CREATINE KINASE AND LACTATE DEHYDROGENASE RESPONSES AFTER UPPER-BODY RESISTANCE EXERCISE WITH DIFFERENT REST INTERVALS

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ABSTRACT

Rodrigues, BM, Dantas, E, de Salles, BF, Miranda, H, Koch, AJ, Willardson, JM, and Simão, R. Creatine kinase and lactate dehydrogenase responses after upper-body resistance exercise with different rest intervals. J Strength Cond Res 24(6): 1657–1662, 2010—The purpose of the current study was to compare serum creatine kinase (CK) and lactate dehydrogenase (LDH) concentrations at multiple time points after resistance exercise sessions that incorporated different rest intervals between sets and exercises. Twenty untrained men (18.65 ± 0.49 years, 68.30 ± 7.98 kg, and 174.4 ± 4.80 cm) performed 2 resistance exercise sessions (i.e., 3 sets with 80% 1 repetition maximum for 5 upper-body exercises) with either 1-minute (SEQ1) or 3-minute (SEQ3) rest between sets and exercises. For each session, CK and LDH concentrations were measured before exercise (PRE) and 24, 48, and 72 hours after exercise (24P, 48P, and 72P). Subjects lifted a 24% greater (p < 0.05) volume load during SEQ3 than during SEQ1. Within SEQ1, significant differences in CK concentrations were demonstrated between most time points, except between 24P and 72P. Similarly, within SEQ3, significant differences in CK concentrations were demonstrated between most time points, except between 24P and 72P and between 48P and 72P. The CK concentrations were highest at 48P for both sessions. When the CK concentrations were compared between SEQ1 and SEQ3, no significant differences were demonstrated at any time point. Within SEQ1, a significant difference in LDH concentration was demonstrated between 48P and 72P. Within SEQ3, significant differences in LDH concentrations were demonstrated between PRE and 24P and between PRE and 48P. The LDH concentrations were highest at 72P for SEQ1 and at 24P for SEQ3. When the LDH concentrations were compared between SEQ1 and SEQ3, no significant differences were demonstrated at any time point. These results suggest that muscle damage was similar between rest intervals; however, the volume load completed to induce the muscle damage was significantly greater when 3-minute rest intervals were employed. Therefore, when considered relative to the volume load completed, 1-minute rest intervals during resistance exercise may invoke greater muscle damage.

KEY WORDS recovery time, exercise volume, muscle damage, muscular stress, biochemical markers

INTRODUCTION

According to the American College of Sports Medicine (2), the primary variables incorporated into resistance exercise prescription include the intensity, number of repetitions and sets, rest interval between sets, exercise order, repetition velocity, and weekly frequency. Among such variables, the rest interval between sets can significantly impact exercise performance and subsequent neuromuscular adaptations (4,6,13,17,19–23). Previous studies have demonstrated that resting less than 3 minutes between sets resulted in significant declines in the repetitions performed over consecutive sets (13,17,19–23). Furthermore, Abdesselamed et al. (1) demonstrated that resting less than 3 minutes between sets resulted in an accumulation blood lactate, indicative of incomplete resynthesis of creatine phosphate, and greater reliance on anaerobic glycolysis. Therefore, the rest interval length between sets can determine the primary energy system used and the subsequent mechanism of fatigue.

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Study conducted at the Rio de Janeiro Federal University.
24(6)/1657–1662
Journal of Strength and Conditioning Research
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Highly fatiguing resistance exercise protocols such as those that involve moderate intensity sets performed with full repetition maximums (i.e., voluntary exhaustion) may induce significant microtrauma to muscle fibers. Serum creatine kinase (CK) and lactate dehydrogenase (LDH) concentrations have been used as indicators of muscle damage after resistance exercise and may indicate the status of the muscle cell membranes (7,8,14,15). However, there is little research that has investigated the effect of different rest intervals between sets on these biomarkers.

In the only study to date on this topic, Mayhew et al. (12) compared CK concentrations before exercise and 24 hours after resistance exercise protocols that incorporated 1-minute or 3-minute rest interval between sets. When resting 1 minute between sets, significant increases in CK concentrations were observed 24 hours after exercise. Conversely, when resting 3 minutes between sets, no significant differences were observed between before exercise and 24 hours after exercise. However, a possible limitation of this study was that CK was only measured at one time point after exercise, when recovery processes (and elevations in CK) may extend beyond this time point.

There is a need for additional research to assess CK and LDH concentrations over longer periods after resistance exercise sessions that incorporate different rest intervals between sets. This would lend insight into how the rest interval between sets may influence the time necessary for muscle repair and recovery. Therefore, the purpose of the current study was to compare CK and LDH concentrations at multiple time points after resistance exercise sessions that incorporated different rest intervals between sets and exercises. We hypothesized that different rest interval lengths would invoke differences in the volume load completed, which would in turn invoke differences in CK and LDH responses. Furthermore, we hypothesized that these responses would normalize 72 hours after the resistance exercise sessions.

METHODS

Experimental Approach to the Problem
To compare the effect of resistance exercise with different rest intervals on CK and LDH responses, 2 experimental sessions were performed using a randomized crossover design. Before the intervention, 2 testing sessions (separated by 72 hours) were conducted to determine a 1 repetition maximum (1RM) for 5 upper-body exercises (barbell bench press (BP), machine lat pull-down (LPD), seated machine shoulder press (SP), machine triceps extension (TE), and free weight standing biceps curl) and also to collect anthropometric variables. Seven days after the last testing session, subjects performed the first of 2 experimental resistance exercise sessions (separated by 7 days) that consisted of 3 sets of each exercise with 80% of 1RM and 1-minute (SEQ1) or 3-minute (SEQ3) rest between sets and exercises. The CK and LDH concentrations were measured before exercise (PRE) and 24, 48, and 72 hours after exercise (24P, 48P, and 72P).

Subjects
Twenty untrained men (18.65 ± 0.49 years, 68.30 ± 7.98 kg, and 174.4 ± 4.80 cm) volunteered for the current study. Inclusion criteria consisted of the following: (a) physically active but had not taken part in resistance exercise for at least 6 months before the current study, (b) did not have medical conditions that might be aggravated by participation, and (c) did not use nutritional supplements that may enhance performance (i.e., creatine). All subjects read and signed an informed consent document and were asked not to participate in any resistance exercise other than that prescribed as part of the current study. The experimental procedures were approved by the Ethics Committee of the Rio de Janeiro Federal University.

One-Repetition Maximum Testing
The 1RM tests were performed on 2 nonconsecutive days (separated by 72 hours) from which intraclass coefficients (ICC) were calculated (10). The 1RM was determined in fewer than 5 attempts with a rest interval of 5 minutes between attempts and 10 minutes between assessments for different exercises. The exercise order during testing followed the same order as the subsequent experimental resistance exercise sessions and included BP, LPD, SP, TE, and free weight standing biceps curl with a straight bar (BC).
Experimental Sessions

Seven days after the last testing session, subjects performed the first of 2 experimental resistance exercise sessions (separated by 7 days) that consisted of 3 sets of each exercise with 80% of 1RM and 1-minute (SEQ1) or 3-minute (SEQ3) rest between sets and exercises. Warm-up consisted of 2 sets of 12 repetitions for the first exercise (i.e., BP) at 40% of 1RM; this was followed by a 2-minute rest interval before beginning the assigned protocol (SEQ1 or SEQ3). Subjects were verbally encouraged to perform all sets with full repetition maximums and no pause between the eccentric and concentric phases of each repetition. No attempt was made to control the repetition velocity. The total number of repetitions completed for each exercise was recorded. Resistance exercise sessions for individual subjects were performed at approximately the same time of the day. Evaluation of the rating of perceived exertion (RPE) was done immediately after completion of each exercise using the OMNI-RES scale (9) specifically designed for resistance exercise.

Measurement of Serum Creatine Kinase and Serum Lactate Dehydrogenase

Blood samples were collected into untreated serum collector tubes and allowed to clot for 15 minutes before being centrifuged for 5 minutes at 3,000 rpm. The resulting serum was harvested and frozen for later analysis. Serum CK and LDH concentrations were determined using an optimized UV at 37°C in the BT 3000PLUS (Biotecnica Instruments, Rome, Italy), in which specific reagents were used to analyze the concentrations of each enzyme. All blood samples were collected at multiple time points that included PRE, 24P, 48P, and 72P.

Statistical Analyses

The statistical analysis was initially done using the Shapiro-Wilk normality test and the homoscedasticity test (Bartlett criterion). All variables presented normal distribution and homoscedasticity. Two-way analysis of variance with repeated measures were used to compare differences in CK and LDH concentrations between SEQ1 and SEQ3 at different time points. Significant main effects were followed by LSD post hocs. Independent t-tests were used to compare the volume load (load × sets × repetitions) completed for each exercise between SEQ1 and SEQ3. The Wilcoxon test was used to compare the RPE for each exercise between SEQ1 and SEQ3. An alpha level of 0.05 was used to determine significance for all comparisons. The software Statistica 6.0 (Statsoft; Tulsa, Oklahoma, USA) was used for all statistical comparisons.

RESULTS

The 1RM ICC for each exercise were as follows: BP = .95, LPD = .98, SP = .96, TE = .96, and BC = .94. Differences in CK concentrations for SEQ1 and SEQ3 at different time points are presented in Figure 1. Within SEQ1, significant differences in CK concentrations were demonstrated between most time points, except between 24P and 72P (p = 0.92). Similarly, within SEQ3, significant differences in CK concentrations were demonstrated between most time points, except between 24P and 72P (p = 0.30) and between 48P and 72P (p = 0.17). The CK concentrations were highest

Figure 2. Serum LDH concentrations SEQ1 and SEQ3 at PRE, 24P, 48P, and 72P. §Significant difference 48P vs. 72P SEQ1. #Significant difference vs. PRE SEQ3.

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<th>Table 1. Volume load completed in kg (load × sets × repetitions) for SEQ1 and SEQ3 (mean ± SD).</th>
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<td><strong>Bench press</strong></td>
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at 48P for both sessions. When the CK concentrations were compared between SEQ1 and SEQ3, no significant differences were demonstrated at any time point.

Differences in LDH concentrations for SEQ1 and SEQ3 at different time points are presented in Figure 2. Within SEQ1, a significant difference in LDH concentration was demonstrated between 48P and 72P ($p = 0.04$). Within SEQ3, significant differences in LDH concentrations were demonstrated between PRE and 24P ($p = 0.01$) and between PRE and 48P ($p = 0.04$). The LDH concentrations were highest at 72P for SEQ1 and at 24P for SEQ3. When the LDH concentrations were compared between SEQ1 and SEQ3, no significant differences were demonstrated at any time point.

There were significant differences between SEQ1 and SEQ3 in volume load completed for each exercise, with exception of the SP (Table 1). Overall, subjects lifted a significantly greater load (+24%; $p < 0.05$) during SEQ3 vs. SEQ1. The RPE after each exercise was significantly higher in SEQ1 for SP ($p < 0.01$) and BC ($p < 0.01$) with no significant differences in BP ($p = 0.13$), LPD ($p = 0.08$), and TE ($p = 0.21$). The coefficient of variation data for CK and LDH concentrations at different time points is presented in Table 2.

**DISCUSSION**

Our hypothesis was that different rest interval lengths would invoke different CK and LDH responses and that these responses would normalize 72 hours after the resistance exercise sessions. This hypothesis was rejected in that there were no significant differences in CK and LDH concentrations between SEQ1 and SEQ3 at any time point, despite a significantly greater volume load completed for most exercises during SEQ3. Furthermore, the CK and LDH concentrations were still elevated at 72P for SEQ1 and SEQ3.

One study to date has examined CK concentrations after resistance exercise sessions that incorporated different rest intervals. Mayhew et al. (12) compared CK concentrations PRE and 24P for resistance exercise sessions that incorporated 1-minute or 3-minute rest intervals between sets. When resting 1 minute between sets, significant increases in CK concentrations were observed at 24P. Conversely, when resting 3 minutes between sets, no significant differences were observed between PRE and 24P. The authors concluded that 1-minute rest intervals increased the extent of postexercise muscle damage.

In the study of Mayhew et al. (12), the volume load completed was equalized between rest conditions. Previous studies have indicated that the length of the rest interval between sets can significantly affect the volume load completed over multiple sets performed to voluntary exhaustion (13,17,19–23). However, in the study of Mayhew et al. (12), subjects did not perform full repetition maximum sets, which allowed for the volume load completed to be equalized between rest conditions. Conversely, in the current study, all sets were performed with full repetition maximums for both
rest conditions, which resulted in similar CK concentrations, despite a significantly greater volume load completed for most exercises during SEQ3. Therefore, it appears that the greater volume load completed during SEQ3 was balanced by a higher metabolic demand induced through shorter rest intervals during SEQ1, thus producing similar CK and LDH responses but through different mechanisms.

In the current study, the magnitude of increase in both CK and LDH after both rest conditions was similar to previous studies that examined resistance exercise sessions (5,7,8,16). As others have documented, CK rose substantially (7,12,14,15,24), whereas LDH levels exhibited a less drastic fluctuation (5,7).

Previous studies that have investigated the impact of resistance exercise on markers of muscle damage have employed exercises that stressed the lower-body muscles (7,8,12,16). The current study employed an exercise challenge that stressed the upper-body muscles. Jamurtas et al. (7) compared CK levels after upper-body and lower-body eccentric exercise at the same relative intensity and found that the upper-body exercise produced greater increases in CK at 72P and 96P vs. the lower-body exercise in untrained subjects. Jamurtas et al. hypothesized that untrained subjects might be less accustomed to eccentric work for the upper-body muscles, although because of such daily activities as descending stairs or walking downhill, subjects’ leg muscles were more familiar with eccentric work.

Subjects in the current study were similarly untrained and experienced a rise in CK similar to that reported by Jamurtas et al. (7) up to 48P. However, in the current study, CK levels had started to decrease by 72P (although still elevated above preexercise levels). The relatively shorter elevation in CK in the current study vs. Jamurtas et al. was most likely attributable to the nature of the exercise protocol. Jamurtas et al. employed an exercise bout of eccentric-only muscle actions, whereas subjects in the current study exercised in a more traditional manner, involving both concentric and eccentric muscle actions.

Eccentric muscle actions have been documented to produce greater increases in CK vs. concentric muscle actions at the same intensity (24). These differences in the time course of peak CK and LDH concentrations may indicate that resistance exercise protocols that involve exclusively eccentric muscle actions (7,14,15) have a more sustained effect on muscle damage vs. traditional resistance exercise protocols that involve both concentric and eccentric muscle actions (5,12). The current study was consistent with Ferri et al. (5) in that the CK concentrations were highest at 48P for SEQ1 and SEQ3, whereas the LDH concentrations were highest at 72P for SEQ1 and at 24P for SEQ3.

In the current study, the SEQ1 and SEQ3 had similar effects on muscle damage, but possibly through different mechanisms. For SEQ3, the stimulus may have been a greater volume load completed. Thus subjects’ muscles were subjected to a greater volume of work during SEQ3, leading to physical disruption of myofibrils and subsequent elevations in markers of muscle damage. Conversely, for SEQ1, the stimulus may have been the accumulation of protons and reactive oxygen species, induced through increased acidosis in the exercising muscles. Lactate production during exercise has been linked to free radical damage (11), and resistance exercise with shorter rest intervals has been demonstrated to induce greater lactate levels (1) vs. exercise with longer rest intervals.

Rietjens et al. (18) recently demonstrated significant oxidative damage in response to a single bout of resistance exercise in untrained subjects, using a 2-minute rest interval between sets. In contrast, anaerobically trained subjects displayed minimal evidence of oxidative damage after a single bout of resistance exercise (3). If increased oxidative stress is indeed the primary mechanism behind muscle damage induced by resistance exercise with shorter rest intervals, then this raises a question: how would training status have altered the impact of rest interval length on CK and LDH levels, given an exercise bout of the same relative intensity? Further study is needed to answer this question. The results of the current study indicate that muscle damage, as indicated by CK and LDH concentrations, was similar when resistance exercises were performed to voluntary exhaustion in untrained subjects, despite significant differences in the volume load completed.

**Practical Applications**

The data from the current study may be useful when prescribing resistance exercise programs to allow for sufficient recovery between sessions. If untrained lifters are performing multiple sets of full repetition maximums, greater than 3 days (i.e., 72 hours) between workouts for the same muscle groups might be necessary to allow for sufficient muscle repair, recovery, and ultimately adaptation. Additionally, coaches should be aware that, in novices, performing resistance exercise sets with shorter rest intervals may induce more muscle damage relative to the volume load completed vs. that with longer rest intervals and thus may provide a greater challenge to recovery.

**References**


