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The Effect of Intensity on Heart Rate and Blood Lactate Response to Resistance Exercise

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ABSTRACT

The present study compared the effects of two relative intensities on heart rate and blood lactate response to resistance exercise while controlling training variables such as number of sets, number of repetitions, exercise time, and time of recovery. On two occasions 8 male subjects were asked to perform five sets of 10 repetitions (reps) in the bench press at either 50 or 70% of a one-repetition maximum (1-RM). Each set required 20 to 25 seconds to complete. Recovery time between sets was 3 minutes. Mixed factorial analysis of variance revealed an intensity and set dependent effect for heart rate (HR) and blood lactate concentrations (bLA). HR and bLA were significantly higher ($p<0.05$) following the 70% 1-RM trial as compared to the 50% 1-RM trial. Differences between the 50% and 70% 1-RM trials occurred following the first set of exercise. At 50% 1-RM, HR and bLA leveled off following the first two sets. However, at 70% 1-RM, significantly elevated responses were observed with increasing set number. Results from this study suggest that the bench press exercise is capable of producing significant changes in heart rate and blood lactate concentrations. These changes are affected by the exercise intensity as well as the number of sets employed and should be considered when designing a resistance exercise training program.

Key Words: weightlifting, exertion, lactic acid, cardiovascular system

Introduction

Training intensity is a key component in causing gains in maximum strength (4, 21). However, too much emphasis on high intensity resistance training may result in overwork, fatigue, and reduced performance (20). Proper selection and variation of training intensity is an important factor in reducing the potential for overwork and eventual decreased performance (14, 20). Considering the importance of selecting an appropriate exercise and training intensity, surprisingly little is known about physiological alterations as a result of manipulating the intensity of resistance exercise. Furthermore, there is confusion as to the exact physiological responses resulting from a specific resistance exercise during a workout.

Part of the reason for this confusion has been the use of trained versus untrained subjects (2, 13, 15, 22), different set and repetition combinations (1, 7, 10, 24), different exercises (6, 8, 13), different rest periods between sets (13), relative versus absolute intensities (7, 10, 15, 22) and, in some studies, exercise to muscle failure (2, 8, 13, 15, 22, 23). Although increases in intensity (using constant repetitions per set) produce increases in total work accomplished, differences in repetitions can also produce additional work differences that modify physiological responses (5, 7). Exercising to muscle failure may also modify this response (3).

The purpose of this study was to compare the effects of two different relative intensities on heart rate and blood lactate concentrations using the bench press exercise, while controlling for the number of sets and repetitions, exercise time, and duration of the rest intervals.

Methods

Ten healthy males ages 21 to 29 volunteered for the study. All were familiar with the bench press exercise, but none of the subjects were participating in a weight training program at the time of this study. Prior to giving written consent, all subjects were informed of the purpose and possible risks associated with the investigation. The physical characteristics of the subjects are found in Table 1.

Maximal oxygen uptake ($\dot{V}O_2max$) was determined using a motor driven treadmill. Gas exchange was measured using a Beckman MMC metabolic measurement cart that was calibrated prior to each test. The primary criterion for achieving $\dot{V}O_2max$ was a plateauing or decline of $\dot{V}O_2$ with increasing exercise intensity. Secondary criteria included a respiratory exchange ratio of greater

Table 1
Physical Characteristics of Subjects

Subject no.	Age (yrs)	Height (cm)	Weight (kg)	1-RM bench press (kg)	$\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)
1	29	179.9	75.5	73	54.7
2	26	179.9	78.2	96	48.9
3	27	185.4	76.8	68	49.6
4	25	185.4	78.2	95	55.1
5	21	170.2	85.9	97	45.9
6	29	180.3	77.2	84	58.1
7	23	182.9	77.7	65	60.3
8	24	175.3	72.7	121	64.1
Mean	25.5	181.9	77.8	87.4	54.6
SD	2.8	2.5	3.8	18.7	6.2

than 1.15 and attainment of maximum heart rate (HRmax).

Weight training tests were performed 3 days within a week. A 1-RM bench press was used as the maximum strength criteria (21). Two days following the 1-RM tests, the subjects performed an exercise session consisting of either five sets of 10 repetitions at 50% or 70% of the 1-RM. Subjects were unaware of which relative intensity would be used at the first exercise session, and the sessions were counterbalanced (equal number of subjects performed 50% 1-RM or 70% 1-RM). Three days of rest separated the two sessions. Each set required 20 to 25 seconds to complete. Three-minute rest periods were allowed between sets. The number of sets, repetitions, and rest intervals had been suggested as a method of increasing muscular endurance and strength (21). The bench press was selected as the model for this study because it is an upper extremity exercise commonly used in weight training programs.

Heart rate and blood samples were obtained immediately following each set. Heart rate was measured with a Hewlett-Packard (model 1511B) electrocardiograph using a CM_5 lead system. Blood lactate concentrations were determined using a Yellow Springs Lactate Analyzer (Model 23L). Blood was obtained by finger prick with a sterile lancet and collected in heparinized micropipettes. Samples were immediately placed into microcentrifuge tubes containing sodium fluoride; they were mixed and kept on ice until analysis. All samples were measured in duplicate. Intraassay and interassay coefficients of variation were 1.5% and 2.5%, respectively.

Data were analyzed using a two-way analysis of variance (ANOVA) with a mixed factorial design. Main effects were trial and set. Where main effects were observed to be significant, a one-way ANOVA was used to test for differences within trials and between sets. A student Newman Keul follow-up test was used for post-hoc analysis. The level of statistical significance was $p<0.05$ for all tests.

Results

Of the 10 subjects volunteering for the experiment, 8 completed at least three sets at both relative intensities. Four of the subjects completed all five sets at both relative intensities. A significantly higher percentage of HRmax was achieved during the 70% trial when compared to the 50% trial across all sets. Significant increases in %HRmax were observed from rest to the end of Set 1 in both trials (see Figure 1). No additional significant changes were noted in the 50% trial. During the 70% trial, the %HRmax continued to increase significantly throughout the exercise period.

Differences in blood lactate concentrations were evident after the first set of exercises (see Figure 2). The 70% trial produced higher lactate concentrations across each set. In the 50% trial, lactate concentrations increased significantly through Set 2 and then leveled off. In the 70% trial, lactate concentrations did not change significantly until after the first set. Blood lactate concentrations were significantly higher following Set 5 compared to Set 2. Significant trial-by-set interactions occurred for %HRmax and blood lactate concentrations.

Discussion

The intermittent nature of resistance exercise, number of training variables (e.g., number of sets, repetitions, recovery time, relative intensity, type of exercise, and training status), and different combinations of training variables employed in resistance exercise studies has made it difficult to interpret the effects of intensity on associated physiological responses. The present study demonstrates an intensity-and-set dependent effect on heart rate and blood lactate concentrations as a result of the bench press exercise when variables such as exercise time, recovery time, and total number of sets and repetitions are controlled for. It should be emphasized that the measurements made in this study reflect physiological adjustments as a result of resistance exercise and may not reflect what is actually occurring during the exercise itself.

Heart rate response to exercise involves integration of the muscular, cardiovascular, and central nervous systems. Activation of skeletal muscle afferent fibers by stretch, muscular contraction, or metabolites produced from increased cellular activity can result in modifications of the heart rate response (19). Muscular contraction capable of producing occlusion of the blood vessels in exercising muscle can also stimulate a pressor response that

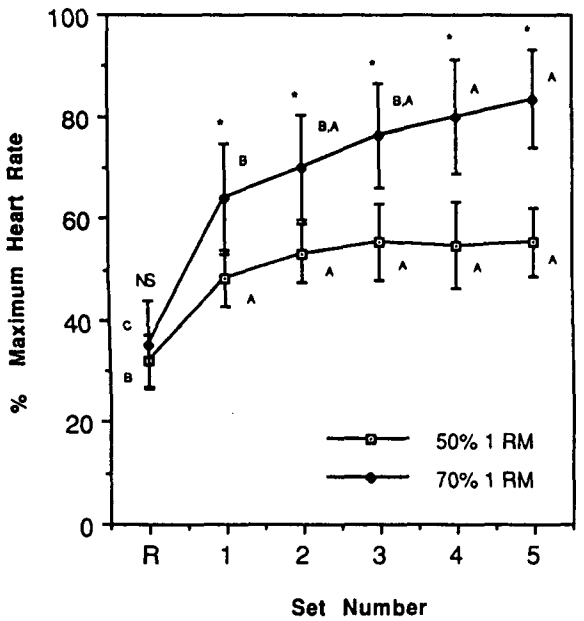

Figure 1. Percent maximum heart rate versus set number. *Indicates significant differences between 50% and 70% 1-RM trials. NS = not significant, $p<0.05$. A, B, C indicate significant differences across sets within a trial.

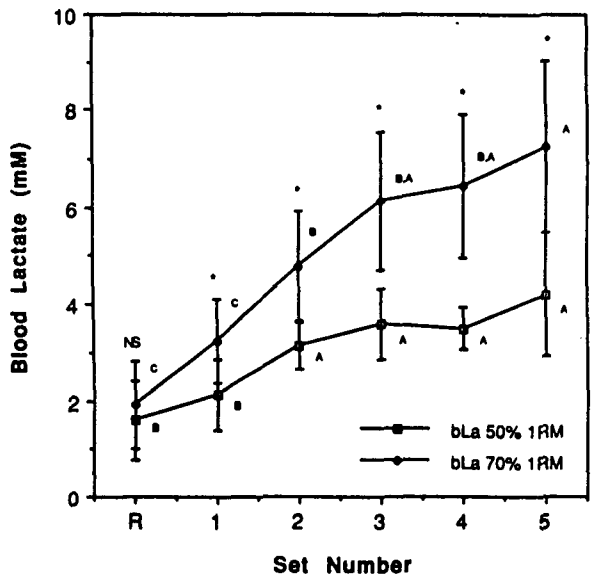

Figure 2. Blood lactate concentrations versus set number. *Indicates significant differences between the 50% and 70% 1-RM trials. NS = not significant, $p<0.05$. A, B, C indicate significant differences across sets within a trial.

can activate the sympathetic nervous system (9, 12) and influence heart rate response. The size of the muscle mass activated, as well as the activation of fast-twitch muscle fibers, may also influence the cardiovascular response to exercise (15, 16, 17).

The interaction of these factors may explain differences in heart rate response observed between the 50% 1-RM and 70% 1-RM trials. At 70% 1-RM, subjects may have required a larger muscle mass, especially as fatigue became evident with increasing set number. This would have resulted in recruitment of a larger number of fast-twitch fibers as compared to the 50% trial. The greater amount of recruitment would cause more skeletal muscle afferents to be activated. This, combined with an increased pressor response and greater metabolite production, may have led to the observed differences between trials.

Initially it was thought that immediate energy stores were the primary fuel source for resistive exercise (10). However, recent studies have demonstrated significant involvement of muscle glycogenolysis (18) and relative high accumulations of blood or serum lactate (7, 14, 22, 23). Lactate concentrations approaching 20 mmol $\cdot$ l^{-1} have been reported following a combination of upper and lower extremity resistance exercise (13). Robergs et al. (18) have observed an intensity-dependent increase in the rate of muscle glycogenolysis and suggested an increased involvement of fast-twitch muscle fibers at higher intensities of resistance exercise.

In the present study, blood lactate concentrations rose early in the exercise period, even at a relatively low intensity (50% 1-RM), but tended to level off with the performance of additional sets. These results suggest that lactate accumulation begins at the onset of resistance exercise. This is in agreement with observations by Tesch and co-workers (23) demonstrating increases in lactate production within the first few repetitions of resistance exercise. At a high relative intensity (70% 1-RM), blood lactate concentrations continued to rise with an increasing number of sets performed. This was most likely due to the greater amount of muscle mass used and increased recruitment of fast-twitch fibers (18).

The peak lactate concentrations at 70% 1-RM were higher than those observed by Hunter et al. (7), who also used the bench press exercise. Although Hunter and co-workers used a 1:1 exercise-to-rest-time ratio, the trained status of the subjects and the fewer number of sets and repetitions used in their protocol may explain the differences observed between the two studies. Under the training conditions of the present study, the exercise : rest time ratio (1:6) may not have been long enough for adequate replenishment of phosphagen stores and may have resulted in greater dependence on glycolytic metabolism for energy production during the bench press exercise.

Practical Applications

One of the primary goals in designing a strength training program is to provide sufficient volume

and intensity without producing undue fatigue. Although the type of exercise protocol employed in this study has been used to stimulate increased strength, muscular endurance, and hypertrophy (21), it may not be appropriate in all situations. Results from this study suggest that the bench press exercise, by itself, is capable of producing significant changes in heart rate and blood lactate concentrations, particularly at an intensity of 70% 1-RM. Heart rate and blood lactate concentrations continue to rise with an increasing number of sets at this higher intensity.

It has been suggested that relative intensities as low as 50 to 60% are sufficient to stimulate strength gains in untrained individuals (21). Based on the results of the present study, this would appear to be reasonable since subjects working at 50% 1-RM did not show signs of undue fatigue. Although higher intensities are capable of producing superior strength gains, they result in more marked physiologic and metabolic responses. These responses should be taken into account when designing resistance training programs using the bench press exercise.

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