INFLUENCE OF UPPER-BODY EXERCISE ORDER ON MUSCLE DAMAGE IN UNTRAINED MEN

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Annotation. *Aim:* The purpose of this study was to examine acute muscle damage after different sequences of an upper-body resistance exercise session. *Methods*: Twelve untrained men completed two sessions (three sets; 80% one repetition maximum; two min passive rest between sets) of the same exercises in opposite sequences (larger to smaller vs. smaller to larger muscle group exercises). For each session, serum creatine kinase (CK) concentrations were measured before exercise (pre) and 24, 48 hours after each sequence (24P, 48P). *Results:* Within sequence (larger to smaller muscle-group exercises), significant differences in CK concentrations were demonstrated between most time points (P<0.05). Similarly, within sequence (smaller to larger muscle-group exercises), significant differences in concentrations were demonstrated between most time points (P<0.05). The CK concentrations were highest at 48P for both sessions. When CK concentrations were compared between sequences, no significant differences were demonstrated at any time point (P>0.05). *Conclusion:* These results suggest that muscle damage was similar between sequences (larger to smaller vs. smaller to larger muscle-group exercises).
Key words: muscle damage, creatine kinase, exercise, order.

Introduction

For a correct training prescription, it is of the utmost importance to understand the interaction among training variables, such as the volume, load, muscle mass involved, rest interval between sets and exercises, frequency of sessions, exercise modality, repetition velocity and, finally, exercise order (Simao et al., 2012). Sports medicine research has indicated that exercise order is an important variable that effects on acute responses to resistance training programs (Simao et al., 2012). Exercise order is an important variable that should receive greater attention in resistance training prescription. When prescribed appropriately with other key prescriptive variables (i.e. load, volume, repetition velocity, failure versus or non-failure sets, rest interval between sets and exercises), the exercise order can influence the efficiency, safety and ultimate effectiveness of an resistance training programmed (Simao et al.,2012). Current guidelines for resistance-exercise program design recommend that large muscle group exercises generally be performed first in a training session This exercise order recommendation has been supported by studies that found greater strength gains (Dias et al. 2010; Simao et al. 2010; Spineti et al. 2010) and hypertrophy (Simao et al. 2010; Spineti et al. 2010) in muscles that were trained at the beginning, rather than at the end, of a session during a long-term training program. Furthermore, studies examining the effect of exercise order (i.e., either large or small muscle group exercises performed first in a training session) on repetition performance demonstrated significantly greater total repetitions (across all sets) for the same exercise when large muscle group exercises were performed first than when they were performed last in a sequence (Bellezza et al. 2009; Farinatti et al. 2009; Gentil et al. 2007; Miranda et al. 2010; Sforzo and Touey 1996; Simao et al. 2005, 2007; Spreuwenberg et al.2006). Thus, performing large muscle group exercises first in a session results in a larger total volume (load × repetitions) completed; however, whether the exercise order effect on volume translates into acute differences in physiological responses, including serum creatine kinase (CK) after a session, has not yet been elucidated. Delayed onset muscle soreness (DOMS) is a sensation of discomfort or pain that occurs in response to unaccustomed exercise, or in response to large increases in the volume of exercise (Saka et al., 2009). It is first felt between 8-24 h after exercise, peaks in intensity between 24 and 72h and usually disappears by 5 days. Serum CK concentrations have been used as an indicator of muscle damage after resistance exercise and may indicate the status of the muscle cell membranes. We speculate that the difference in total number of repetitions and the level of RPE (rating of perceived exertion) at the end of a session could be explained by differences in muscle damage. Resistance exercise protocols are often structured to concentrate on upper- and lower-body muscle groups in separate sessions, and often on separate days; this is particularly true for hypertrophy oriented protocols practiced by bodybuilders, rehabilitation sessions during physical therapy, and for individuals who have only upper-body capabilities (Simao et al., 2013). The previous studies showed that the magnitude of muscle damage was greater following the arm eccentric exercise than that following the leg. Several studies have examined the effect of exercise order (Bellezza et al. 2009; Farinatti et al. 2009; Gentil et al. 2007; Miranda et al. 2010; Sforzo and Touey, 1996; Simao et al. 2005, 2007, 2012, 2013; Spreuwenberg et al. 2006), but none of these investigated influence of upper-body exercise order on muscle damage to an exercise session. Therefore, the purpose of this study was to examine acute muscle damage to an upper-body resistance exercise session performed in opposite sequence.

Methods and material

Twelve untrained men (age, 23.12±3.05 years; weight, 68.33±9.26 kg; height, 173.47±4.35 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 study,(b) did not have medical conditions that might be aggravated by participation, and (c) did not use nutritional supplements that may enhance performance. All subjects read and signed an informed consent document and were asked not to participate in any resistance exercise other than that prescribed as

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part of the current study. Two experimental sessions were performed using a randomized crossover design. Before the intervention, two testing sessions (separated by 72 hours) were conducted to determine 1RM for five upper-body exercises (barbell bench press (BP), seated machine front lat pull-down (LPD), seated machine shoulder press (SP), free weight standing biceps curl(BC) and machine triceps extension (TE) and also to collect anthropometric variables. Seven days after the last testing session, subjects performed the first of two experimental resistance exercise sessions that consisted three sets; 80% 1RM; two min passive rest between sets of the same exercises in opposite sequences (larger to smaller vs. smaller to larger muscle-group exercises). The CK concentrations measured before exercise (pre) and 24, 48 hours after exercise (24P, 48P).

Four testing sessions were conducted (prior to completing the two experimental sessions) to assess 1RM for the following exercises: barbell bench press (BP); seated machine front-lat pull down (LPD); seated machine shoulder press (SP) with straight bar ; standing free weight biceps curl (BC) with a straight bar; and seated machine triceps extension (TE). The 1RM was determined in fewer than five attempts with a rest interval of 5 minutes between attempts and 10 minutes between assessments for different exercises. No exercise was allowed in the 48 h between tests, so as not to confound the test–retest reliability. To standardize the test protocol, the following strategies were adopted (Simao et al. 2007): standardized instructions concerning the testing procedure were given to subjects; verbal encouragement was provided during the testing procedure; and the mass of all weights and bars was determined using a precision scale. One week after, the 1RM test had been determined; subjects performed one of the two exercise sequences in a counterbalanced crossover design. The two sessions consisted of the same exercises, but performed in opposite sequences. Sequence A began with compound (larger muscle group) exercises and progressed toward assistance (smaller muscle group) exercises for BP, LPD, SP, BC, and TE. Conversely, sequence B was performed in the reverse order (i.e., TE, BC, SP, LPD, and BP). Warm-up prior to each exercise sequence consisted of two sets of 20 repetitions for the first exercise of the session (BP for sequence A and TE for sequence B) at 40% of the predetermined 1RM load. Both exercise sequences consisted of three sets of each exercise to failure with 80% of 1RM load with two minute rest intervals between sets and exercises. The second sequence was performed two weeks after performance of the first assigned exercise sequence. During the experimental sessions, subjects were instructed to perform repetitions to the point of voluntary exhaustion. Total volume was calculated (load × repetitions) for each experimental session. 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 specifically designed for resistance exercise. During the study, all subjects were asked to continue with their normal activities of daily living.

Blood samples (5 ml) were drawn from an antecubital vein into 10-ml serum Vacutainer tubes and after approximately 45 min, serum tubes were centrifuged at 3000 rpm (5000 g) for 10 min at room temperature. Serum was separated from blood cells and stored at -20 °C until analyzed. To eliminate interassay variance, all samples for a particular assay thawed once manufactured by Germany Hettich Company and then Serum creatine kinase (CK) activity was determined using a commercially available kit (PARS AZMUN CO. TEHRAN, IRAN). Normal reference range for CK is 24-195 IU/L.

Statistical analyses

Intraclass correlation coefficients (ICCs) were used to determine 1RM test– retest reliability. Data was evaluated using two-way ANOVA with repeated measures to compare differences in CK concentrations between larger to smaller vs. smaller to larger muscle group exercises at multiple time points and the total number of repetitions completed for each exercise and each set individually between larger to smaller vs. smaller to larger muscle-group exercises. with a Least-significant deference (Bonferroni) pairwise comparisons were used to analyze any significant group × time interaction effects. Level of statistical significance was set at $p < 0.05$ in all comparisons. A Data were entered into a personal computer and statistical procedures performed using the SPSS- 16. Statistical analysis compared the blood samples for each sequence against resting. Descriptive statistics were expressed as means (±SD).

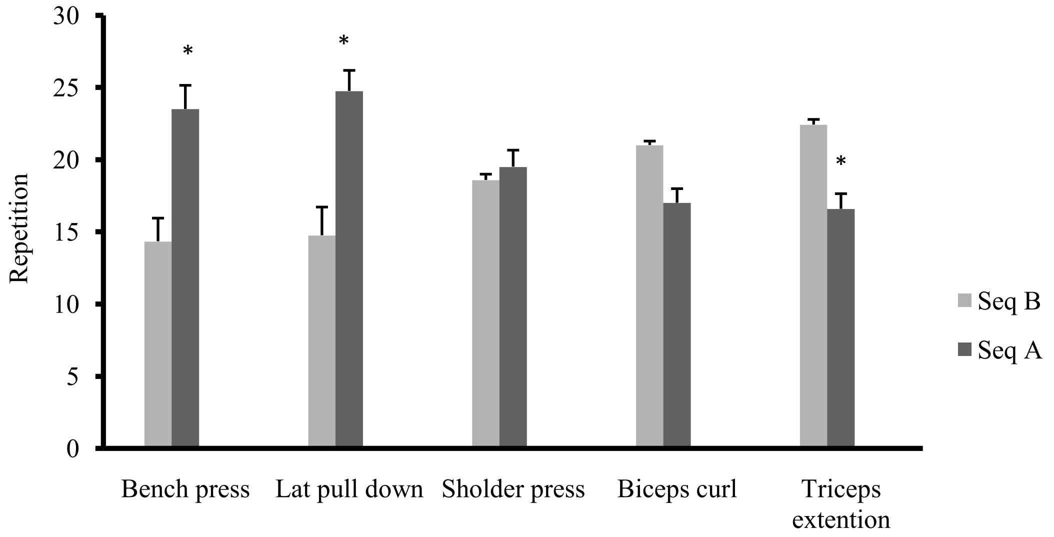
Results

Total exercise repetitions

Figure 1 represents the total number of repetitions for the BP, LPD, SP, BC and TE in Seq A and Seq B. The total number of repetitions for the BP, LPD exercises were significantly greater in Seq A comparing Seq B (P<0.05).

Plasma CK

Differences in CK concentrations for Seq A and Seq B at different time points are presented in Figure 2. Within Seq A, significant differences in CK concentrations were observed between most time points (P<0.05). Similarly, within Seq B, significant differences in CK concentrations were observed between most time points (P<0.05). The CK concentrations were highest at 48P for both sessions. When the CK concentrations were compared between Seq A and Seq B, no significant differences were seen at any time point.



Seq A – sequence A, Seq B – sequence B, BP – bench press, LPD – lat pull-down, SP – shoulder press, BC – biceps curl, TE – triceps extension, * significant difference found when compared to Seq B

Figure 1. Total Exercise Repetitions at 3-sets for Seq A and Seq B

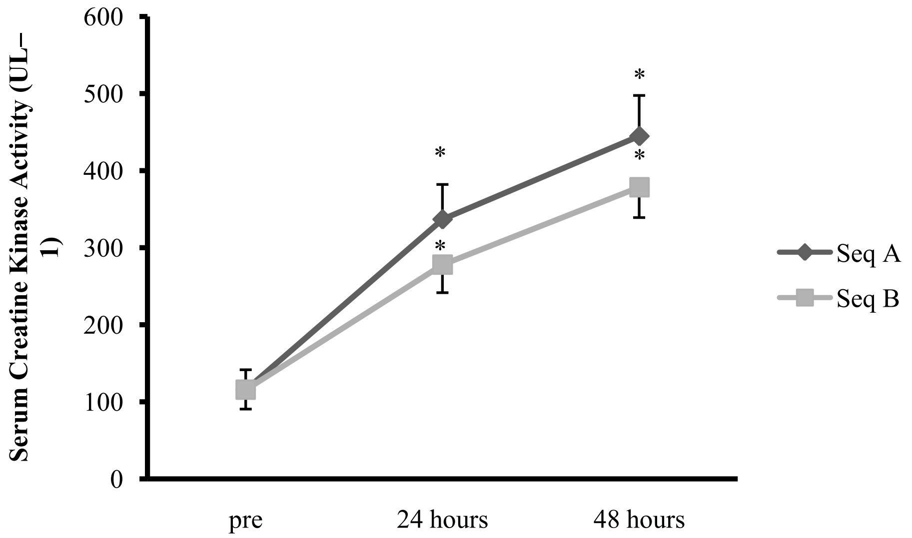


Figure 2. Serum CK concentrations for Seq A and Seq B at pre, 24, 48 hours.
**Significant difference in pre-CK concentration at Seq A and Seq B.*

Rating of perceived exertion

The RPE values were not significantly different between exercise sequences (Seq A and Seq B) (P>0.05). Increases in RPE for BP (Seq A: 8 and Seq B: 9) and TE (Seq A: 9 and Seq B: 8) were observed when they were performed later in the sequences (Tab. 1).

Table 1.

Rating of Perceived Exertion (RPE) per exercise in both exercise sequences (average of 3 sets).

	BP	LPD	SP	BC	TE
Seq A	8	8	8	9	9
Seq B	9	9	7	8	8

Seq A – sequence A, SP – shoulder press, Seq B – sequence B, BC – biceps curl, BP – bench press, TE – triceps extension, LPD – lat pull-down.

Discussion

According to the findings of current study, there were no significant differences in CK concentration between sequences at any time point, despite a significantly greater volume load completed for most exercises during two different orders. Furthermore, the CK concentration was still elevated at 24P and 48P for both sequences. The main finding of this study is that exercise order did not affect the muscle damage to an upper-body resistance exercise session. When the larger muscle group exercises were placed first (i.e., sequence A), rather than last (i.e., sequence B), no significant differences between sequences for muscle damage at multiple time points post training were observed. To our knowledge, this is the first study to examine the effect of exercise order on the muscle damage response to an upper - body resistance exercise session performed in opposing sequences. Similar significant CK elevation at 24 and 48 hours after both trainings demonstrates that muscle damage was occured by both exercise order conditions. These could propose that, in spite of the order of exercises and different number of repetitions for an exercise, both sequences can induce muscle damage. These results are in accordance with previous studies (Lee et al., 2002; Clarkson et al., 2006; Rodrigues et al., 2010) that found elevated blood CK concentration post high intensity resistance exercise. Previous studies that have investigated the effect of resistance exercise on markers of muscle damage have employed exercises that stressed the lower-body muscles (Jamurtas et al., 2005). The current study employed an exercise challenge that stressed the upper-body muscles. (Jamurtas et al., 2005) 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 vs. the lower-body exercise in untrained subjects. They 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 (Rodrigues et al., 2010).

The other hypothesis considered refers to the cognitive perception of exercise effort. In the present study, the RPE was higher for TE in Seq A and for BP in Seq B. These results are in accordance with previous studies (Simao et al., 2012; Simao et al., 2013; Figueiredo et al., 2011). These exercises were executed in distinct moments of the sequences; TE was the last exercise in Seq A, and the BP was the last exercise in Seq B. This suggests that when a single-joint exercise is performed at the end of the session it presents more difficulties than in the middle. With respect to the decreased number of repetitions, the RPE in exercises performed in the middle of each sequence tended to be greater when compared with the same exercises executed earlier in the sequence (Simao et al., 2013). The number of repetitions had also been considered in this study. Bench press (BP) in Seq B had fewer repetitions than in Seq A, probably because in Seq A BP was performed after some rest. With respect to BC in Seq A, when it was executed, three exercises for the same body part had already been done before, and this may have caused fatigue in the upper limbs and evoked a higher RPE. Moreover, in some aspects these results corroborate previous studies (Gentil et al., 2007; Simao et al., 2005; Simao et al., 2007) as the number of repetitions per exercise performed later was fewer than when done earlier in the session.

Repetition performance during resistance exercise sessions conducted with a high-intensity load was significantly different based on exercise order, irrespective of whether the exercise involved large muscle group or small muscle group. Significantly greater repetition performance was noted when exercises were placed first in a sequence and for the first set of a given exercise within a sequence (Simao et al., 2012).

Anecdotally, the recommendation regarding exercise order within resistance training workouts is to perform exercises involving multiple-joint exercises before single-joint exercises (e.g. bench press prior to biceps curl or lat pull-down prior to triceps extension) (Simao et al., 2012).

The reasoning behind this recommendation seems sound when considering that if smaller muscle groups (e.g. triceps brachii, anterior deltoids), considered to be secondary movers, are pre-fatigued via single-joint exercises (e.g. triceps extension, shoulder flexion), then the larger muscle groups (e.g. pectoralis major) might receive a less effective overload during performance of multi-joint exercises (e.g. bench press) due to less capacity to maintain the load and/or repetitions per set. Therefore, it has been recommended for several years that structural exercises, which involve multiple joints, precede accessory exercises, which often involve a single joint (Simao et al., 2012).

Several studies have examined the influence of exercise order on RPE scores following RT sessions with conflicting results. More studies conducted to date did not demonstrate differences in RPE scores between opposing RT sequences, while only one study presented significant increases in RPE scores by older women following an RT sequence that was ordered from small to large muscle group exercises vs large to small muscle group order (Simao et al., 2012). All studies utilized the Borg Cr-10 Scale (Borg Cr-10, Omni-Res scale). A key limitation of the methodology in validating the RPE scales was the performance of exclusively submaximal RM sets; whereas, the aforementioned studies involved performance of full RM sets to voluntary exhaustion. Therefore, it is possible that significant differences in RPE scores occur only when a submaximal number of repetitions are performed at a predetermined percentage of 1RM; this might be the reason for the lack of significant differences in studies examining the influence of exercise order on RPE (Simao et al., 2012).

Conclusion

Our results indicate that the difference in total number of repetitions and the level of RPE at the end of a session cannot be explained by differences in muscle damage. Results also suggest that whenever one exercise is the last of a sequence performed in a training session, its performance will be negatively affected. Applying the results to exercise prescription, a large to small muscle group order might be more beneficial for untrained men, when trying to improve health.

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