Muscle Damage of Resistance-Trained Men After Two Bouts of Eccentric Bench Press Exercise

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Abstract

Meneghel, AJ, Verlenzia, R, Crisp, AH, Aoki, MS, Nosaka, K, da Mota, GR, and Lopes, CR. Muscle damage of resistance-trained men after two bouts of eccentric bench press exercise. J Strength Cond Res 28(10): 2961–2966, 2014 –The present study tested the hypothesis that resistance-trained individuals would also show less muscle damage in the second than in the first eccentric exercise bout (i.e., repeated bout effect) as shown in untrained individuals. This study investigated changes in indirect markers of muscle damage after 2 bouts of free weight eccentric exercise performed by 8 resistance-trained men. The participants (24.4 ± 1.2 years) performed 4 sets of 8 eccentric actions (3 seconds for each repetition) at 70% of eccentric 1 repetition maximum (1RM) load in a bench press exercise with 2 minutes of rest between sets, and repeated the same exercise 2 weeks later. Bench press 1RM, delayed onset muscle soreness (DOMS) assessed by a 6-point Likert scale, serum creatine kinase (CK) activity, and plasma prostaglandin E2 concentration (PGE2) were measured before and 24, 48, 72, and 96 hours after the exercise, and the changes were compared between bouts. The changes in the variables were smaller (p ≤ 0.05) after the second than the first bout indicated by a smaller decline in 1RM strength (first bout: −10.2 ± 1.0% vs. second bout: −5.7 ± 1.5%), peak DOMS (3.8 ± 0.4 vs. 1.7 ± 0.5), peak CK (637.3 ± 133.3 vs. 305.4 ± 63.6 IU·L⁻¹), and peak PGE₂ (761.2 ± 171.0 vs. 307.2 ± 48.3 pg·mL⁻¹). These results show a typical repeated bout effect. Thus, it is concluded that the repeated bout effect occurs in resistance-trained individuals.

Key Words: eccentric exercise, repeated bout effect, 1RM, muscle soreness, creatine kinase, prostaglandin E₂

Introduction

A high-intensity and/or a high-volume resistance exercise can result in muscle damage, especially when an exercise consisting of eccentric muscle actions is performed by individuals who are not accustomed to this kind of exercise (8,24). The magnitude of muscle damage can be estimated by the magnitude of decrease in muscle function, development of delayed onset muscle soreness (DOMS), and increase in skeletal muscle proteins such as creatine kinase (CK) activity in the blood (8). It has been shown that the magnitude of muscle damage is attenuated when the same or similar eccentric exercise is repeated in a certain time interval such as 4 weeks (20), and this adaptation is referred to as the repeated bout effect (16). Although the exact mechanisms underpinning the repeated bout effect are not fully understood, a combination of neural, mechanical, and cellular adaptations is thought to be associated with this phenomenon (18,22).

The majority of the previous studies that investigated muscle damage and the repeated bout effect used untrained subjects (1,4,17,23). Thus, less is known about muscle damage and repeated bout effect in resistance-trained individuals, and controversy exists concerning the repeated bout effect of resistance-trained individuals. For example, some studies reported that resistance-trained men did not show significant attenuation of muscle damage makers (maximal isometric force and CK) after the second bench press eccentric exercise with submaximal intensity (70% of 1 repetition maximum [1RM]) when compared with the same exercise performed 2 weeks earlier (2,9,10), suggesting that the repeated bout effect was absent in these individuals. However, other studies...
showed that individuals who were familiar with resistance training demonstrated significantly smaller changes in CK activity in the blood, DOMS, maximal isometric force, and range of motion after the secondary attempt of high-intensity isokinetic eccentric exercise of the elbow flexors when compared with the initial attempt performed 2 weeks earlier (13,14,26).

One of the factors affecting the repeated bout effect of resistance-trained individuals seems to be exercise intensity because the previous studies using submaximal eccentric exercise did not find the repeated bout effect (2,9,10), but other studies using higher intensities found the repeated bout effect (13,14,26). It should be noted that no previous studies have used a high-intensity free weight exercise to investigate the repeated bout of well-trained individuals.

Therefore, the aim of the present study was to assess changes in some indirect muscle damage markers after the first and second bouts of high-intensity bench press eccentric-only exercise performed by resistance-trained individuals. It was hypothesized that changes in the muscle damage markers would be smaller after the second than the first bout, indicating that the repeated bout effect would be observed in these individuals.

**METHODS**

**Experimental Approach to the Problem**

The main question of the present study was whether the resistance-trained individuals who had more than 2 years of experience in resistance training would show a significant attenuation of muscle damage after the second bout of high-intensity eccentric bench press exercise compared with the first bout. This study compared changes in some indirect markers of muscle damage after 2 bouts of the bench press exercise separated by 2 weeks performed by 8 resistance-trained men. The bench press was chosen because it is a common exercise in resistance training, and previous studies (2,9,10) used bench press exercise and failed to find the repeated bout effect of resistance-trained individuals.

**Subjects**

This study recruited 8 male university students (mean ± standard error of the mean (SD); age: 24.4 ± 1.2 years, body height: 175.2 ± 1.2 cm, body mass: 75.5 ± 2.3 kg, percent body fat: 10.6 ± 1.3%) who had been performing resistance training for at least 2 years (4.5 ± 0.8 years). The participants had been performing eccentric muscle actions in their resistance training routine but had not experienced the eccentric bench press exercise that was used in the present study. The sample size was determined using the data of changes in maximal eccentric strength after high-intensity eccentric bench press exercise from a pilot study, and 8 subjects were shown to be necessary based on effect size of 1, alpha level of 0.05, and a power (1-β) of 0.80 for a possible difference in the strength (10%) at 1 day postexercise between the first and second exercise bouts. None of the participants had previous injuries of the upper limbs, and never used nutritional supplements containing creatine or anabolic steroids. All participants completed a health questionnaire and signed a consent form after being informed the experimental protocol. This study was approved by the Research Ethics Committee of the Methodist University of Piracicaba, Piracicaba, Brazil. The participants were instructed to refrain from any exercises for 7 days before the study (eccentric exercise) to minimize the effect of daily training on the measurements taken in this study. Additionally, the participants were instructed not to take any medications, alcohol, or supplements (e.g., vitamins, amino acids) during the experimental period, and asked to maintain their normal dietary habits.

**Experimental Procedure**

All participants performed 2 bouts of high-intensity eccentric bench press exercise separated by 2 weeks. A week before the first exercise bout, the participants were asked to stop resistance training and any other strenuous physical activities and reported to the laboratory on 4 separate days with a 24-hour interval for the following measures: (a) 1RM test and retest to determine the maximum muscle strength (baseline measures); and (b) 1RM test for eccentric phase only (1RMecc) and retest to determine the eccentric exercise load in bench press exercise. In addition, the pace of eccentric movement (cadence) was familiarized using a metronometer and a bar (10 kg) in the first visit. After 4 days without any type of intense physical activity, the participants performed the first eccentric exercise bout. To indirectly assess muscle damage, the 1RM test was repeated at 30 minutes and 24, 48, 72, and 96 hours after the eccentric exercise. In addition, DOMS, serum CK activity, and plasma prostaglandin E₂ (PGE₂) concentration were assessed 30 minutes before (baseline measures) and 24, 48, 72, and 96 hours after the exercise. Two weeks after the first bout without exercise during this period, the same eccentric exercise and the measurements of 1RM (30 minutes and 24, 48, 72, and 96 hours), DOMS, CK, and PGE₂ (30 minutes before and 24, 48, 72, and 96 hours) were repeated. A period of 2 weeks was chosen to ensure full recovery from the initial eccentric exercise bout based on previous studies (2,10,11). All participants were verbally encouraged to make maximal efforts during the exercise and tests. The tests were performed in the following order: blood sampling, muscle soreness assessment, and 1RM test. The exercise and measurements were performed between 07:00 and 11:00 AM.

**Eccentric Exercise**

The eccentric exercise was a bench press free-weight exercise consisting of 4 sets of 8 eccentric contractions at 70% of IRMecc, with 2 minutes of rest between sets. The movement began with an elbow extended position, and after a start signal, the participants lowered the bar to the chest in 3 seconds, and 2 safety spotters returned the bar to the elbow extended position in 2 seconds. To indicate
the velocity of execution, a metronome was used, and the investigator verbally instructed the movement to each participant. All participants had been regularly performing bench press exercise in their training routines; however, none of them had previously performed the same bench press exercise that was used in the present study. An intensity of 70% of 1RMecc was chosen because the pilot study found that it was the maximal intensity for participants who were similar to those used in the present study to complete 4 sets of 8 repetitions in an appropriate manner. Although it was not maximal eccentric exercise in which forced lengthening of maximally contracting muscles was performed, the load (8 eccentric repetitions maximum: 8RM) to perform the bench press exercise was of high intensity. In the present study, the intensity of 70% 1RMecc corresponded to ~97% of 1RM, and when the barbell was lowered from an elbow-extended position to the chest, the pectoralis major muscles were lengthened under force generation.

Muscle Strength Test—1 Repetition Maximum
The bench press 1RM was assessed according to the protocol by Brow and Weir (3). After warm-up including 2–3 sets of 5–10 repetitions with a 40–60% of estimated 1RM test, a single maximum repetition to failure was performed, in which the load was increased ~10% in the subsequent attempts separated by 3 minutes of rest until the participant was unable to complete an attempt with adequate technique. The test was performed with a maximum of 4 attempts and rest intervals of 3–5 minutes between them.

Muscle Eccentric Strength Test—1RMecc
The bench press 1RMecc test was determined in the following procedures based on Hollander et al. (12). Briefly, each participant performed 2–3 sets of 5–10 repetitions with a 40–60% of 1RM before the test. After 3 minutes of rest, a single maximum eccentric action for 3 seconds (entire range of motion) was performed. The pace of movement was indicated by a metronome. Depending on whether the participant was able to control the movement for 3 seconds, the load was adjusted in the subsequent attempt until the participant was able to complete the attempt in 3 seconds with appropriate technique. An investigator checked the range of eccentric motion and pace of the movement. Two safety spotters were responsible for positioning the bar and ensuring safety of the participants. The test was performed with a maximum number of 4 attempts with a rest interval of 3–5 minutes.

Delayed Onset Muscle Soreness
The level of muscle soreness was assessed using a Likert scale ranging from 0 to 6 (0 = no soreness; 1 = dull feeling of soreness; 2 = light, continuous soreness; 3 = more than light soreness; 4 = annoying soreness; 5 = severe soreness; 6 = intolerable soreness), and it was permitted to report an intermediate value (e.g., 2.5), if necessary (11). The investigator palpated the medial part of the right pectoralis major by applying pressure with the tip of 3 fingers (II, III, and IV) for approximately 3 seconds (27). The participants were instructed to report pain sensation experienced during the palpation. The same investigator assessed the muscle soreness of all participants over days.

Blood Sampling and Analysis
Blood samples (~5 ml) were obtained by a standard venipuncture in 2 vacutainer tubes (Becton Dickinson, Juiz de Fora, Brazil), one containing heparin for plasma separation and the other for serum separation. After allowing to clot at room temperature for 30 minutes, both tubes were centrifuged at 2000 rpm for 20 minutes at 4°C, and the plasma and serum samples were stored at ~70°C for later analyses. Serum CK activity was measured using an automated equipment Konelab 60i (Wiener Lab, Rosario, Argentina) at 37°C using a test kit (Wiener Lab). The normal reference range for serum CK activity using this method is 24–195 IU·L⁻¹. Plasma PGE₂ concentration was measured using a commercially available ELISA kit (Cayman Chemical, Ann Arbor, MI, USA), and the reference range is 0–125 pg·mL⁻¹. Intraassay coefficients of variation (CVs) were 3.9% for CK and 9.1% for PGE₂.

Statistical Analyses
The normality of data was assessed by a Shapiro–Wilk test. A 2-way repeated measures of analysis of variance was used to compare between bouts for changes in the dependent variables (1RM, serum CK activity, and plasma PGE₂ concentration) over time. When a significant interaction effect or time effect was found, a Bonferroni post hoc test was performed for multiple comparisons. Changes in the Likert scale between bouts were compared by a nonparametric Friedman test with a Dunn post hoc test. Paired 𝜋-tests were used to compare the peak values of the dependent variables between bouts, regardless of the time point. The level of significance was set at 𝑝 ≤ 0.05. Cohen’s formula for effect size (ES) was also used for comparison between bouts based on the following criteria: <0.35 trivial effect; 0.35–0.80 small effect; 0.80–1.50 moderate effect; and ≥1.50 large effect (25). Data are presented as mean ± SD.

Results
Baseline Values
No significant differences in the baseline values for any of the dependent variables were evident between bouts (𝑝 > 0.05).

Eccentric Exercise Load
The 1RM and 1RMecc measures showed high test-retest reliability (Intra-class Correlation Coefficient [ICC] = 0.96–0.94, CVs = 3.7–4.8%). The baseline values for 1RM test ranged 80–116 kg amongst the participants with a mean value of 95.7 ± 5.9 kg. Regarding 1RMecc test, the values ranged 106–160 kg amongst the participants with a mean value of 132.2 ± 7.7 kg. The absolute load of 1RMecc was 38% greater than that of 1RM. The load used for the eccentric bench press exercise was the same for both bouts.
(92.6 ± 15.2 kg). All participants were able to complete the exercise (4 sets of 8 repetitions) in both bouts, thus the total volume load lifted (sets × repetitions × load) was the same between bouts (2,962 ± 172 kg).

**One Repetition Maximum Strength**

The maximum decline in 1RM strength showed significant interaction effect \((F = 5.96; \ p < 0.01)\). The post hoc test indicated significant difference \((p \leq 0.05; \ ES = 0.96)\) at 24 hours postexercise between bouts (Figure 1). The paired \(t\)-test also showed that the maximum decline in 1RM strength was greater \((t = 4.93; \ p < 0.002; \ ES = 0.86)\) for the first bout \((-10.2 \pm 1.0\%)\) than the second bout \((-5.7 \pm 1.5\%)\).

**Muscle Soreness**

Delayed onset muscle soreness assessed by the 6-point Likart scale showed significant interaction effect \((p \leq 0.05)\). The post hoc analysis indicated a significant difference \((p < 0.001; \ ES = 1.99)\) at 48 hours postexercise between bouts (Figure 2). The peak muscle soreness was greater \((t = 5.19; \ p < 0.001; \ ES = 1.72)\) after the first bout \((3.8 \pm 0.4)\) than the second bout \((1.7 \pm 0.5)\).

**Serum Creatine Kinase Activity**

Serum CK activity was significantly different between bouts \((F = 3.42; \ p \leq 0.05)\). A significant difference \((p \leq 0.05; \ ES = 0.78)\) between bouts was observed by the post hoc test at 72 hours postexercise (Figure 3). Peak serum CK activity was also greater \((t = 2.57; \ p < 0.037; \ ES = 0.81)\) after the first bout \((637.3 \pm 133.3 \text{ IU·L}^{-1})\) than the second bout \((305.4 \pm 63.6 \text{ IU·L}^{-1})\).

**Plasma PGE\(_2\) Concentration**

Plasma PGE\(_2\) concentration showed no significant interaction effect \((F = 0.45; \ p = 0.71)\). However, a significant time effect \((F = 13.52; \ p = 0.001)\) was observed for the first bout (Figure 4). The paired \(t\)-test revealed that peak plasma PGE\(_2\) concentration was greater \((t = 2.45; \ p = 0.044; \ ES = 1.28)\) after the first bout \((761.2 \pm 171.0 \text{ pg·mL}^{-1})\) when compared with the second bout \((307.2 \pm 48.3 \text{ pg·mL}^{-1})\).
**Discussion**

The main finding of the present study was that the magnitude of muscle damage is attenuated after the second bout compared with the first bout, suggesting the repeated bout effect. These support the hypothesis that the repeated bout effect would be found for resistance-trained men.

The present study recruited resistance-trained individuals who had been performing resistance training for more than 2 years, but the participants had never performed the eccentric bench press exercise that was used in the present study, thus the exercise was unaccustomed to them. The decrease in IRM strength (Figure 1), development of DOMS (Figure 2), increase in serum CK activity (Figure 3), and plasma PGE\textsubscript{2} concentration (Figure 4) collectively indicate that muscle damage was induced after the first eccentric exercise bout. It is important to note that resistance-trained individuals still experience eccentric exercise-induced muscle damage. However, the magnitude of changes in these variables was smaller when compared with previous studies that used untrained men (1,4). Newton et al. (19) reported that muscle damage induced by maximal eccentric exercise of the elbow flexors was less for resistance-trained than for untrained individuals. It seems likely that some protective effect against muscle damage had been conferred by their training. It should be noted that the participants in the present study stopped their regular training for 7 days before the first exercise bout, and for 2 weeks between the first and second eccentric exercise bouts. It might be that detraining effect due to the absence from their regular training contributed to the results. To minimize the effect of regular training, the participants were asked to stop their training, but it is interesting to investigate whether the same results are found if the participants are allowed to continue their regular training normally.

The results of the current investigation support the work previously reported using isokinetic eccentric exercise of the elbow flexors in resistance-trained individuals (13,14,26). For instance, Howatson et al. (13) and Starbeck and Eston (26) used high-intensity isokinetic dynamometry exercise of the elbow flexors and found greater response of muscle damage markers in the first than second bout of eccentric exercise, suggesting the occurrence of the repeated bout effect. Additionally, both studies (13,26) observed decreases in median frequency of surface electromyography of elbow flexors from the first to second eccentric exercise bout, suggesting that the possible protective effect was attributed to neural mechanism. Howatson and Someren (14) also investigated the repeated bout of elbow flexor isokinetic eccentric exercise performed by resistance-trained individuals and demonstrated significantly smaller changes in maximal voluntary isometric contraction strength, DOMS, and CK activity after the second than the first exercise bout. It should be noted that all of these studies used maximal eccentric exercise of the elbow flexors.

In contrast, other studies reported that resistance-trained individuals did not show the repeated bout effect (2,9,10). Falvo et al. (9) reported that changes in maximal voluntary isometric contraction force and bench press throw performance were not significantly different between the first and second bouts of bench press eccentric exercise (10 sets of 10 repetitions, 70% 1RM), although muscle soreness was significantly attenuated in the second bout. Using the same eccentric bench press exercise, Blommer et al. (2) and Falvo et al. (10) showed no evidence of the repeated bout effect for CK activity and maximal voluntary isometric contraction force. These authors stated that the absence of the repeated bout effect was attributed to a reduced adaptive reserve of resistance-trained individuals, and the repeated bout effect only occurred during the early phase of training (2,9,10).

It should be noted that the previous studies (2,9,10) that did not find the repeated bout effect using eccentric bench press exercise used lower intensity (70% of IRM) than the present study (70% 1RM ecc, or 97% of IRM). Thus, the absolute load in the present study was greater than that of the previous studies. It has been documented that the greater the muscle damage in the initial bout, the greater the repeated bout effect conferred (21). As discussed previously, it seems that the magnitude of changes in the indirect markers of muscle damage was greater in the present study when compared with that of the previous studies (2,9,10). For example, Falvo et al. (10) reported that peak serum CK activity at 24 hours was ~300 IU·L\textsuperscript{-1}, but the serum CK activity in the present study was 545 IU·L\textsuperscript{-1} at 72 hours. It seems possible that resistance-trained individuals require greater extent of muscle damage in the first bout to confer the repeated bout effect.

A limitation of the present study was that the subjects performed 3 maximal eccentric muscle actions a week before eccentric exercise to determine 1RMecc load, a stimulus that could possibly induce protective effect. It has been reported that only a few eccentric muscle actions (6,7), even if these actions are submaximal (5,15), confer the repeated bout effect. However, it is important to note that these studies used untrained individuals. In the present study, all participants had been regularly performing submaximal eccentric muscle contractions in their resistance training routines. Thus, the effect of 1RMecc was minimal if any, and it is possible that the repeated bout effect would have been greater if no 1RMecc test had been performed.

In conclusion, the results of the present study showed that the repeated bout effect was evident for resistance-trained individuals. Because the magnitude of muscle damage induced by the initial eccentric exercise bout was already smaller for the resistance-trained individuals than for untrained individuals, the magnitude of the repeated bout effect was not as great as that demonstrated by untrained individuals. Further studies are necessary to investigate the effects of different intensities, training status, and muscle group recruited on the repeated bout effect in resistance-trained individuals.
Muscle Damage in Resistance-Trained Men

**Practical Applications**

The present study shows that muscle damage is induced to resistance-trained individuals by high-intensity eccentric bench press exercise, but the magnitude of muscle damage is reduced after the second bout of the same exercise. In previous studies using lower-intensity bench press exercise, this adaptation referred to as the repeated bout effect was not found for resistance-trained individuals. Thus, it seems that for repeated bout effect to be induced for resistance-trained individuals, intensity of the exercise should be higher. There is a common belief that an effective training session should cause DOMS, based on “no pain no gain” theory. As shown in the present study, the magnitude of DOMS is attenuated, and changes in other indirect markers of muscle damage (e.g., strength loss) are smaller, when the same high-intensity eccentric bench press exercise is repeated. It is important to note that the same exercise does not result in the same symptoms of muscle damage because of the repeated bout effect even for resistance-trained individuals. The use of DOMS as an indicator of training effect should be cautioned.

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**References**