. These values indicate that pain primarily varied as a function of time and trial, and that power was adequate to detect these differences.

Heart rate. Heart rate increased during both trials with the CON trial eliciting higher HR than the ECC trial (see Fig. 3). The ANOVA revealed a significant trial effect ($P < 0.001$) with higher mean HR values (128.85 ± 3.01 bpm) for CON exercise as compared with ECC exercise (94.55 ± 1.31 bpm). Significant time effects were evident as well ($P < 0.001$). *Post hoc* analyses comparing each exercise time point to the previous time point indicated significant differences between the bp3-bp4, le4-mp1, and mp4-lc1 ($P < 0.01$). Additionally, a significant interaction effect was demonstrated between CON and ECC heart rates ($P < 0.0001$). *Post hoc* comparisons at each exercise time point indicated that HR during the CON trial was higher than that during the ECC trial at every time point except the first. Examination of *post hoc* power estimates indicated that HR primarily varied as a function of trial (eta-squared = 0.66, observed power = 1.00) and time (eta-squared = 0.55, observed power = 1.00). The interaction accounted for 21% of HR variance and observed power for this factor was 0.88.

Lactate. Lactate increased during both CON and ECC trials with the greatest increase evident in the CON trial immediately post and 15 min postexercise (see Fig. 4). Data analysis revealed a significant trial effect ($P < 0.0001$) with CON resistance exercise exhibiting a higher lactate than ECC resistance exercise. Also, a significant time effect was demonstrated ($P < 0.0001$); follow-up comparisons of each exercise time point to the previous time point indicated significant differences between pre to immediate post to 15 min postexercise. In addition, a significant interaction was revealed ($P < 0.001$), indicating lactate changed at differing rates during the CON and ECC trial. *Post hoc* comparisons

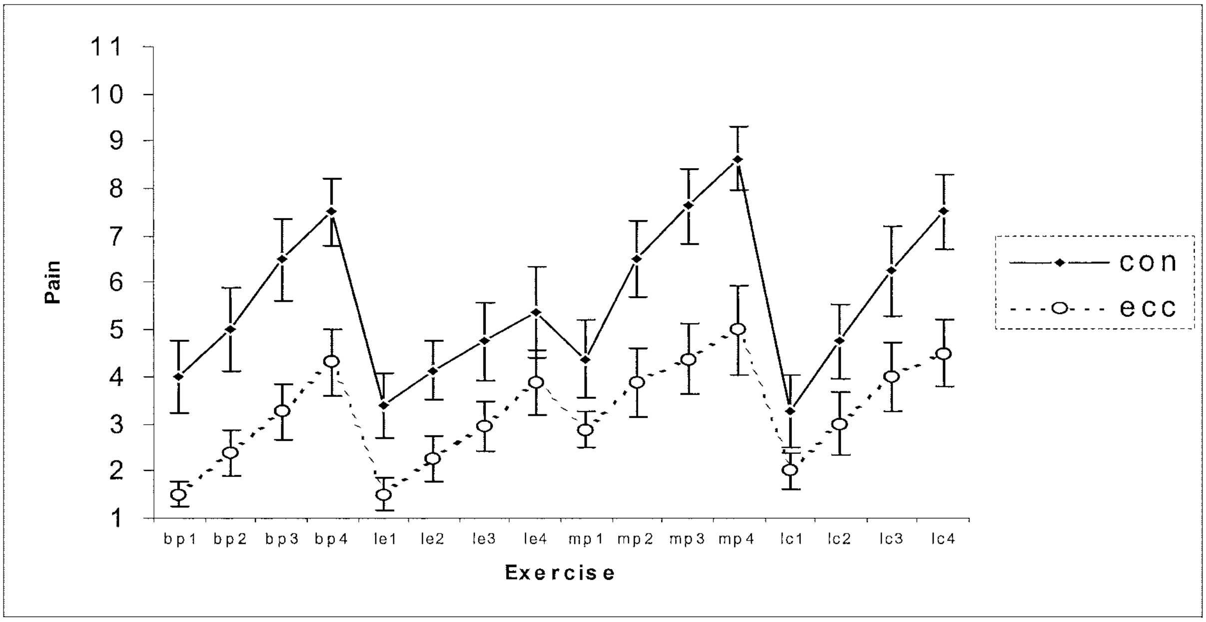

FIGURE 2—Data represent mean ± SE pain values for the concentric (CON) and eccentric (ECC) trials. Overall CON was greater than ECC trials for ratings of pain but no interaction effects were demonstrated. For sets 1–4: bp, bench press; le, leg extension; mp, military press; lc, leg curl.

indicated lactate was significantly different between trials immediately and 15 min postexercise. Eta-squared and observed power for trial, time, and the interaction respectively were 0.67/1.0, 0.74/1.0, and 0.64/1.0.

Cortisol. Cortisol declined for both trials with the greater decline in the ECC trial (see Fig. 5). The ANOVA revealed no significant trial effect. However, a significant time effect as well as an interaction effect was revealed ($P < 0.05$). *Post hoc* comparisons of each exercise time point to the previous time point demonstrated a significant main effect for time at pre to immediately postexercise for cortisol ($P < 0.01$). These comparisons indicated cortisol did not change significantly during the CON trial. But a significant decline during the ECC trial was observed from pre to

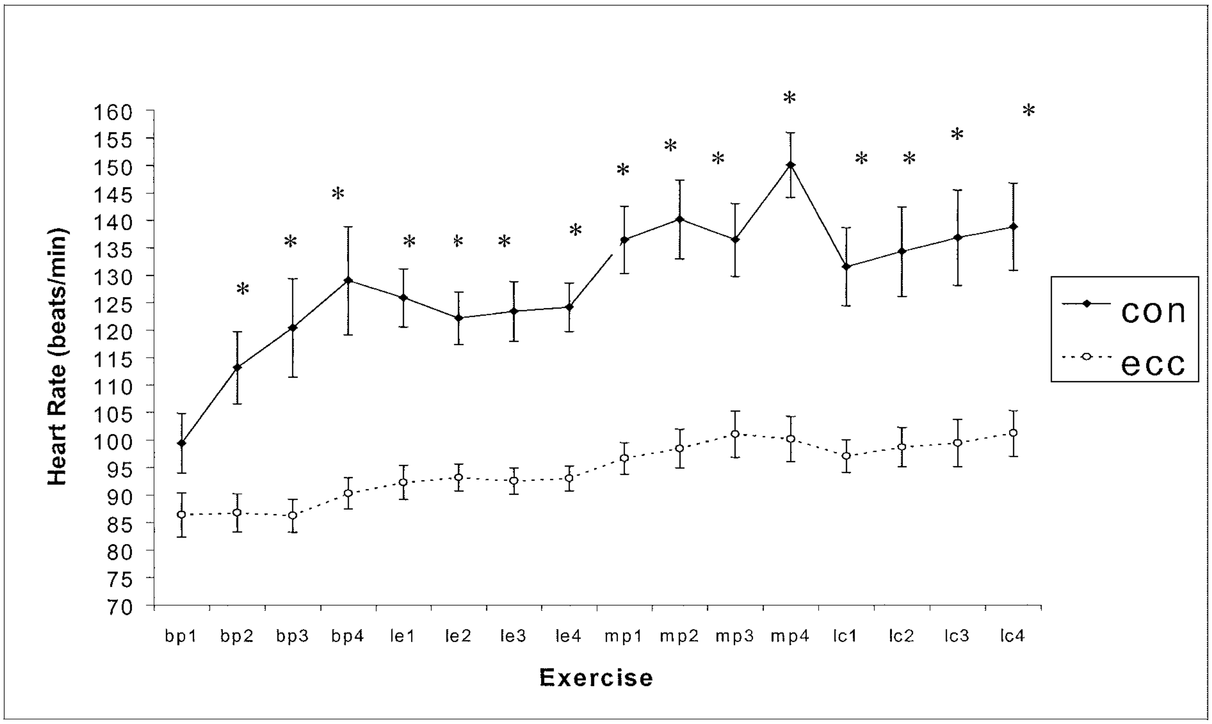

FIGURE 3—Data represent mean ± SE heart rate values for the concentric (CON) and eccentric (ECC) trials. * Represents a significantly different ($P < 0.05$) value compared with the same time point in the ECC trial. For sets 1–4: bp, bench press; le, leg extension; mp, military press; lc, leg curl.

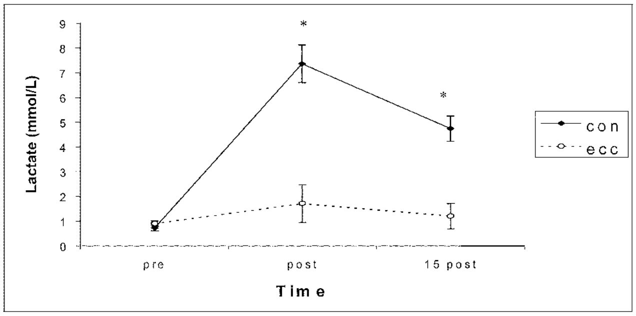

FIGURE 4—Data represent mean ± SE lactate values for the concentric (CON) and eccentric (ECC) trials. * Represents a significantly different ($P < 0.05$) value compared with the same time point in the ECC trial.

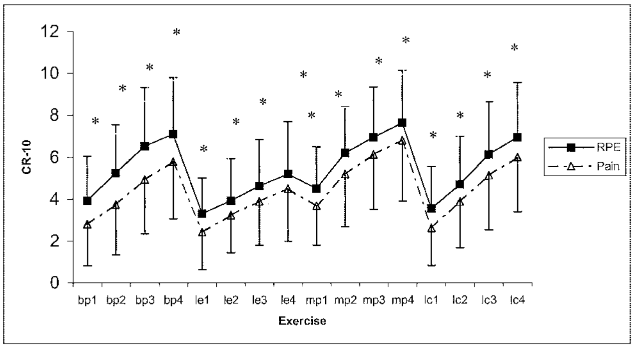

FIGURE 6—Data represent mean ± SD between RPE and pain on the CR-10 scale. * All correlations were significant at the $P < 0.01$.

immediately postexercise. Examination of *post hoc* power estimates indicated that cortisol primarily varied as a function of time (eta-squared = 0.64, observed power = 1.00). Comparatively, the interaction and trial factors had lower eta-squared values (0.25 and 0.09, respectively), and the ability to detect significant differences was reduced (0.66 and 0.20).

Comparison of RPE and pain perceptions. Data indicated that RPE and pain perceptions followed similar patterns over each trial (Fig. 6). However, RPE scores were slightly higher than pain during exercise. Correlations between RPE and pain were computed for each set. Relationships observed ranged from 0.71 to 0.86, all significant at $P < 0.001$.

Relationships between physiological variables and subjective perceptions. To assess the relationship between physiological variables and subjective perceptions, correlations were computed between the final ratings of pain and RPE and immediate postexercise HR, lactate, and cortisol. High positive correlations were demonstrated between the last rating of RPE and immediate postexercise lactate ($r = 0.73$, $P < 0.001$), cortisol ($r = 0.51$, $P < 0.05$), and heart rate ($r = 0.76$, $P < 0.001$). Relationships between the last pain rating and immediate postexercise lactate ($r = 0.61$, $P = 0.012$), cortisol ($r = 0.56$, $P < 0.05$), and heart rate ($r = 0.76$, $P < 0.001$) were also strong and positive.

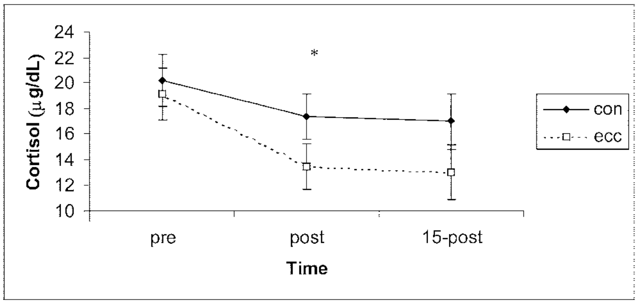

FIGURE 5—Data represent mean ± SE cortisol values for the concentric (CON) and eccentric (ECC) trials. * Represents a significant time different ($P < 0.05$) from the previous time point.

DISCUSSION

We hypothesized that CON muscle contractions would produce higher RPE, pain ratings, heart rate, lactate, and cortisol concentrations at the same absolute workload than ECC muscle contractions. Moreover, we hypothesized that RPE and pain ratings would be related for each muscle action. These hypotheses were tenable. Our data revealed that at a constant load, RPE and pain: 1) were higher in response to CON than ECC contractions, 2) provided constant perceptual markers of resistance exercise stress, and 3) were significantly related. Additionally, heart rate, lactate, and cortisol concentrations were higher in the CON trial than the ECC trial corroborating greater physiological stress occurred in the CON trial. Data indicated that RPE and pain were associated with the same physiological cues assessed in the present study. To our knowledge, this is the first study to document either RPE or pain responses to both types of muscle actions during resistance exercise. Moreover, this is the first study to examine RPE and pain perception from CON and ECC muscle actions separately at a constant load. Although this study had a relatively small sample size, dependent measures were taken several times in the repeated measures design, which resulted in increasing power. *Post hoc* power analyses indicated that when eta-squared values were greater than 0.40, power was > 0.90.

The heart rate data in the present study showed a clear cumulative effect of resistance exercise during CON muscle actions. For instance, HR rose 41% from baseline in the CON trial versus only 17% in the ECC trial. Thus, HR data demonstrated a greater cardiac demand during CON actions compared with ECC muscle actions at the same absolute workload. The increases in cardiac demand during CON muscle actions could be related to the higher percentage of absolute maximal force employed for the CON trial as compared with the ECC trial (2). With regard to lactate, it was also clear that CON muscle actions produced higher levels than ECC muscle actions. Higher lactate concentrations would be expected from greater recruitment of fast-twitch muscle fibers and greater glycogenolytic activity. Our findings support previous research suggesting lactate concentrations are also related to RPE and pain (5) and that higher rating of these perceptual markers are induced, in part, by lactate (23). Thus, present data support that differences in lactate levels induced by CON and ECC muscle actions were associated with differences in perceptions of effort sense and pain.

Decreased cortisol levels in the present study reflect normal morning decline consistent in pattern and magnitude with previous research (18). A lesser decrease in cortisol was evidenced for the CON as compared with the ECC muscle actions during our study. The attenuated cortisol decline during the CON trial compared with the ECC trial was probably due to greater effort and/or pain that could stimulate the HPA axis. This supposition seems tenable as researchers have proposed a link between pain, fatigue, and heighten HPA-axis stimulation (1,5).

In the present investigation, overall body RPE and pain were assessed using a category-ratio technique. Results showed similar patterns of response between these perceptual constructs but revealed a trend of greater absolute values of RPE than pain. These results are similar to previously reported RPE and pain responses to cycle ergometry (6).

The present study did not provide specific cues for pain ratings such as stinging, throbbing, or burning sensations. Gearhart and Robertson have recommended specific scaling of RPE for resistance exercise and have noted that this type of scaling can benefit the coach/trainer in monitoring athlete perceptions and enable the exerciser/athlete to become aware of the effects of perception on power output (3,11,22,28). Additionally, it is quite possible for pain to occur without effort sense changing. Studies could explore secondary measures beyond self-report such as EEG/EMG data to more objectively validate how changes in RPE and pain impact local versus peripheral physiological adjustments. Specific scale development for pain and resistance exercise would be illuminating if time of sampling (preexercise, during exercise, and postexercise) and type of specific sensation (throbbing, stinging, pressure, burning/tearing, and delayed onset muscle soreness) could be clearly delineated. This type of pain scale would also aid the strength coach or personal trainer to determine the emotional responses and inhibited efforts that can occur during fatiguing resistance exercise.

In summary, CON exercise elicited a greater perceptual (RPE and pain rating), cardiac, lactate, and cortisol response than ECC exercise at the same absolute workload. Implications are that relative to absolute load, CON contractions are more challenging, both perceptually and physiologically, than ECC contractions in a common resistance exercise protocol. Both RPE and pain provide perceptual markers of resistance exercise stress and are related to the same physiological cues, heart rate, lactate, and cortisol. Future studies should examine perceptual responses to CON and ECC muscle actions employing higher and lower absolute loads to determine whether alterations in loading affect the findings from the present study. Moreover, studies are needed to determine whether the use of higher relative loading would result in greater RPE and pain perceptions for ECC muscle actions than CON muscle actions (2).

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