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Perception of Effort During Resistance Exercise

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Reference Data

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ABSTRACT

This study used ratings of perceived exertion for the overall body (RPE-O) to examine the perception of effort during resistance exercise. Eight men completed 2 trials in a counterbalanced design: a single bout of resistance exercises at 70% 1-RM, and the same exercises at 50% of 1-RM. Blood lactate concentrations [bLa] were measured before each trial, immediately after each exercise, and at 30 and 60 min post for each trial. Heart rate and systolic BP were also recorded at these same time periods. RPE-O were obtained immediately after each exercise using the Borg 10-point category-ratio scale. Significant elevations in [bLa], HR, and SBP occurred in response to both bouts of exercise. The increase in exercise intensity from 50 to 70% of 1-RM corresponded with a significant increase in [bLa] and RPE-O, but not HR or SBP. It appears that the perception of effort increases along with increases in % 1-RM lifted. Accumulation of [bLa] may mediate this. These findings support the use of the Borg scale for monitoring resistance exercise intensity.

Key Words: category-ratio scale, one-repetition maximum, blood lactate concentration

Introduction

There has been considerable research on exertional perception during exercise, and the findings are reviewed elsewhere (5, 16, 22). Early studies related subjective perceptions to isometric work or force production (6, 7, 8, 25). Later, Borg (2) devised a rating of perceived exertion (RPE) scale to probe the perception of effort during aerobic exercise employing a large muscle mass. The Borg 15-point category-ratio scale was designed so that perceptual ratings increased linearly with exercise intensity. Therefore most physiological variables that express a linear relation with exercise intensity, for example heart rate, parallel perceptions of effort obtained with this scale. Significant correlations noted between RPE and heart rate have ranged from 0.42 to 0.94 (22). Given this relationship, the Borg 15-point category-ratio scale is widely used in laboratory, occupational, and clinical settings to provide information on the physical stress of dynamic exercise.

The Borg 10-point category-ratio (CR-10) scale of perceived exertion was later developed to identify fatigue associated with nonlinear physiological responses (1). Its numbers range from 0 to 10 and correspond with verbal descriptions ranging from "nothing at all" to "very, very strong." Ratings beyond 10 can be given and decimals can be expressed. Blood and muscle lactate, but not heart rate, were found to be highly correlated with exertional perceptions obtained with the CR-10 scale during cycling to exhaustion (18). Kraemer et al. (13) used the CR-10 scale to monitor perceptual responses during high-intensity resistance exercise (7-repetition max) that involved the sequential performance of 10 exercises. Ratings of perceived exertion obtained from trained bodybuilders and power lifters significantly increased during the exercise session. The increase in the perception of effort corresponded with an accumulation of lactate in the blood ($r = 0.84$, $p < 0.05$).

Heart rate, blood pressure, and blood lactate concentration [bLa] are directly related to % of 1-RM lifted (15, 23). Thus it is not unreasonable to assume that increases in % of 1-RM lifted would be perceived as requiring greater effort (i.e., higher RPE). The monitoring of RPE during resistance exercise would provide information on exercise intensity.

Therefore this study examined the effect on RPE of lifting different percentages of 1-RM. It was hypothesized that effort during resistance exercise would be perceived as being greater at 70% than at 50% of 1-RM. This hypothesis was addressed in men, 20 to 24 years of age, who weight trained, but only for recreational purposes. This group was chosen in order to de-emphasize the need to be an experienced weight lifter to use the RPE method of monitoring the physical stress of resistance exercise.

Methods

Subjects

The physical characteristic (mean ± *SE*) of the 8 men in this study were as follows: age, 22.4 ± 0.8 yrs; weight, 83.1 ± 1.4 kg; height, 181.1 ± 2.2 cm; body fat, 14.5 ±

1.9%. All subjects were familiar with weight lifting procedures and were currently weight training on a recreational basis. Their weight training regimens averaged 1–2 exercises per muscle group, 3–4 sets of 8–12 reps per set. They trained 2 or 3 days a week, primarily with chest, back, shoulder, arm, and leg exercises. The men completed a health history questionnaire and obtained medical clearance to participate in the study. The risks and benefits of the experiment were explained to each subject, and each signed informed consent to participate. All experimental procedures were approved by the university's review board for human subject experimentation.

Experiment

Subjects completed 2 trials, 7 days apart, using a counterbalanced design. Both trials involved a single training session of resistance exercise—at 70% of 1-RM for Trial A and at 50% of 1-RM for Trial B. During the experimental period, subjects continued training but did not increase the volume or intensity. All experimental tests were conducted from 8:00 to 11:00 a.m. Subjects were instructed to abstain from exercise training during the 24 hrs prior to the screening assessment and experimental trials. An overnight 8-hr fast preceded each experimental trial.

Assessment Session. One week before the experimental trials, all subjects were instructed on proper weight lifting technique and the use of the CR-10 scale. Their 1-RM was determined for 7 exercises according to the method of Lombardi (14) and used to calculate a 50 and 70% resistance for each exercise (Table 1). This method requires the subject to perform as many repetitions as possible with a weight approximating his or her self-estimated 1-RM. The procedure required only one attempt to determine the 1-RM for an exercise. In every case, fewer than 10 repetitions were completed. The 1-RM was estimated based on the weight used, repetitions performed, and a correction factor. All descriptive data (height, weight, etc.) were also obtained during this session.

Experimental Trial Protocol. Subjects reported to the laboratory at 8:00 a.m. An indwelling catheter was inserted into an antecubital vein and kept patent with an infusion of heparinized saline solution after each blood draw. Prior to the collection of blood for determining [bLa], the line was cleared of all heparinized saline/blood contaminants. At 9 a.m., 30 min after insertion of the catheter, the first blood was drawn and resistance exercise was immediately undertaken. Afterward the subjects returned to the laboratory for the rest of the trail.

Resistance Exercise Protocol. The resistance exercise protocol called for 3 sets at 70% (Trial A) and 50% (Trial B) of 1-RM for each exercise. The subjects were to perform 10 reps each set, but due to fatigue they could not complete 10 reps for all 3 sets at 70% 1-RM. A repetition was deemed successful when the subject performed the exercise through the complete range of motion. Rest periods were 1 min between sets and 3 min between each exercise. Seven exercises involving most major muscle groups were performed, in sequence, from those involving a large muscle mass to those involving a small muscle mass.

Table 1
Values (in kg) During 1-RM Testing

	1-RM		70% load		50% load	
Exercise	*M*	±*SD*	*M*	±*SD*	*M*	±*SD*
Leg press	186.8	9.0	130.9	6.3*	93.4	4.5
Leg extension	77.7	2.5	54.5	1.7*	38.9	1.2
Bench press	113.9	7.0	79.5	4.9*	56.8	3.5
Back pulldown	89.9	4.0	61.4	2.9*	44.8	2.0
Shoulder press	71.4	3.1	50.0	2.2*	35.7	1.6
Biceps curl	43.2	2.3	30.5	1.6*	21.6	1.2
Triceps pushdown	45.7	2.5	31.8	1.7*	22.7	1.3

Note. 70% and 50% loads calculated from 1-RM.
*Greater than 50%, $p < 0.05$

The following approach was used to maximize the efficiency of the exercise session by reducing the overall difficulty of the workout. The exercises were done in this order: leg press, leg extension, bench press, back pulldown, shoulder press, biceps curl, and triceps pushdown. The leg press, leg extension, back pulldown, and triceps pushdown were performed on Universal weight machines; the bench press, shoulder press, and biceps curl were done with free weights.

Measurements

Blood Sampling. Blood samples were drawn from an antecubital vein via an indwelling catheter. Samples were obtained immediately prior to exercise (Time 0), immediately after the third set of each exercise, and again at 30 and 60 min postexercise.

Lactic Acid Concentration. Blood was collected at each sampling point in a 3-ml vacutainer containing potassium oxalate sodium fluoride. The samples were immediately analyzed with a YSI 2700 lactate analyzer. The average of 2 measurements was used for [bLa].

Ratings of Perceived Exertion. Ratings of perceived exertion for the overall body (RPE-O) were obtained immediately after each set of repetitions using the Borg CR-10 scale (1). These ratings were chosen because they can be easily applied in real exercise settings without having to adjust for each exercise. During the assessment session prior to data collection, standard instructions and anchoring procedures were explained (19). Briefly, subjects were asked to use any number (with decimals) on the scale regarding their overall effort. Any number above 10 could also be used. A rating of 0 was to be associated with no effort (rest) and a rating of 10 (very, very strong) was to be associated with the most stressful exercise ever performed. The subjects were also told it was possible to perceive effort that is even more stressful than 10.

Heart Rate and Blood Pressure. Heart rate was recorded with a Polar wrist heart rate monitor immediately before each exercise and immediately after the third set of each exercise. Blood pressure was obtained by ausculation immediately before each exercise and within 30 sec of completion of the third set of each exercise.

Statistical Analysis

Exercise performance variables for both trials were compared via the paired student *t*-test. A two-way repeated measure ANOVA, followed by simple-effects analysis, was used to examine [bLa], RPE-O, HR, and systolic BP responses during the experimental trials. Values in the Results section are expressed as means ± standard error (*SE*). All statistical procedures were conducted using the statistical applications software package (24).

Results

Exercise performance during Trial A (70%) differed from Trial B (50%) with respect to total weight lifted (repetitions × weight), total repetitions completed, and % of total possible repetitions completed. The duration of the exercise session and time spent performing the exercises were the same for both trials (Table 2). No side effects or injuries occurred during the trials.

Trial A and B [bLa], HR, and SBP values recorded after the third set of each exercise were elevated compared to preexercise values, indicating that both exercise protocols elicited a significant physiological response. In both trials, HR and SBP returned to preexercise levels 30 min postexercise, and [bLa] returned to preexercise levels 60 min postexercise.

Peak [bLa] and the highest reported RPE-O occurred after the latissimus pulldown exercise (E4 in Figures 1 and 2). For Trials A and B, respectively, [bLa] was 11.2 ± 0.3 and 6.6 ± 0.4; RPE-O was 9.8 ± 0.4 and 6.0 ± 0.6. The highest HR and SBP values during 50% 1-RM occurred after the leg extension exercise (E2 in Figures 3 and 4) (150 ± 8.1 b · min^{-1} and 145 ± 4.5 mm · Hg^{-1}, for

Table 2
Exercise Session Comparisons

Variables	Trial A (70%) *M*	Trial A (70%) *±SD*	Trial B (50%) *M*	Trial B (50%) *±SD*
1. Total weight lifted (kg) (weight × reps)	11,195	324*	9417	264
2. Total repetitions	182.7	3.4*	210.0	0.0
3. % of total poss. reps completed	87.0	2.3*	100.0	0.0
4. Exercise session length	53:00	1:50	54:30	1:13
5. Time spent doing exercises (min:sec)	21:06	0:40	22:30	0:40

*$p < 0.05$

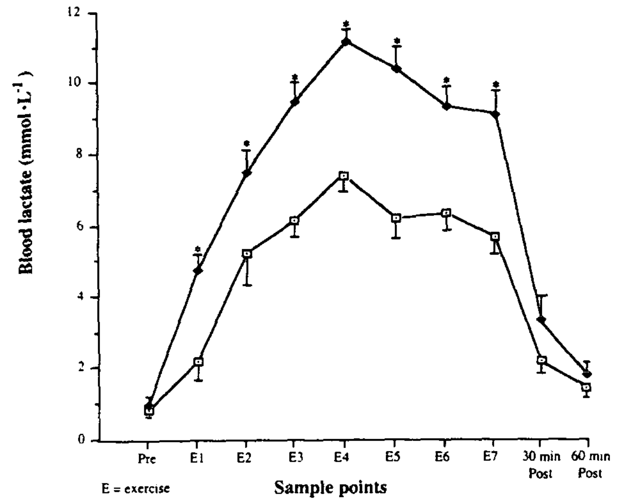

Figure 1. Blood lactate concentrations during resistance exercise at 50% ☐ and 70% ◆ 1-RM (means ± *SE*), *$p < 0.05$.

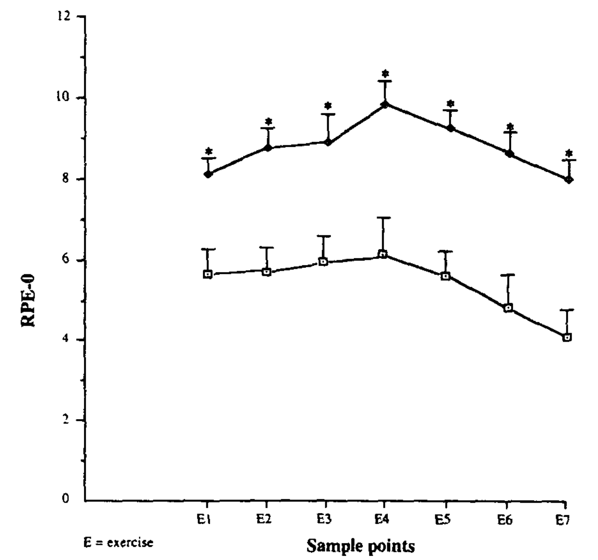

Figure 2. Ratings of perceived exertion during resistance exercise at 50% ☐ and 70% ◆ 1-RM (means ± *SE*), *$p < 0.05$.

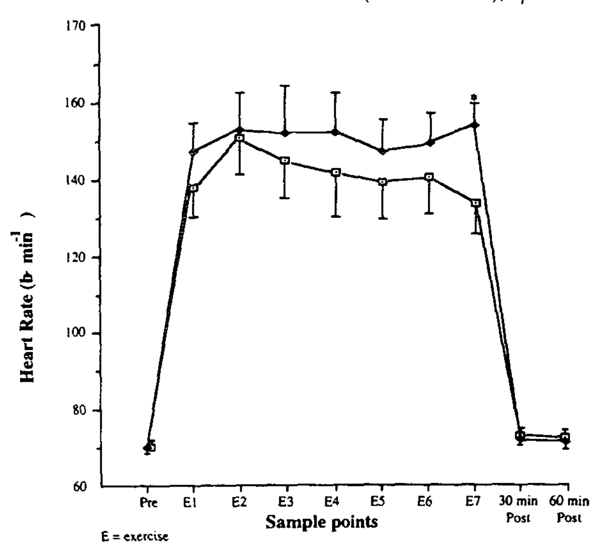

Figure 3. Heart rate responses to resistance exercise at 50% ☐ and 70% ◆ 1-RM (means ± *SE*), *$p < 0.05$.

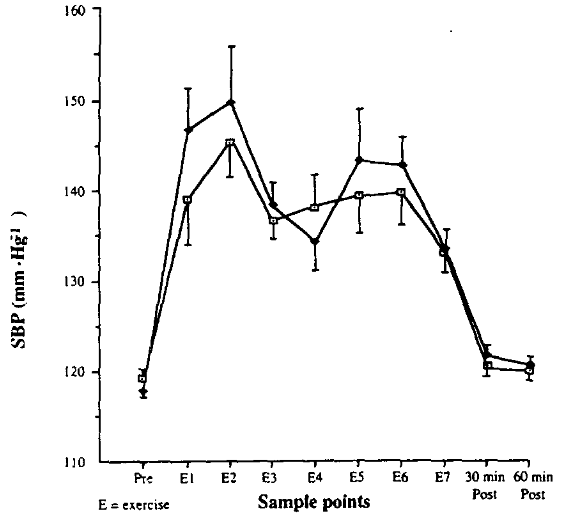

Figure 4. Systolic blood pressure responses to resistance exercise at 50% ☐ and 70% ◆ 1-RM (means ± *SE*), $*p < 0.05$.

HR and SBP, respectively). For the 70% trial, peak HR occurred after the triceps pushdown (E7) (157 ± 4.9 b · min^{-1}) and peak SBP occurred after the leg extension (E2) (149 ± 6.1 mm · Hg^{-1}).

Resistance exercise at 70% 1-RM resulted in higher average exercise session [bLa] (8.7 ± 1.1 vs. 5.5 ± 0.6 mM) and RPE-O (8.8 ± 0.7 vs. 5.5 ± 0.6). Heart rate (150 ± 6.7 vs. 143 ± 7.8 b · min^{-1}) and SBP (141 ± 5.2 vs. 138 ± 4.2 mm · Hg^{-1}) were higher during the 70% trial, but not significantly so. Separating the entire exercise session into its 7 component exercises revealed that [bLa] and RPE-O after the third set of each exercise were higher at 70% than at 50%. HR was also higher after each exercise at 70%, but a significant difference was evident only after the triceps pushdown. No significant differences were noted for SBP after each exercise between both trials.

Discussion

The results demonstrate that (a) an increase in perceptions of exertion during resistance exercise is accompanied by an increase in [bLa], but not HR and SBP; and (b) RPE-O via the Borg CR-10 scale may be useful in monitoring resistance exercise intensity, thus providing information on certain aspects of the resistance exercise protocol such as % 1-RM.

An increase in RPE-O was observed at 70% compared to 50% 1-RM. Blood lactate concentration also increased as % 1-RM lifted increased. The CR-10 scale had been used by Nobel et al. (18) during an anaerobic cycling protocol. They reported RPE-O values that paralleled the curvilinear responses of [bLa]. Kraemer et al. (13) found a significant association between [bLa] and RPE-O during resistance exercise involving 10 exercises performed at one intensity. Our results support their findings in that both higher [bLa] and RPE-O were noted at the higher exercise intensity. However, this study also indicates that perception of effort corresponds to an aspect of the resistance exercise protocol, % 1-RM, that is commonly used for program design. Therefore RPE-O may be a practical way to prescribe and monitor resistance exercise intensity. However, more information is needed to further delineate the relationship between RPE-O, [bLa], and % 1-RM lifted.

Previously proposed explanations for the relationship between [bLa] and RPE-O during exercise may apply to the present findings (3, 4, 20, 26, 27). During and after relatively short periods of resistive work, substantial increases in [bLa] occurred in healthy men (9, 29). In the present study, peak [bLa] were noted after only approximately 12 min of actual exercise (6.6 and 11.2 mM for 50 and 70% 1-RM, respectively).

The concentration of lactate in the muscle has been estimated to be approximately 25–40% greater than [bLa] for a given workload (18, 29). Therefore, during resistance exercise, intramuscular metabolic acidosis may result from profound elevations in muscle lactate concentration. The acidic environment acts as a stimulus to free-nerve endings in the muscle cell, causing discomfort, pain, and fatigue during exercise (20, 26). In addition, concurrent local stimulation of mechanoreceptors, chemoreceptors, and/or ligament receptors may also have contributed to the conscious perception of effort (3, 4, 27).

Therefore muscle lactate, along with intramuscular receptor stimulation, may provide the subconscious information needed for the conscious expression of effort during resistance exercise. Caution is recommended when generalizing this conclusion to resistance exercises utilizing near maximal loads, however, due to the increased energy contribution from creatine phosphate and adenosine triphosphate and to the decreased reliance on glycolysis (10, 29).

Heart rates did not differ between the two exercise intensities used in the present study, and thus do not appear to be related to RPE-O. This finding is consistent with previous research that failed to confirm an association between HR and RPE-O obtained with the CR-10 scale (18). The CR-10 scale was not designed to parallel variables that are linearly related to exercise (e.g., heart rate), but rather, variables such as [bLa] that rise according to a power function with exercise intensity (18). Rozenek et al. (23) found that HR increased as the percent of maximum lifted weight was raised from 50 to 70% 1-RM. Other studies using comparable intensities found similar HR responses (11, 12, 21). In contrast, the present study did not demonstrate a significantly greater HR at 70% 1-RM.

Our use of different muscle groups of varying mass and the sequencing of exercises may have affected skeletal muscle afferent fiber activation and/or muscular contraction to a different extent than other protocols (11, 12, 18, 21). Since such factors are associated with HR responses during resistance exercise (17, 28), we suggest that variables inherent to the exercise protocol (e.g., exercise sequence or muscle group used) affect the HR response. This concept differs from that of [bLa] expression in that [bLa] is related to the intensity of exercise—% 1-RM—and its accumulation is a function of previously performed exercises. Thus it appears that HR responses to resistance exercise do not provide a central signal to the sense of effort. Moreover, the control of HR is not associated with the same peripheral aspects of resistance exercise that influence the perception of effort.

In conclusion, RPE-O was higher when a greater percentage of 1-RM was lifted. The higher RPE-O does not appear to be related to factors associated with HR and SBP control during resistance exercise. However, muscle lactate, as evidenced by [bLa], may act as a mediator between RPE-O and %1-RM lifted. This study supports the use of the CR-10 scale during resistance exercise to monitor exercise intensity.

Practical Application

Ratings of perceived exertion using the Borg CR-10 scale can provide an easy method for monitoring specifics of a resistance exercise protocol, such as % 1-RM lifted. This would help researchers, clinicians, and coaches in designing and monitoring resistance training programs. For example, exercise intensity could be set according to the perception of effort expressed by the trainee during program design. Later, exercise intensity could be adjusted during the course of the training period in accordance with RPE-O. However, changes in 1-RM and the corresponding changes in % 1-RM used during training must also be documented. Researchers should continue to explore the application of perceptions of exertion during resistance exercise in order to realize the benefits already obtained during other modes of exercise.

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