Ultrasound Treatment and Recovery From Eccentric-Exercise-Induced Muscle Damage

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Objectives: To evaluate ultrasound’s effectiveness after eccentric-exercise-induced muscle damage. Participants: 22 subjects. Intervention: Random assignment to ultrasound (UT) or placebo (PT). Ultrasound was applied immediately and 24, 48, and 72 h after 50 maximum eccentric contractions of the biceps. Outcome Measures: Concentric and eccentric peak torques, resting elbow angle, and subjective muscle soreness were measured before and 24, 48, 72, and 96 h afterward. Results: No significant differences between UT and PT for biceps concentric or eccentric peak torque were noted. Both groups exhibited significant ($P < .01$) depression in eccentric and concentric peak torques with a slow return toward preexercise values over 96 h. Resting elbow angles for both groups were significantly lower than preexercise values up to 96 h ($P < .01$). Muscle soreness increased significantly ($P < .05$) at 24 and 48 h and returned to preexercise levels by 96 h. Conclusions: Daily ultrasound did not influence recovery after eccentric-exercise-induced muscle damage. Key Words: muscle soreness, muscle force

Although ultrasound is often used in the treatment of acute muscle and soft-tissue injuries, research to support its use in athletic settings is limited. Ultrasound treatment has been reported to influence a number of physiological responses that might result in accelerated healing of muscle and connective tissue after contraction-induced damage. These include increased muscle blood flow, muscle temperature, and in vitro collagen synthesis and fibroblast proliferation.

Relatively few studies have examined the effects of ultrasound treatment on recovery from eccentric-contraction-induced muscle damage. Although no definitive ultrasound protocol is universally accepted for the treatment of exercise-induced muscle damage, most studies have employed some form of pulsed ultrasound at 1.0-MHz intensity. This type of treatment protocol maximizes the ultrasound tissue penetration; enhances the nonthermal effects of ultrasound on tissues, including cavitation and microstreaming; and has minor effects on tissue heating. It has been sug-
gested that nonthermal effects of ultrasound (1:4 pulsed mode) optimize healing of injured tissues.\textsuperscript{2,9,10}

The limited research on the influence of ultrasound treatment on recovery from contraction-induced muscle damage in humans has tended to produce conflicting results. Hasson et al\textsuperscript{5} reported attenuation of muscle soreness and a lesser degree of muscle-strength loss 48 hours after eccentric exercise of the quadriceps muscles with application of 1:4 pulsed ultrasound (0.8 W/cm\textsuperscript{2}, 20 minutes total over various sites) 24 hours postexercise. Three more recent studies, however, failed to demonstrate any positive effects of pulsed ultrasound treatment on overt symptoms of eccentric-exercise-induced muscle damage and recovery. Plaskett et al\textsuperscript{6} applied 1:4 pulsed ultrasound (1.0 MHz, 1.0 W/cm\textsuperscript{2} for 8 min) daily for 4 days to eccentrically exercised quadriceps muscles with no significant effects on soreness sensation or isometric or dynamic, isokinetic, concentric peak torques. Craig et al\textsuperscript{7} reported no influence of daily 1:4 pulsed ultrasound (0.8 W/cm\textsuperscript{2}, 1 MHz for 7 or 14 minutes) on elbow-flexor soreness, resting elbow angle, or range of motion for 3 days after eccentric biceps exercise. Stay et al\textsuperscript{8} also failed to demonstrate a positive effect of twice-daily 1:4 pulsed ultrasound treatment (1.0 MHz, 1.5 W/cm\textsuperscript{2}) on muscle soreness, relaxed elbow angle, and 1-repetition-maximum elbow-flexion strength for up to 4 days after weight-lifting exercise. One preliminary study, however, using continuous 1.0-MHz (0.5 W/cm\textsuperscript{2}, duration unspecified) ultrasound treatment in a rodent model did report enhanced force recovery of hind-limb muscles 5 days after eccentric-contraction-induced damage.\textsuperscript{11}

One potential limitation of all of these human studies\textsuperscript{5-8} is that they might have had suboptimal precision and specificity in muscle-force measures, relative to the methods used for soreness and damage induction. In a recent review, Warren et al\textsuperscript{12} noted that in human subjects, the best measure of muscle recovery after eccentric-exercise-induced damage is the return of maximum voluntary contraction (MVC) muscle force. This measure could account for all aspects of muscle damage throughout the events mediating muscle excitation–contraction coupling, including structural muscle damage and neuronal inhibition of the affected muscles secondary to damage.\textsuperscript{12} They also noted, however, that in order to optimize the accuracy of MVC measures as an index of postexercise muscle damage and repair, the measures need to be made on the same apparatus, employing the same motion and velocity as that used to induce the muscle damage, and quantified as isokinetic-movement peak torques.\textsuperscript{12} None of the studies cited\textsuperscript{5-8} met all these criteria in their measures of muscle force and hence might not have attained optimal accuracy in measuring changes in muscle force as an index of muscle damage and repair.

This study was designed to evaluate the effect of daily ultrasound treatment on recovery from eccentric-exercise-induced muscle damage using concentric and eccentric isokinetic evaluation of voluntary elbow-flexor MVC peak torques as recommended by Warren et al,\textsuperscript{12} as well as other indices of muscle damage, including measures of muscle soreness and
resting elbow angle. Because depth of ultrasound penetration might be a limiting factor when treating large muscle groups such as the quadriceps, we examined the effect of ultrasound on the smaller biceps muscles.

**Methods**

The study was approved by the Human Research Ethics Committee of the Department of Kinesiology and Physical Education at Wilfrid Laurier University, following the guidelines of the Canadian Tri-Council policy on ethical conduct for research involving humans. All subjects signed an informed consent before the start of the study.

Twenty-two subjects were randomly assigned to either the ultrasound treatment (UT) group (3 men, 8 women) or placebo treatment (PT) group (4 men, 7 women). Subjects ranged in age from 19 to 23 years (mean = 21.1). All were healthy, recreationally active individuals who had not participated in weight training for at least 1 year prior to the study. For the duration of the study, subjects abstained from anti-inflammatory drugs, physical rehabilitation, and exercise involving the upper body.

Eccentric elbow flexion was used to induce muscle damage at time 0. Eccentric and concentric MVC, relaxed elbow angle, and delayed-onset muscle soreness (DOMS) were assessed before and 24, 48, 72, and 96 hours after eccentric exercise. UT or PT was applied to the biceps muscles immediately after the eccentric-exercise protocol, as well as 24, 48, and 72 hours after muscle-damaging exercise.

Eccentric and concentric isokinetic MVC peak torques, as well as the eccentric-exercise protocol, were performed using isolated biceps elbow flexors of the left arm on a CYBEX NORM dynamometer (CYBEX, Ronkonkoma, NY). Eccentric and concentric isokinetic MVC peak-torque measures at 60°/s were determined as the best of 3–4 trials separated by adequate rest and expressed as Nm/kg body weight. Subjects warmed up by performing light eccentric and concentric biceps contractions for 1 minute before testing. Eccentric and concentric MVC tests were performed in random order with verbal encouragement, 5–10 minutes rest between tests, and visual feedback on torque from the computer screen. Subjects were familiarized with the CYBEX NORM apparatus and with producing MVC eccentric and concentric contractions on 2 separate occasions before testing. Eccentric and concentric MVC tests as described were repeated at 24, 48, 72, and 96 hours after eccentric exercise.

The eccentric elbow-flexion exercise protocol was performed using the left biceps muscles as primary movers. After a 3-minute warm-up of light concentric elbow flexion, subjects performed an eccentric elbow flexion–contraction protocol modified from Sayers et al. Five sets of 10 isokinetic eccentric contractions at 60°/s separated by 1 minute of rest (50 in total) were performed. Subjects were verbally encouraged and allowed to see visual feedback of movement torques on the computer screen to motivate maximum effort.
Resting elbow angle (REA) was determined by placing the goniometer axis on the olecranon process and using the greater tubercle of the humerus and the head of the ulna as reference points. These anatomical landmarks were marked with indelible ink to ensure repeatability of measures throughout the study. REA measures were taken with the subject standing and the left arm resting naturally at the side as described by Cleak and Eston. REA was determined before and 24, 48, 72, and 96 hours after eccentric exercise.

DOMS was assessed on movement (raising and lowering a 1-kg weight), during daily activities, and via light manual palpation of the tenderest part of the biceps (usually near the muscle belly). The subject indicated degree of soreness using a Likert-type scale ranging from 1 to 10, with 1 representing no soreness and 10 representing the most extreme soreness. DOMS was assessed before and 24, 48, 72, and 96 hours after eccentric exercise.

UT or PT was applied in a circular motion using a 5-cm² transducer head (ERA 4.0 cm²) and ultrasound gel to a 10- to 12-cm² area surrounding the sorest part of the muscle of each subject (as determined by palpation) as previously described. UT consisted of 8 minutes of pulsed (1:4 ratio; 2 milliseconds on, 8 milliseconds off) with an intensity of 1.0 MHz and a temporal peak intensity of 1.5 W/cm² using a Forte CPS ultrasound apparatus (Chattanooga Group, Hickson, Tenn). PT consisted of the same treatment with the ultrasound machine turned off. Treatment mode and duration were selected based on previous studies and standard recommendations for ultrasound treatment of muscle strain, collagen damage, and muscle pain. UT and PT application occurred within 20 minutes of completion of the eccentric-exercise protocol and 24, 48, and 72 hours later. All UT and PT at 24, 48, and 72 hours postexercise were preceded by peak eccentric- and concentric-torque determinations and REA and DOMS measurements.

The data were analyzed using multivariate analysis of variance (MANOVA) with repeated measures. Significance level was set a priori at $P < .05$.

**Results**

Peak eccentric and concentric left biceps muscle torques (60°/s) for UT and PT groups, expressed as Nm/kg body weight, are depicted in Figure 1. Both eccentric and concentric biceps peak torques were significantly reduced ($P < .01$) in both the UT and PT groups at 24 hours postexercise. Eccentric and concentric peak torques slowly returned toward preexercise levels by 96 hours postexercise in both groups. There were no significant differences in eccentric or concentric peak torques between the UT and PT groups at any of the time points before or after eccentric exercise.

REA results are depicted in Figure 2. REA was significantly ($P < .05$) reduced in both the UT and PT groups at 24 hours postexercise and remained significantly depressed ($P < .05$) up to 96 hours postexercise in
both groups. There were no significant differences between the UT and PT groups at any time point.

DOMS results on movement, during daily activities, and on palpation are depicted in Figure 3. DOMS in the biceps was significantly ($P < .05$) elevated on movement and during daily activities at both 24 and 48 hours postexercise in both the UT and PT groups. No significant differences in biceps DOMS between the groups was evident at any time point. DOMS in the biceps was significantly elevated at 24 hours postexercise on light palpation in both the UT and PT groups. The greatest DOMS was usually found near the midpoint or belly of the biceps. No significant differences

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Figure 1  Elbow-flexion eccentric and concentric peak torques before and after eccentric elbow-flexion exercise. No significant difference between ultrasound and placebo treatment groups at any time point.

*Significantly lower than preexercise peak torques ($P < .01$).
between the groups in palpation-induced DOMS were seen at any time point.

Post hoc power tests were also run on the data. These indicated that the differences between the UT and PT groups were so small that there would need to be at least the following numbers of subjects per group in order to detect a difference: 247 for REA, 900+ for any DOMS measure, 97 for eccentric peak torque, and 31 for concentric peak torque. This suggests that the nonsignificant differences between the UT and PT groups in this study were not a result of small sample size and that any differences have little functional significance.

**Comments**

This study found no overt influence of daily pulsed ultrasound treatment on indices of muscle recovery from eccentric-exercise-induced biceps muscle damage up to 4 days postexercise. We had previously reported similar lack of effect of daily ultrasound treatment after eccentric exercise in a larger muscle group (quadriceps). If muscle size had limited depth of ultrasound penetration in our previous negative findings, it was possible that using a smaller muscle group (biceps) might eliminate this limitation. This study confirms findings by others who also found no significant effect of ultrasound treatment on indices of muscle recovery from eccentric-exercise-induced muscle damage.

Because it can reflect disruption at any point in the excitation–contraction
Figure 3  Delayed-onset muscle soreness on movement, during daily activities, and on palpation before and after eccentric elbow-flexion exercise. No significant difference between ultrasound and placebo treatment groups at any time point.

*Significantly higher than preexercise muscle soreness ($P < .05$).
coupling process, recovery of muscle force has been used in human\textsuperscript{8,12,17} and animal\textsuperscript{18} models as a prime indicator of muscle damage and recovery from eccentric-exercise-induced muscle damage. This reflects physical disruption of the muscle-contractile elements and muscle cell, as well as potential neuronal inhibition of muscle force, secondary to the damage. Because muscle-force deficits do not necessarily correspond directly with physical muscle disruption, it is likely that at least some of the loss and recovery of muscle strength is related to neuronal inhibition of force development.\textsuperscript{12}

It has also been proposed that optimal determination of postexercise muscle-force recovery, as the prime index of postdamage muscle repair in humans, would best be achieved by isokinetic measurement of peak torques using the same apparatus, movement pattern, and contraction speed as were used to induce the muscle damage.\textsuperscript{12} This was the first study examining the effects of ultrasound treatment on indices of postexercise muscle recovery to employ such a protocol in determining postexercise muscle-force recovery. Despite this apparent increase in precision, and in agreement with 2 previous studies,\textsuperscript{6,8} no differences in postexercise muscle-force recovery were noted between the UT and PT groups.

Changes in REA have been interpreted as reflecting changes in post-exercise muscle swelling, edema, and stiffness\textsuperscript{15,17} and as such might reflect intramuscular changes occurring as a consequence of damage-repair mechanisms.\textsuperscript{19} Nevertheless, as also reported by one other study,\textsuperscript{8} ultrasound treatment did not influence this measure of muscle damage or recovery in this experiment.

DOMS can to some degree reflect inflammation- and swelling-related changes in muscle consequent to damaging exercise.\textsuperscript{7,19,20} The lack of influence of ultrasound treatment on post-eccentric-exercise biceps movement or palpation-induced DOMS suggests that insofar as DOMS reflects muscle damage and recovery, these aspects of muscle repair were not influenced by daily ultrasound application. This also reflects the findings of previous studies.\textsuperscript{6-8}

The weight of evidence from this and previous studies suggests that pulsed ultrasound treatments do not influence overt indices of postexercise muscle recovery in humans\textsuperscript{6-8} or animals.\textsuperscript{10} At least one human\textsuperscript{5} and one animal\textsuperscript{11} study, however, found some evidence for a positive influence of ultrasound treatment on muscle-related injury. These differences in findings cannot be fully explained by this study. However, it might be that differences in ultrasound-application protocol alter its effect. Hasson et al.,\textsuperscript{5} who found positive results, employed a stationary transducer head for pulsed ultrasound application (a method no longer recommended, because of its potential for unstable cavitation).\textsuperscript{9} The animal study\textsuperscript{11} that reported a greater post-eccentric-exercise muscle-force recovery employed continuous ultrasound application, a method that results in greater rise in muscle temperature.\textsuperscript{3,9} To clarify these questions it is recommended that further studies employing different modes of ultrasound application, in-
including continuous or different-pulsed mode frequencies, as well as longer or more frequent applications, be employed to determine their potential effects on postexercise muscle repair.

In conclusion, this study found no evidence of a beneficial effect of daily pulsed ultrasound treatment, as applied in this study, on indices of muscle damage and repair for 4 days after eccentric-exercise-induced muscle damage. This combined with other previous findings suggests that once-daily pulsed (1:4) ultrasound treatments do not appear to have a beneficial effect on muscle recovery after eccentric-exercise-induced damage.

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References


