Dissociated Time Course of Recovery Between Genders After Resistance Exercise

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ABSTRACT

Flores, DF, Gentil, P, Brown, LE, Pinto, RS, Carregaro, RL, and Bottaro, M. Dissociated time course of recovery between genders after resistance exercise. J Strength Cond Res 25(11): 3039–3044, 2011—Comparisons between men and women of time course responses of strength, delayed-onset muscle soreness (DOMS), and muscle swelling after a resistance training session are still controversial. Therefore, this study examined gender differences in strength loss, muscle thickness (MT), and DOMS between young men and women. Thirty apparently healthy, untrained volunteers (14 women and 16 men) participated in the study protocol. The resistance exercise session consisted of 8 sets at 10 repetition maximum load of the elbow flexor muscles of their dominant arm. Maximum isokinetic peak torque (PT), MT, and DOMS were recorded at baseline (TB), immediately after exercise (T0), and at 1 (T1), 2 (T2), 3 (T3), and 4 (T4) days after exercise. Baseline strength was expressed as 100%. There were no significant differences between the sexes for relative PT loss immediately after exercise (T0 = 74.31 ± 8.26% for men and 76.00 ± 6.31% for women). Also, PT was still significantly less than baseline from T1 to T4 for both genders. In contrast, recovery from PT was longer in women when compared with that in men. Muscle thickness responded similarly to PT in both genders. However, there was no significant difference between genders for DOMS at any time point. The time point that showed the greatest degree of mean soreness was T2 (4.94 ± 2.38 mm for men and 4.45 ± 2.07 mm for women). Our data suggest that after resistance exercise, women and men experience similar immediate strength loss; however, they have dissimilar strength recovery across 4 days of recovery. Likewise, both genders experience a different time course of MT response after a traditional resistance exercise protocol. In contrast, men and women develop and dissipate muscle soreness in a similar manner.

KEY WORDS muscle soreness, strength loss, thickness

INTRODUCTION

Resistance training has become a popular form of exercise and is recommended by many major health organizations as an important part of any exercise program (2,49). To develop muscular strength and hypertrophy, high-intensity training, with maximal or near maximal muscle actions, is frequently used (23,46). This elevated muscle tension can cause temporary muscle damage, and its subsequent repair process may be one of the stimuli that initiates compensatory hypertrophy (19).

Muscle damage is associated with a complex sequence of events and results in decreased muscle force production, elevated circulating muscle proteins, inflammation, decreased speed, delayed-onset muscle soreness (DOMS), and muscle swelling (10–12,14–16,27,29,33,50). Arguably, strength loss may be the most important functional consequence and the most reliable indicator of muscle damage (15,50). Several studies have shown that muscle strength may decrease by >50% immediately after injury (11,26,31), and recovery may take 28 days or longer (22,24,41). Another important functional consequence of muscle damage is an increase in DOMS and muscle swelling. Delayed-onset muscle soreness usually occurs between 24 and 48 hours postexercise and persists up to 7 days after the resistance exercise bout (32,36,48). Muscle inflammation reflects muscle damage that occurs during the physiological adaptation and may be attributable to structural damage of the sarcomeres, such as tearing of the Z-lines (32).

Animal research has demonstrated gender differences in markers of muscle damage, suggesting that female animals experience an attenuated response (3,25,43), which may be attributed to the effects of estrogen on skeletal muscle (47). This has led to the speculation that women may experience less muscle damage than men do (45); however, studies in humans...
have shown equivocal results. Rinard et al. (39) reported no significant differences in strength loss or recovery rate between men and women. Similarly, Sayers and Clarkson (41) have shown no gender differences in force loss or recovery after eccentric actions between men and women; however, they reported that a greater number of women experienced profound muscle strength loss immediately after exercise compared to men. In a previous study, Stupka et al. (44) reported that muscle damage was similar between genders, yet the inflammatory response seemed to be attenuated in women. More recently, Sewright et al. (42) reported that women experienced significantly greater relative strength loss immediately after 50 repetitions of maximal eccentric muscle actions than men did; however, men exhibited a larger creatine kinase (CK) response. It is important to note that most studies involving the analysis of muscle damage in humans were conducted in extreme conditions, such as 50 or more repetitions of maximal eccentric actions (39,41,42) or multiple sets at loads >100% of 1 repetition maximum (RM) (44), which is not usually seen during typical strength and hypertrophy resistance training protocols (2). Therefore, the purpose of this study was to examine gender differences in strength loss, muscle thickness (MT), and muscle soreness after a multiple set resistance training session typically used to induce muscle hypertrophy.

**Methods**

**Experimental Approach to the Problem**

Participants visited the laboratory 7 times. On the first day of the experiment, subjects performed a baseline elbow flexion 10RM test. The 10RM test was repeated, after 72 hours, on visit 2. On visit 3, 72 hours later, baseline measures of peak torque (PT), DOMS, and MT were taken from the elbow flexors. After 10 minutes of rest, subjects performed a resistance training session that comprised 8 sets of 10 concentric and eccentric repetitions of elbow flexion exercise. Measures of PT, DOMS, and MT were repeated immediately after the exercise session (T0), 1 (T1), 2 (T2), 3 (T3), and 4 (T4) days after training (visits 4–7).

**Subjects**

Sixteen men (22.69 ± 0.49 years; 82.01 ± 2.50 kg; 1.78 ± 0.17 m) and 14 women (22.21 ± 0.71 years; 56.4 ± 1.83 kg; 1.65 ± 0.12 m) were selected at random from respondents to fliers distributed over the university campus and by word-of-mouth. Before participating, volunteers had to present a physician approval attesting they had no health problems that could be aggravated by the tests. All participants were physically active but were not involved in regular resistance training in the 6 months before the experiment. Participants were instructed to maintain their nutritional habits and not take any kind of nutritional supplements or ergogenic aids for the duration of the study. Volunteers were also instructed not to perform any form of vigorous or nonhabitual physical activity throughout the study. All tests were performed at the same time of the day for each subject. Before participation, each volunteer read and signed a detailed informed consent form approved by the University Institutional Review Board.

**Determination of 10 Repetition Maximum Load**

In the week before the experiment, the elbow flexion 10RM load was assessed for each subject by determining the maximum weight that could be lifted for 10 consecutive repetitions. The exercise was performed with a dumbbell on a seated Scott Bench. This same device was used for the isokinetic strength tests (Figure 1). If the subject did not accomplish the 10RM on the first attempt, the load was adjusted by 1–5 kg, and a minimum of 5 minutes of rest was given before the next attempt. Only 3 trials were allowed per testing session. To confirm the 10RM load, and to avoid any learning effect, the 10RM test was repeated 72 hours later in all subjects. Intraclass correlation coefficient (ICC) for the baseline 10RM test and retest was 0.93.

**Resistance Training Protocol**

On the third visit, 72–96 hours after the second 10RM test, the exercise protocol was performed. Volunteers performed 8 sets of concentric and eccentric elbow flexion exercise at the 10RM load. The exercise was performed with a dumbbell on a Scotch Bench. To prevent large decreases in training volume, the first 4 sets were performed at the 10RM load. After the fourth set, the load was reduced by 20%. Between the sets rest interval was 2 minutes, and movement velocity was 1 second concentric and 2–3 seconds eccentric. In women, who were not using oral contraceptives, all tests and training protocols were performed in the follicular phase, between the first and 13th days of their menstrual cycle. In women taking oral contraceptives, all tests were performed in the phase of low hormonal concentration.

**Peak torque**

Unilateral elbow flexion PT was tested via 2 sets of 4 repetitions at 60° s⁻¹, on a Biodex System 3 isokinetic dynamometer.
(Biodex Medical, Inc., Shirley, NY, USA) with 60 seconds of rest between sets. Calibration of the dynamometer was performed before each testing session according to the manufacturer’s specifications. Participants were seated with their elbow on a Scott Bench and aligned with the axis of rotation of the dynamometer’s lever arm (Figure 1). The forearm remained in a supinated position throughout the test. Verbal encouragement was given throughout the test, and all tests were administered by the same investigator (8). Baseline test and retest ICC and standard error of the mean values for PT were 0.96 and 2.4%, respectively.

Muscle Swelling
Muscle swelling was expressed as MT and was measured by Ultrasonography using B-Mode ultrasound (Philips-VMI, Ultra Vision Flip, model BF; Lagoa Santa, MG, Brazil) (36). All tests were conducted at the same time of the day, and participants were instructed to hydrate normally 24 hours before testing. A water-soluble transmission gel was applied to the measurement site, and a 7.5-MHz ultrasound probe was placed perpendicular to the tissue interface without depressing the skin. Muscle thickness of the biceps brachii was measured using the reference points suggested by Bemben (6). Once the technician was satisfied with the quality of the image, it was frozen on the monitor. With the image frozen, a cursor was used to measure MT, which was taken as the distance from the subcutaneous adipose tissue–muscle interface to muscle–bone interface (1). A trained technician performed all analyses. The coefficient of variation was <3.0%, and baseline test/retest ICC was 0.96.

Delayed-Onset Muscle Soreness
Muscle soreness was assessed using a previously reported procedure (39). Soreness of the exercised elbow flexor muscles was assessed using a 100-mm visual analog scale, with “no soreness” (0 mm) and “severe soreness” (100 mm) serving as the left and right anchors, respectively. The participants gently palpated their own elbow flexor muscles and rated their soreness on the basis of the feeling of the sorest aspect.

Statistical Analyses
All values are reported as mean ± SD. Normality of the distribution for outcome measures was tested using the Kolmogorov–Smirnov test. After determining that the sample was normally distributed (p > 0.05), comparisons were done using a 2 × 6 (gender [male and female] × time [TB, T0, T1, T2, T3, T4]) mixed factor analysis of variance (ANOVA). Dependent variables were PT, DOMS, and MT. A Fisher’s Least Significant Difference (LSD) post hoc test was run when there was a significant main effect. Significance was set at p ≤ 0.05.

Results
The PT ANOVA revealed a significant interaction of gender by time. This was followed up with two 1 × 6 ANOVAs for time for each gender and revealed a significant main effect for both men and women (Figure 2). In men, PT at T0 significantly decreased to 74.31% of TB values (TB values are expressed as 100%). At T1, it significantly increased to 87.19% and continued to significantly increase (93.38%) until T4. However, at T4, it was still significantly less than TB. In women, PT at T0 significantly decreased to 76.00% of TB. However, the women’s PT did not follow the same trend as that of the men. Women’s PT was not significantly different between T2 and T3 (p = 0.764) or between T3 and T4 (p = 0.976). However, at T4, it was still significantly less than TB.

The MT ANOVA revealed a significant interaction of gender by time. This was followed up with two 1 × 6 ANOVAs for time for each gender and revealed a significant...
Muscle Recovery and Gender

The purpose of this study was to examine gender differences in strength loss, muscle swelling (MT), and muscle soreness after a traditional resistance training protocol typically recommended by the American College of Sports Medicine to induce muscle hypertrophy (2). The major finding was that after unaccustomed high-intensity resistance training, men and women showed a similar acute loss in strength but a different time course of recovery across the 4-day testing session. There was also a difference between men and women in muscle swelling at 4 days after exercise. However, they did exhibit similar development and dissipation of muscle soreness.

Muscle damage in response to strenuous exercise has been well documented in humans. Exercise-induced muscle damage is characterized by DOMS, decreased force generation, and inflammatory cell infiltration, and increased plasma CK activity. Most previous research that has assessed gender differences in exercise-induced muscle damage has concentrated on measuring enzymes released from the muscle, primarily CK (3–5, 42, 44). Studies of gender differences in animal models have shown that females have less increase in blood CK activity compared with males after strenuous exercise (3, 47). This is probably because women have lower resting CK levels than men do, which has led to the belief that women may be protected from muscle damage induced by strenuous exercise (9, 20). However, analysis of CK levels is difficult because of the high inter and intraindividual variabilities. Additionally, CK release may be dependent on other factors other than just muscle damage, such as membrane permeability, which weakens the correlation between muscle damage and CK levels (10, 11, 34, 44). Furthermore, the difference in muscle damage between men and women has been largely explained by higher circulating estrogen levels in women. Some authors have suggested that estrogen may play a protective role, minimizing muscle damage (12, 47). Estrogen is supposed to act as an antioxidant and a membrane stabilizer through its interaction with the phospholipid bilayer (47). Studies in animals have suggested that female rodents show less muscle damage than male rodents do after exercise (3, 25), leading to the speculation that women show less muscle damage (42).

A more reliable assessment of exercise damage than the presence of enzymes in blood is muscle strength (50). Our results showed a significant interaction of gender by time in PT recovery over the 4 days after exercise, suggesting that women and men responded differently to the exercise protocol, which is not in agreement with the findings of previous studies (39, 41, 44). Conversely, Borsa and Sauers (7) examined the effect of gender on muscle damage indices after 50 near maximal concentric and eccentric actions of the elbow flexors. After exercise, both groups experienced strength loss with relative force loss in men (15.3%) being similar to that in women (18.2%). Their results were similar to the results reported in this study where men demonstrated a relative strength loss of 25.7% and women 24.0%. Previous research has demonstrated typical force reduction after maximal eccentric exercise to be approximately 50–60% (11, 39, 41). However, in this study, values did not fall below 70% of baseline strength. This difference may be because of the protocol used. The studies that reported larger strength decreases involved sets of 50 or more repetitions of maximal eccentric actions (39, 41), and previous studies have shown that the greatest disruption occurred during eccentric actions (18, 35). In this study, the sets were interrupted when concentric failure was reached.

One interesting observation in this study was that women seemed to have a delayed strength recovery process when compared to men. One possible explanation may be the history of muscle usage, because from childhood until young adulthood women tend to be less active than men (40). Therefore, male muscles may be more habituated to torque...
production than female muscles, and it has been previously suggested that trained muscle recovers faster than untrained ones (17). Additionally, previous studies have reported that despite similar muscle damage, men showed a higher inflammatory response than did women (44, 45). Because the inflammatory response may be one of the triggers of muscle regeneration (21, 28, 30), an attenuated inflammatory response may delay the process of muscle recovery after damage. Also, these higher inflammatory responses are consistent with the hypothesis that men, who are usually stronger than women, can sustain greater absolute forces when the contraction is performed at a relative intensity. Pincivero et al. (38) have shown that greater force production is correlated with greater fatigue. One explanation for this is probably because of stronger men experiencing greater intramuscular pressures, blood flow occlusion, accumulation of metabolites, and impairment of oxygen delivery to the muscle when compared to women (23). These factors can also explain the greater inflammatory responses in men.

It is also well known that an acute exercise bout, especially if it contains eccentric muscle actions (31), results in the disruption of contractile tissue and initiates an immune-mediated inflammatory response, which is in turn associated with DOMS. The local acute response to tissue injury involves the production of cytokines, which are released at the site of inflammation, facilitating an influx of lymphocytes, neutrophils, monocytes, and other cells that participate in the healing of the tissue. In regard to muscle soreness and gender differences, Sewright et al. (42) did not see a significant difference in the pattern of soreness between men and women. The time point in their study that showed the greatest degree of soreness was 2 days after exercise (51.0 ± 22.5 mm for men and 58.0 ± 21.5 mm for women). Likewise in this study, there was no significant difference between genders for muscle soreness. The time point that showed the greatest degree of soreness was also the second day after the exercise session (49.1 ± 23.8 mm for men and 44.5 ± 20.7 mm for women). Dannecker et al. (13) also reported the greatest degree of pain 48 hours after eccentric training with no difference between genders (3.43 ± 2.38 cm for men and 4.17 ± 2.48 cm for women).

In contrast, Rinaudo et al. (39) found no differences in muscle soreness values between men and women. However, women experienced a greater loss in range of motion than did men beginning 3 days after exercise and persisting through 7 days. According to the authors, this may be indicative of a higher functional deficit in women vs. men through this time period. Unfortunately, range of motion was not assessed in this study. We assessed MT and demonstrated that women also have greater MT after 4 days. Thus, we can hypothesize that the time course of muscle swelling, after a resistance exercise session, may be more associated with the range of motion than with the DOMS. These results may also explain why women in this study demonstrated a delay in muscle strength recovery when compared to men. In summary, men and women demonstrated similar relative strength loss after a traditional concentric and eccentric isoinertial resistance exercise protocol; however, 3 days after exercise, strength was still depressed in women. Recovery from MT was also longer in women when compared to men. On the other hand, men and women developed and dissipated muscle soreness in a similar manner.

**Practical Applications**

To promote long-term training and performance improvement, the strength and conditioning professional should include preplanned variations and systematic periodization within an overall strength program. One important variable during periodization is the optimal recovery time between training sessions. Our results showed that decreases in muscle strength and increases in MT persisted longer in women than in men. Thus, strength and conditioning coaches should program resting days between resistance training sessions in a gender-specific manner. In summary, for the same muscle group trained, women might need longer rest periods between training sessions than men do.

**References**


