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Resistance Training and the Blood Lactate Response to Resistance Exercise in Women

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ABSTRACT

This study examined the effect of resistance training on blood lactate (BL), heart rate (HR), and rating of perceived exertion (RPE) responses to an exhaustive set of squats in 7 college-age women. Baseline testing consisted of a dual set of squats at 70 and 50% of 1-RM performed to exhaustion. Immediate postexercise BL response was elevated 6.5-fold above baseline values while HR exceeded 90% of age-predicted max. After 10 wks of resistance training, the dependent variables were assessed at Post 1 and Post 2 testing sessions. At Post 1, subjects performed a nonexhaustive set of squats using the same workload and number of repetitions completed during baseline testing. At Post 2 they performed an exhaustive set of squats at 70 and 50% of posttraining 1-RM. Immediate postexercise BL was reduced at Post 1 when compared to baseline BL. Post-2 BL was similar to baseline BL and significantly greater than Post-1 BL. Resistance training also lowered the RPE response to resistance exercise at Post 1 ($p \leq 0.01$), but Post-2 RPE did not differ from baseline values. The HR response to resistance exercise was not altered by resistance training.

Key Words: weight lifting, exertion, cardiovascular

Introduction

The metabolic and cardiovascular responses to endurance exercise training have been studied extensively in men (2, 17, 22). However, the responses and adaptations to resistance training are not well known, particularly in women. Following endurance exercise training, the physiological stress associated with a given submaximal exercise bout is reduced. For example, Hurley et al. (9) have demonstrated that the blood lactate (BL) and heart rate (HR) responses to acute aerobic exercise are lower after endurance exercise training. But it is still unknown whether resistance training can improve the BL and HR responses to resistance exercise.

Acute resistance exercise results in considerable BL accumulation. Rozenek et al. (20) reported that 5 sets of 10 repetitions of bench presses at 70% of one repetition maximum (1-RM) resulted in a peak BL value of 7.00 mM. Higher BL levels ranging from 14 to 19 mM have been reported following resistance exercise that incorporated several exercises utilizing a large muscle mass (10, 13, 15, 25). Furthermore, it appears that the BL response to resistance exercise depends on the percentage of 1-RM lifted, number of repetitions performed, and time between sets (12, 13, 20).

A cross-sectional study indicated that resistance trained individuals had a lower BL response to resistance exercise of an absolute workload than sedentary individuals (24). However, Brown et al. (4) reported that resistance trained subjects had higher BL levels following resistance exercise at 80% 1-RM than endurance trained and sedentary subjects. To our knowledge, only one study has investigated the BL response to resistance exercise before and after resistance training. Pierce et al. (18) demonstrated that 8 weeks of resistance training decreased the BL response to resistance exercise performed at an absolute workload. However, the effect of resistance training on the BL response to resistance exercise at relative loads is not known.

There is evidence that high intensity resistance training can elicit a marked HR response (16, 20, 24). A recent review has proposed that the HR response to resistance exercise may be attenuated following high volume resistance training (23). Fleck and Dean (7) found that highly trained bodybuilders had a lower HR response to resistance exercise than experienced weight lifters and untrained controls. Additionally, longitudinal studies have established that resistance training decreases the HR response to lifting an absolute workload (15, 16). To our knowledge, no study has investigated the effect of resistance training on the HR response to resistance exercise at absolute and relative workloads in women.

The purpose of this study was to determine the immediate postexercise BL, HR, and RPE responses to resistance exercise at absolute and relative workloads following a 10-week resistance training program. We

hypothesized that the increase in muscular strength associated with resistance training may result in reduced BL, HR, and RPE responses to resistance exercise at an absolute workload. We also hypothesized that resistance training would not alter the postexercise BL, HR, and RPE responses to resistance exercise performed at relative workloads.

Methods

Subjects

Seven college-age women volunteered for this study (height 161 ± 5.0 cm; weight 55.8 ± 3.1 kg). Prior to participation they gave written informed consent and completed a health history and physical activity questionnaire. The women were normotensive, not on any medication, and free of any orthopedic limitations. None had participated in any resistance training for at least 6 months. The study was approved by the university human subjects review committee.

Experimental Design

Prior to the 10-week resistance training program, the women attended a familiarization session in order to learn proper weight lifting techniques. Afterward they underwent 2 testing sessions on separate days. On the first day of testing, the 1-RM was evaluated on a free-standing Universal Gym squat machine. The machine was adjusted so that each subject's thighs were parallel to the floor at the bottom of the range of motion. The 1-RM was determined by progressively increasing the resistance on subsequent sets until the subject failed to complete one repetition. Subjects were given 3 min between sets to ensure adequate recovery and performed 3 to 5 attempts before the 1-RM was attained.

At least 72 hours after the first day of testing, subjects performed as many repetitions of squats as possible at 70% 1-RM, then immediately performed another set to exhaustion at 50% 1-RM with no rest between sets (Pre). This protocol was designed to produce maximal BL and peak HR responses. During all testing sessions the subjects were instructed to squat to a depth that allowed the thighs to be parallel to the floor. Squatting depth was closely monitored so that all repetitions went through a full range of motion. The test was terminated if a subject failed to go to the prescribed squatting depth.

Resting BL and HR were measured in the seated position 15 min prior to testing. Immediately after the last repetition and again 15 min postexercise, BL was assessed. Immediate postexercise BL was assessed to get a measurement of BL levels during resistance exercise and to coincide with HR and RPE measurements. Blood was collected in a capillary tube following a finger stick by sterile lancet and was immediately analyzed for lactate (YSI Lactate Analyzer, Model 27). A Uniq Heart Watch HR monitor (model 8799) was used to assess HR, and RPE was assessed by the modified Borg scale (3).

Posttraining test procedures were identical to pretraining testing. During the first posttraining testing session, 1-RM was determined according to the previously stated methods. During the second session all subjects performed a nonexhaustive bout of squats using the same resistance and number of repetitions completed during the Pre testing session (Post 1, absolute workload). During a third testing session they performed an exhaustive bout of squats, completing as many repetitions as possible with 70 and 50% of posttraining 1-RM (Post 2, relative workload).

Resistance Training Program

The 10-week resistance training program was performed on free-standing and multistation Universal Gym equipment and consisted of specific resistance exercises in the following order: squat, leg press, leg extension, leg curl, bench press, shoulder press, and lat pulldown. The subjects were required to complete 3 sets of 8–12 reps with 60–90 sec rest between sets, 3 times a week. The resistance was progressively increased by 5.0 kg when 12 reps could be completed. Upon completion of the training program, posttraining data were collected at least 48 hrs after the last exercise session.

Statistical Analysis

A 3 × 3 factorial ANOVA was used to detect significant differences in BL while a 2 × 3 factorial ANOVA was used to detect significant differences in HR values. The LSD post hoc analysis was conducted following a significant F-ratio. The student t-test was employed to detect significant differences in the squat 1-RM and the number of repetitions performed. Level of significance was set at $p \leq 0.05$; data are expressed as mean ± SD. The Systat statistical package was used to analyze all data (Systat, Inc., Evanston, IL).

Results

As shown below, there was a significant increase in the squat 1-RM in response to 10 weeks of resistance training (43%, $p \leq 0.01$). The number of repetitions completed during Pre and Post 2 was not significantly different.

- Squat 1-RM (kg): Pre = 77.0 ± 19; Post = 110.0 ± 20
- Reps at 70% 1-RM: Pre = 33.0 ± 13; Post = 19.0 ± 7
- Reps at 50% 1-RM: Pre = 37.0 ± 3.8; Post = 22.6 ± 11

BL values are shown in Figure 1. The BL response to resistance exercise was reduced when comparing Pre to Post 1 (absolute workload) (5.96 ± 1.3 vs. 8.00 ± 1.1 mmol, $p \leq 0.01$). However, there were no significant differences for postexercise BL between Pre and Post 2 (relative workload) (7.49 ± 1.26 vs. 8.00 ± 1.1 mmol). The 15-min postexercise BL values were significantly lower at Post 1 compared to Pre (4.1 ± 1.8 vs. 6.3 ± 1.0 mmol, $p \leq 0.01$) and Post 2 (4.1 ± 1.8 vs. 5.6 ± 1.3 mmol, $p \leq 0.01$).

HR values are shown in Figure 2. Ten weeks of resistance training did not alter the immediate postex-

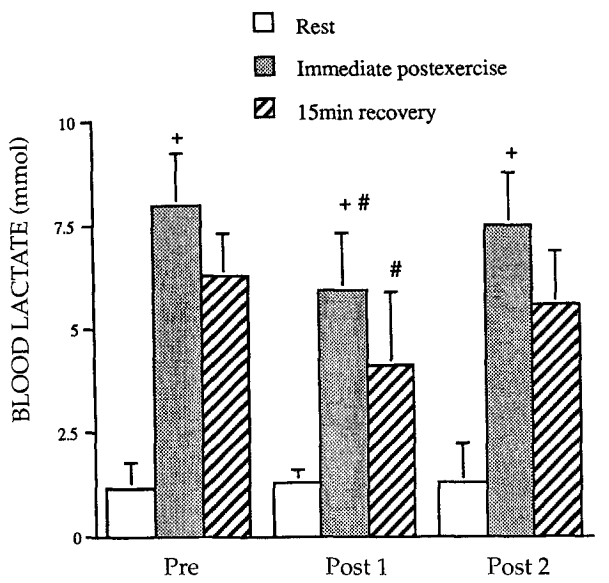

Figure 1. Effect of resistance exercise and training on immediate and 15-min postexercise blood lactate. Post 1 = 70 and 50% pretraining 1-RM; Post 2 = 70 and 50% posttraining 1-RM; + = rest different from immediate postexercise; # = Post 1 different from Pre and Post 2.

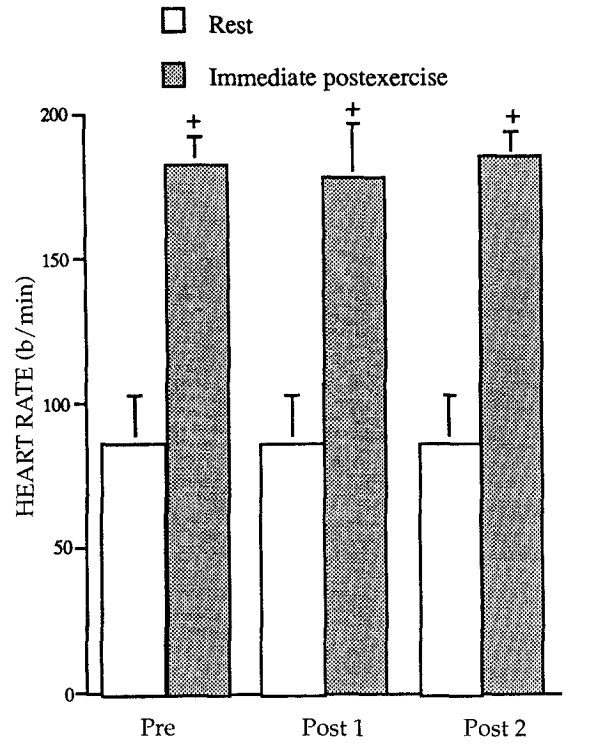

Figure 2. Effect of resistance exercise and training on immediate postexercise heart rate. Post 1 = 70 and 50% pretraining 1-RM; Post 2 = 70 and 50% posttraining 1-RM; + = rest different from immediate postexercise.

ercise HR response at Post 1 when compared to Pre (183.3 ± 9.5 vs. 178.5 ± 18.6 bpm). When the resistance was increased to a relative workload (Post 2), the HR response to exhaustive resistance exercise did not differ significantly from Post 1 (178.5 ± 18.6 vs. 185.1 ± 8.6 bpm). RPE values are shown in Figure 3. Resistance training resulted in lower RPE at Post 1 compared to Pre ($p \leq 0.01$). There were no significant differences for the RPE response when Pre was compared to Post 2.

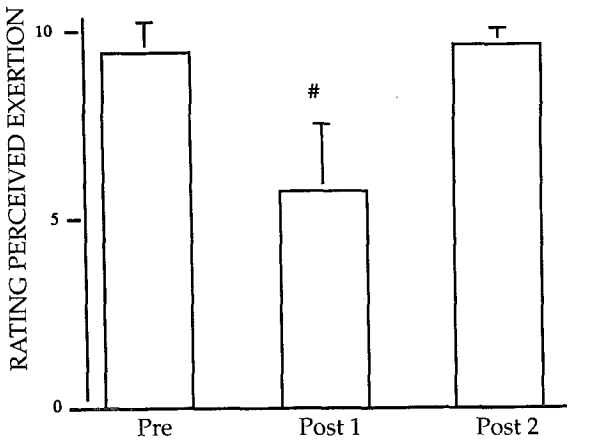

Figure 3. RPE response to resistance exercise before and after resistance training. Post 1 = 70 and 50% pretraining 1-RM; Post 2 = 70 and 50% posttraining 1-RM; # = Post 1 different from Pre and Post 2.

Discussion

The results of this study indicate that in untrained subjects, exhaustive resistance exercise produced a 6.5-fold increase in BL levels and an HR that exceeded 90% of the age-predicted max. Following resistance training, the BL and RPE responses to resistance exercise performed at absolute workloads were reduced; however, the BL and RPE responses to resistance exercise performed at a relative workload were not altered by resistance training. The HR response to resistance exercise was not altered by resistance training.

The reduction in postexercise BL was likely due to a reduced relative workload, since the squat 1-RM increased by 43%. The pretraining workload of 70 and 50% 1-RM corresponded to 49 and 35% 1-RM, respectively, at posttraining. Therefore the women were exercising at a much lower percentage of their 1-RM during the posttraining absolute workload. The physiological consequence of the reduced relative effort was an attenuation of the BL response to resistance exercise performed at the same absolute workload prior to training. Pierce et al. (18) documented that the BL response to resistance exercise at an absolute workload decreased in men following resistance training. Thus it appears that resistance training can improve the performance of tasks involving repetitive lifting of absolute loads by reducing BL accumulation and therefore delaying fatigue. Other studies further support the theory that resistance training can reduce the physiological stress of acute exercise (7, 8, 14, 24).

The present study documented a similar immediate postexercise BL response when the same relative

workload was lifted after training. In other words, following the resistance training program the BL response to resistance exercise at 70 and 50% of posttraining 1-RM did not differ significantly from pretraining BL at 70 and 50% of pretraining 1-RM (Figure 3).

Brown et al. (4) reported a greater BL response to exhaustive resistance exercise in resistance trained subjects when compared to endurance trained and sedentary controls. The higher BL levels in resistance trained subjects may be due to performing more work with a larger muscle mass. Rozenek et al. (20) compared the BL response to the bench press at 50 and 70% 1-RM. The highest BL values were observed following the 70% 1-RM sets. Robergs et al. (19) concluded that the rate of glycogenolysis was twofold greater during leg extension at 70% 1-RM than at 35% 1-RM. As expected, lifting a higher percentage of 1-RM would recruit more type IIb fibers and result in more glycogen breakdown, and thus higher BL concentrations.

Therefore, it is clearly evident that the BL response to resistance exercise is highly dependent on the percentage of 1-RM lifted. Following resistance training, the BL response to resistance exercise at relative loads would be expected to result in similar BL levels since a similar amount of work, relative to maximal capacity (i.e., 1-RM), was performed.

The present study also demonstrated that resistance training reduced the 15-min postexercise BL response to absolute workloads. This is similar to the results of Pierce et al. (18), who found lower 20-min postexercise BL levels following resistance training. The lower recovery BL levels following resistance exercise may well be due to greater BL clearance by the liver and kidneys (5). On the other hand, the reduced recovery BL levels may be a function of less lactate production during exercise (6). In the present study the decrease in BL from immediate postexercise to 15-min postexercise was similar before and after resistance training. Therefore the lower 15-min postexercise BL was most likely due to a lower immediate postexercise BL value. Nevertheless, a lower recovery BL may enhance subsequent exercise performance.

The present findings demonstrate that an exhaustive bout of resistance exercise can produce a heart rate that exceeds 90% of age-predicted HR max. Katch et al. (11) maintained subjects' HR between 170 and 180 bpm during an 8-station resistance training exercise protocol, and Ballor et al. (1) documented an average HR of 163 bpm in response to the squat. McCartney et al. (15) reported a considerably lower HR response of 108 bpm to double leg presses at 80% 1-RM in older men.

The present finding of 183 ± 9 bpm is somewhat higher than former studies and is likely due to the mode of resistance exercise and the fact that our subjects exercised to exhaustion. Furthermore, discrepancies in the magnitude of the HR response to resistance exercise between the present study and McCartney et al. (15) could be explained by the older subjects in McCartney et al.'s study having a lower maximal HR. Furthermore, McCartney et al. (15) and Pierce et al. (18) demonstrated that the HR response to resistance exercise decreased following resistance training.

Cross-sectional studies have also found that highly trained weight lifters have a lower HR response to resistance exercise than untrained controls (7, 24). Contrary to previous results using male subjects, we report no changes in the HR response to resistance exercise following 10 weeks of resistance training in college-age women. It is quite possible that women adapt to exercise training via peripheral muscular adaptations rather than central cardiovascular adaptations (21).

A significant reduction in the RPE response to resistance exercise of a similar absolute workload following 10 weeks of resistance training was documented. Furthermore, a similar RPE response to resistance exercise at a relative workload was also documented. The reduction in RPE to a given absolute workload demonstrates that the 43% strength increase significantly reduced the relative effort when performing a similar amount of work. Our results are supported by Pierce et al.'s (18) findings that resistance training reduced the RPE to resistance exercise. A cross-sectional investigation has demonstrated that highly trained weight lifters had a lower RPE response to resistance exercise than untrained controls (23).

To our knowledge, no other investigations have examined the RPE response to resistance exercise at absolute and relative workloads after resistance training. It is interesting that in the present study the HR and RPE responses to resistance exercise are uncoupled, but the BL and RPE responses remain coupled following resistance training. These results suggest that resistance training in young women induces adaptations in muscle metabolism that are demonstrated by lower postexercise BL levels. This should lessen the sensation of fatigue during activities that require repetitive squatting and therefore allow more work to be completed.

Practical Applications

The present study documented a reduction in immediate postexercise BL, 15-min postexercise BL, and RPE responses to resistance exercise following 10 weeks of resistance training. These results suggest that resistance training can attenuate the physiological and psychological stress of resistance exercise performed at an absolute workload, but not at a relative workload. A resistance training program of moderate intensity can improve lactate metabolism and allow more work to be completed prior to fatigue. A delay in the onset of fatigue can improve resistance exercise performance as well as the performance of athletic skills that require repetitive, explosive movements. Furthermore, the

present findings also indicate that resistance training may have the capacity to enhance endurance exercise performance (8, 14).

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