Effects of High Volume Weight Training on Lactate, Heart Rate, and Perceived Exertion

Kyle Pierce¹, Ralph Rozenek², and Michael H. Stone³

¹Department of Health and Physical Education, Louisiana State University, Shreveport, Louisiana 71115; ²Department of Physical Education, California State University–Long Beach, Long Beach, California 90840; ³Department of Health, Leisure, and Exercise Science, Appalachian State University, Boone, North Carolina 28608.

Reference Data

ABSTRACT
This study investigated the response of lactate [La], heart rate (HR), and rating of perceived exertion (RPE) to acute resistance exercise following a high volume weight training program. Twenty-three untrained male subjects were divided into experimental (GE, n = 15) and control groups (C, n = 8). A pretest (Pre) was performed consisting of full squats for 1 set of 10 repetitions (reps) at 45% of a 1-rep maximum (1-RM), 1 set of 10 reps at 55% 1-RM, and 5 sets of 10 reps at 62.5% 1-RM. Following 8 weeks of training by GE, all subjects were retested (Post) using the original Pre testing protocol. Results showed that peak [La] decreased from 11.9 ± 4.2 mmol·L⁻¹ to 5.1 ± 2.6 mmol·L⁻¹ (p < 0.05) as a result of training. GE displayed a significant (p < 0.05) reduction in heart rate at the end of each set. Significant decreases in RPE during exercise were also observed. These findings suggest that an 8-week high volume weight training program emphasizing large muscle groups can reduce the physiological and perceived stress associated with resistance exercise. The reductions in [La], HR, and RPE following training may enhance an individual's ability to continue work during bouts of acute resistance exercise.

Key Words: weight lifting, exercise, stress

Introduction
Several parameters have been used to estimate the degree of physiological stress imposed by physical exercise; among them are heart rate (HR) and blood lactate [La] responses. It is well established that aerobic training can improve the HR and [La] responses to a given endurance exercise bout (12, 22). However, there is much less information on the effects of chronic weight training on the HR and [La] response to a single weight training session.

Blood lactate concentrations have been observed to increase during bouts of acute resistance exercise (4, 14, 29). Some information suggests that [La] will be lower as a result of weight training exercise at both absolute values (27) and at relative (% 1-RM) intensities (18) in trained weight lifters compared to untrained subjects. Marciniak et al. (16) have observed higher lactate thresholds and improved endurance performance as a result of a 12-week weight training program. Additionally, a decreased postweight training exercise (% 1-RM) lactate concentration as a result of short-term (1 month) training has also been observed (5). Other cross-sectional (6, 15) and short-term longitudinal studies (1, 11), using a variety of test protocols, have not found indications of improvement in cardiovascular or metabolic parameters that would be associated with reduced physiological stress as a result of weight training.

Few longitudinal studies have examined the effect of weight training on exercise HR. Petersen et al. (21) found lower exercise HR during submaximal cycling following a 6-week high velocity circuit training program. By contrast, Hurley and co-workers (11) found no significant differences in exercise HR when subjects performed treadmill exercise requiring 50% VO₂ max following a 16-week high intensity Nautilus strength training program. In a cross-sectional study, Stone et al. (27) found that experienced weight lifters had significantly lower exercise HR than nonlifters when HR was measured during progressive resistance exercise. Based on the results of these studies, it is not clear what effects chronic weight training would have on subsequent responses to resistance exercise.

Differences in training volume (total work), intensity (average mass lifted), relative intensity (% 1-RM), repetitions per set, rest periods between sets, or training state of the subjects may influence the outcome of a weight training program on various physical and physiological parameters including HR and [La] adaptations (8, 25). It has been suggested (8, 25) that weight training programs emphasizing large muscle mass exercises and that are of sufficient training volume and intensity are more likely to reduce physiological stress.
and enhance recovery than low-volume, small muscle-mass programs.

The purpose of this study was to describe the effects of an 8-week weight training program, emphasizing large muscle-mass exercises and a relatively high training volume, on exercise HR, [La] response, and rating of perceived exertion (RPE) during resistance exercise sessions in previously untrained subjects.

Methods

Thirty-one untrained healthy men ranging in age from 18 to 37 years volunteered for the study. Subject consent adhered to American College of Sports Medicine guidelines. No subject had physically trained for at least 3 months prior to the study. Eight subjects dropped out due to nonstudy related factors such as illness. Thus the data analysis was performed on 15 experimental subjects and 8 control subjects. The physical characteristics of the subjects can be found in Table 1. The experimental group (GE) trained twice a day, three times a week. Training consisted of 3 weeks of $3 \times 10$ RM, followed by 3 weeks of $3 \times 5$ RM, followed by 2 weeks of $3 \times 10$ RM. This training protocol was chosen to provide some variation and reduce the monotony of adherence to the same set and repetition protocol. The training protocol emphasized large muscle-mass exercises and a high training volume (Table 2).

The control group (C) did not train during the study but did participate in all tests. Body mass for each group was measured on a calibrated medical scale, with the subjects in shorts and socks. Body composition was assessed using a hydrostatic weighing technique to determine body density (2). Residual lung volumes were measured by a closed-circuit helium dilution technique (19). Relative percent body fat was determined using the equation developed by Siri (24).

All subjects were tested for a 1-repetition maximum (1-RM) parallel squat prior to (Pre) training and following (Post) the 8-week training period (26). They were familiarized with the squat several days before the 1-RM test. Three to 5 days following the Pre and Post 1-RM squat measures, subjects performed a test consisting of 7 sets of parallel squats at percentages of the initial 1-RM: $1 \times 10$ at 45% of 1-RM, $1 \times 10$ at 55% of 1-RM, and $5 \times 10$ at 62.5% of 1-RM. The absolute load (repititions x weight) was the same for the Pre and Post test conditions. Subjects rested 2-1/2 min between sets.

Plasma [La] were determined spectrophotometrically using procedures described in the Sigma Technical Bulletin (UV-826). Blood samples of 20 ml were obtained from an antecubital vein four times during each testing period: 10 min prior to the squat test (T1), immediately before exercise (T2), immediately after exercise (T3), and 20 min following exercise (T4). All blood samples were collected in heparinized vacutainers and immediately centrifuged for 10 min in a refrigerated centrifuge. Plasma was separated and stored at $-20^\circ$C until analysis. The mean recovery of lactate in spiked plasma samples was 102%. Intra-assay and inter-assay CVs were 4.0% and 3.0%, respectively.

Heart rate (HR) was monitored at rest (R) and immediately at the end of each set (S1, S2, S3, S4, S5, S6, S7) with a Quinton Instruments ECG (Model 621) using a CM5 lead system. The Borg scale (3) was used to estimate the rating of perceived exertion (RPE) following each set of the squat test.

Statistical analysis of [La] was performed using a $2 \times 2 \times 4$ (Group x Test x Trial) ANOVA with repeated measures on the last two factors. Heart rate was tested with a $2 \times 2 \times 8$ (Group x Test x Trial) ANOVA and RPE through a $2 \times 2 \times 7$ (Group x Test x Trial) ANOVA. Both analyses were made using repeated measures on the last two factors. Differences between groups were

### Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>79.3 ±8.1</td>
<td>80.4 ±8.2</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>17.2 ±5.4</td>
<td>16.5 ±4.5</td>
</tr>
<tr>
<td>Fat-free mass (kg)</td>
<td>65.3 ±4.5</td>
<td>66.4 ±4.3</td>
</tr>
<tr>
<td>1-RM squat (kg)</td>
<td>99 ±16</td>
<td>122 ±18*</td>
</tr>
</tbody>
</table>

*Indicates significant difference, $p < 0.05$.

### Table 2

**Weekly Weight Training Protocol for the Experimental Group (GE)**

<table>
<thead>
<tr>
<th>Session</th>
<th>Monday &amp; Friday</th>
<th>Wednesday</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power snatch</td>
<td>Power snatch</td>
</tr>
<tr>
<td></td>
<td>Squats*</td>
<td>Clean pull*</td>
</tr>
<tr>
<td></td>
<td>Quarter squats*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shrugs</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Power snatch</td>
<td>Power snatch</td>
</tr>
<tr>
<td></td>
<td>Squats*</td>
<td>Midthigh clean pull*</td>
</tr>
<tr>
<td></td>
<td>Leg curl</td>
<td>Stiff-leg deadlift</td>
</tr>
<tr>
<td></td>
<td>Bench press*</td>
<td>Dumbbell inclines</td>
</tr>
<tr>
<td></td>
<td>Behind neck press</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lateral raises</td>
<td>Bench press*</td>
</tr>
<tr>
<td></td>
<td>Crunches</td>
<td>Cable rows</td>
</tr>
</tbody>
</table>

Protocol: $3 \times 10$ RM for 3 weeks, followed by $3 \times 5$ RM for 3 weeks, followed by $3 \times RM$ for 2 weeks.

*Major exercises were preceded by light and moderate weight warm-up exercises.
analyzed using the appropriate contrasts. Statistical significance was set at $p < 0.05$.

**Results**

The 8-week weight training program produced a significant increase in 1-RM squat strength in the experimental group. Pre 1-RM squat values were 99 ± 16 kg (mean ± SD) with an increase to 122 ± 18 kg Post. No significant change was noted in the control group (89 ± 15 kg Pre vs. 94 ± 22 kg Post).

Significant ($p < 0.05$) main effects for test and trial were observed for [La]. Acute resistance exercise resulted in significant increases in [La] at Pre and Post for both GE and C (Figure 1). A significant ($p < 0.05$) Group × Test interaction was also observed. Peak [La] at T3 dropped significantly from 11.9 ± 4.2 mmol · L⁻¹ to 5.1 ± 2.6 mmol · L⁻¹ from Pre to Post in GE. No significant difference was found for peak [LA] in C following training. Lactate concentrations decreased significantly from immediately after T3 to T4 in both groups. Pre vs. Post training [La] at T4 was significantly different for GE but not for C. Plasma [La] was still significantly elevated above T1 values at T4 for C but not for GE.

Significant ($p < 0.05$) Group × Test interactions were observed for HR and RPE. No significant differences were observed in resting heart rate between GE and C before or after training. However, heart rate response to acute resistance exercise was significantly lower following training in the experimental group (Figure 2). The difference in heart rate response was evident following S1 and lasted throughout the remaining sets. Peak HRs were 185 ± 10 beats · min⁻¹ during Pre and 161 ± 11 beats · min⁻¹ during Post.

![Figure 1. Plasma lactate response (mmol · L⁻¹) to resistance exercise in experimental (GE) and control (C) groups following Pre and Post testing sessions. Asterisk (*) indicates significant ($p < 0.05$) differences from Pre to Post in GE. Values are expressed as the mean ± SD.](image)

![Figure 2. Heart rate response (beats · min⁻¹) to resistance exercise in experimental (GE) and control (C) groups following Pre and Post testing sessions. Asterisk (*) indicates significant ($p < 0.05$) differences from Pre to Post in GE. Values are expressed as the mean ± SD.](image)

![Figure 3. The response of rating of perceived exertion (RPE) to resistance exercise in experimental (GE) and control (C) groups following Pre and Post testing sessions. Asterisk (*) indicates significant ($p < 0.05$) differences from Pre to Post in GE. Values are expressed as the mean ± SD.](image)

Ratings of perceived exertion were significantly lower at each set (S1–S7) from Pre to Post in the experimental group (Figure 3). Neither HR or RPE showed any significant changes in the C group.

**Discussion**

Results of the present study demonstrate that an 8-week, high volume weight training program results in beneficial effects on [La], HR, and RPE responses to weight training exercise at an absolute load (Repetitions × Weight). These posttraining responses suggest
reduced stress. Furthermore, the reduced stress may enhance the ability to continue exercise.

Increased endurance as a result of short-term weight training has been noted in tasks such as squatting to exhaustion (17, 27), incremental cycling, and treadmill running to exhaustion (9, 10, 28), and cycling at constant absolute and relative power outputs (9, 16, 17). The potential underlying mechanisms responsible for increased endurance have been discussed in detail previously (9, 13, 16, 17, 30). Briefly, these mechanisms could include (a) increased stores of energy substrates such as glycogen, (b) alterations in enzyme activities, (c) increased buffering capacity, (d) rightward shift in the lactate threshold, (e) changes in motor unit recruitment, resulting in less dependence on type II motor units at submaximal exercise intensities, and (f) increased strength of each motor unit, resulting in a motor unit reserve.

In this study, using absolute loads, the decreased [La] and exercise HR may have resulted from a decrease in the relative posttraining load, which would have allowed fewer motor units to have been recruited during each set, thus creating a motor unit reserve available for continued exercise. Robergs et al. (23) have shown that muscle glycogenolysis is intensity (% of 1-RM) dependent. Because the training may have reduced the relative intensity of the exercise posttraining, the rate of glycogenolysis may be reduced and less lactate produced. Marcinik et al. (16) have recently demonstrated a 12% increase in the lactate threshold which was associated with a 33% improvement in cycling endurance time at 75% peak VO₂. It is therefore possible that in the present study lactate thresholds may have been altered, resulting in lower [La] production at the same absolute load.

Enhanced recovery, based on changes in lactate concentrations as a result of weight training, have previously been shown to be possible. Trained weight lifters have been shown to exhibit a somewhat faster recovery of [La] than untrained subjects after a standard (% 1-RM) exercise session (18). In the present study, posttraining [La] values immediately postexercise and 20-min postexercise values were different only for GE. This would suggest that recovery may be enhanced as a result of weight training.

Practical Applications

Many daily and athletic tasks are characterized by absolute intensities and loads. This study suggests that a high volume weight training program, emphasizing large muscle-mass exercises, can reduce the physiological and perceived stress associated with resistance exercise. The reduction in markers of stress observed in this study and others (see Ref. 25 for review) would suggest that such training programs can enhance exercise endurance during high absolute intensity exercise and perhaps during exercise at relative intensities.

Aerobic training, which is characterized by relatively long duration, low intensity, and low resistance activity, has been used to reduce the physiological and perceived stress associated with various exercise programs including competitive weight lifting (20). However, there is evidence that aerobic training or a combination of strength and aerobic training may compromise strength/power performance (7, 10). The data from this study suggest that high volume weight training using large muscle groups can reduce lactate, HR, and RPE, adaptations typically associated with aerobic training. The benefit of these adaptations is that they may enhance an individual's ability to continue work during bouts of acute resistance exercise or while engaging in manual lifting tasks, and possibly reduce the need for aerobic training in individuals who are specifically involved in strength/power activities.

References


