Pulsed Ultrasound Fails To Diminish Delayed-Onset Muscle Soreness Symptoms

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Objective: We investigated the effects of pulsed ultrasound on swelling, muscle soreness perception, relaxed-elbow extension angle, and muscular strength.

Design and Setting: Eight sets of concentric and eccentric actions induced delayed-onset muscle soreness of the elbow flexors. Group 1 received 20% pulsed ultrasound treatments (1-MHz, 7 minutes, 1.5 W/cm² temporal peak intensity) twice a day immediately after postexercise assessments and at 3, 24, 27, 48, 51, 72, and 75 hours postexercise. Group 2 received sham treatments immediately after postexercise assessments and at 3, 27, 51, and 75 hours postexercise and true treatments of pulsed ultrasound at 24, 48, and 72 hours postexercise. Group 3 received sham treatments of no ultrasonic output immediately after postexercise assessments and at 3, 24, 27, 48, 51, 72, and 75 hours postexercise.

Subjects: Thirty-six college-age females.

Measurements: We recorded upper-arm circumference, perceived soreness, relaxed-elbow extension angle, and elbow-flexion strength before (pretest), immediately postexercise, and at 24, 48, 72, and 96 hours postexercise.

Results: We noted differences over time but no treatment effect between groups or interactions between time and group for upper-arm circumference, perceived soreness, relaxed-elbow extension angle, or elbow-flexion strength.

Conclusions: Pulsed ultrasound as used in this study did not significantly diminish the effects of delayed-onset muscle soreness on soreness perception, swelling, relaxed-elbow extension angle, and strength.

Key Words: swelling, pain, modalities

Exercise-induced muscle soreness is a common occurrence in athletics. Athletes starting a new season, a new training program, or a weightlifting program involving unaccustomed concentric and eccentric work will likely experience delayed-onset muscle soreness (DOMS). DOMS is easily induced by relatively intense, slow, eccentric muscle actions.[1,2] These eccentric actions produce microinjury to the active muscle fibers,[3–6] exhibiting muscular soreness, loss of joint range of motion, swelling, and decreased force production.[4,7–12] Clinical signs of DOMS include increases in plasma enzymes,[8,10,12] muscular fiber degeneration,[13] and the protein degradation[14] that accompanies the degeneration.

Previous researchers[3,4,15–17] have explained possible etiologies and mechanisms for DOMS. Relatively few studies have examined the effect of therapeutic modalities in reducing the detrimental effects of DOMS. Previous researchers[18–23] focused on reducing the symptoms associated with DOMS. To prevent or significantly diminish the symptoms of DOMS, a few researchers[20–23] applied various modalities and treatments immediately after high-intensity exercise. These studies achieved little success in preventing DOMS. It has been suggested in previous research,[19] articles,[24,25] and textbooks[26,27] that, in order to achieve maximal benefit, ultrasound

treatments should begin soon after injury and acute conditions should be treated once or twice daily.

The purpose of our study was to investigate the effects of pulsed ultrasound on the following symptoms associated with DOMS: upper-arm swelling, muscle soreness perception, decreased range of motion, and decreased muscle strength.

METHODS

We investigated the effects of pulsed ultrasound on upper-arm swelling, muscle soreness perception, relaxed-elbow extension angle, and muscle strength loss associated with DOMS. The design of this study consisted of pretest assessments, exercise protocol, postexercise measures, and treatment protocol.

Participants

Thirty-six college-age females (age = 21.5 ± 2.0 years; ht = 164.5 ± 6.2 cm; wt = 57.5 ± 6.5 kg) volunteered for participation in this study, which was approved by the Committee on Human Research at Brigham Young University. Participants read and signed an institutionally approved consent form, which outlined the procedures of the study. All

participants reported pain-free range of motion about their elbow joints and no arm pain for at least 3 months before the study. Participants were allowed to perform their normal activities of daily living during the testing period but were asked not to stretch, take pain medication, or receive any other therapy.

Instrumentation

The Omnisound 3000 (Accelerated Care Plus-LLC, Topeka, KS) ultrasound unit was used for the treatments. The 5-cm^2 transducer contained a crystal made of lead zirconate titanate. The effective radiating area of the crystal registered 3.7 cm^2, and the beam nonuniformity ratio was listed at 2.8:1.0. The Omnisound 3000 ultrasound unit was calibrated before the study. UltraPhonic ultrasound gel (Pharmaceutical Innovations, Inc, Newark, NJ) served as the conducting medium.

We measured upper-arm circumference using a retractable, flexible steel tape measure (J.A. Preston Corp, New York, NY). One end of this tape measure had a tension gauge with a preset mark to register consistent tension on the tape. Relaxed-elbow extension angle was measured using a 50-cm-long, full-circle plastic goniometer. Elbow-flexion strength was assessed using free-weight dumbbells in increments of 0.45 kg and a preacher curl bench.

Pretest Assessments

We assessed circumference, perceived soreness of the elbow flexors, relaxed-elbow extension angle, and elbow-flexion strength of the subject's nondominant arm before the exercise bout. To maintain uniformity in measurements and protocol, one investigator took the daily measurements throughout the study.

Upper-arm circumference measurements were taken at 4 sites[28] (4 cm, 6 cm, 8 cm, and 10 cm above the elbow joint) to evaluate swelling of the elbow flexors. The investigator placed the tape measure around the upper arm so that he consistently pulled the tension gauge to the left and obtained measurements while the relaxed arm was hanging at the subject's side. The investigator used a black permanent ink pen to mark measurement sites on the arm and to darken the sites each day. We recorded circumference to the nearest 0.1 cm.[29] The accuracy of this technique has been previously established to be within 2 mm.[30]

Participants subjectively reported perceived soreness in their elbow flexors using the following soreness rating scale: 0 (none), 1 (very slight), 2 (mild), 3 (moderate), 4 (severe), and 5 (extreme). Subjective soreness rating scales similar to this have been used by others.[7–10,12,14,15] The investigator applied light palpation to the elbow flexors while the participant rated her soreness according to the scale. Participants could not see any previously reported scores.

Next, we assessed relaxed-elbow extension angle, which was defined as the angle between the humerus and ulna when the subject was standing with the arm hanging by her side in a semipronated position. The investigator used a permanent marker to label anatomical reference points on the arm at the lateral edge of the acromion at the shoulder, the lateral epicondyle of the elbow, and the ulnar styloid process of the wrist. The investigator placed the goniometer over the lateral epicondyle of the humerus with the measurement arms of the goniometer aligned along the lateral markers on the shoulder and wrist. The reliability ($r = 0.9$)[31,32] of this measurement procedure using a standard goniometer has been previously established.

Participants performed a 1-repetition maximum (1RM) biceps curl using free-weight dumbbells and a preacher curl bench to assess elbow-flexion strength. The bench stabilized the upper arm at a 45° angle of shoulder flexion. The 1RM was established when the participant could perform a biceps curl from full elbow flexion to approximately 10° elbow flexion with a dumbbell weight, yet could not perform the curl with a 0.45-kg heavier weight.

Exercise Protocol

To exercise and induce DOMS, participants performed concentric and eccentric dumbbell curls. The elbow flexors were isolated by stabilizing the arm on a preacher curl bench. First, each participant performed 4 sets of concentric and eccentric actions consisting of 10 repetitions or muscular failure at 80% of her 1RM. Next, participants completed 4 sets of eccentric actions consisting of 10 repetitions or muscular failure at 100% of 1RM. The participants slowly (over 5 seconds) lowered the dumbbell from a fully flexed to a fully extended position. The researcher returned the weight to the starting position of full elbow flexion after each eccentric repetition to emphasize the eccentric action of the elbow flexors. The participant rested 1 minute between sets.

Postexercise Assessments

Postexercise measurements were taken to assess upper-arm swelling, perceived soreness in the elbow flexors, relaxed-elbow extension angle, and elbow-flexion strength immediately postexercise and 24, 48, 72, and 96 hours postexercise. We followed the same procedures for measurement as for pre-exercise assessments. To measure the effects of the previous day's treatments, we recorded assessments before ultrasound treatment.

Treatment

After the postexercise assessments, participants received either 20% pulsed ultrasound treatment (1 MHz, 7 minutes, 1.5 W/cm^2) or a sham treatment to an area 10 cm × 5 cm on the anterior surface of the upper arm and elbow joint. A precut template, secured to the arm, ensured that treatment size was consistent. Participants were positioned supine on a treatment

table during each treatment, and the ultrasound machine was placed out of sight. The examiner maintained slow, constant motion of the ultrasound head within the template. While giving placebo treatments, the examiner manipulated the timer to signal the end of each treatment.

Participants were randomly assigned to 1 of 3 treatment groups (12 subjects per group). Group 1 received pulsed ultrasound treatments twice a day immediately after postexercise assessments and at 3, 24, 27, 48, 51, 72, and 75 hours postexercise. Group 2 received sham treatments immediately after postexercise assessments and at 3, 27, 51, and 75 hours postexercise and true treatments of pulsed ultrasound at 24, 48, and 72 hours postexercise. Group 3 received sham treatments of no ultrasonic output immediately after postexercise assessments and at 3, 24, 27, 48, 51, 72, and 75 hours postexercise.

Statistical Analysis

A 3 × 6 factorial repeated-measures analysis of variance was used to test for significant differences ($P < .05$) in upper-arm circumference, perceived soreness, relaxed-elbow extension angle, and 1RM elbow-flexion strength. The between-subjects factor (group) had 3 levels (twice-daily applications; once-daily application of pulsed ultrasound, followed by once-daily sham application of pulsed ultrasound; and twice-daily sham applications of pulsed ultrasound). The within-subjects factor (time) had 6 levels (pretest, immediately postexercise, 24, 48, 72, and 96 hours). Tukey tests were used for all post hoc comparisons.

RESULTS

The exercise protocol produced significant differences over time for swelling, soreness, relaxed-elbow extension angle, and strength. We did not find significant interactions between time and group, nor were there significant differences among groups for the symptoms of DOMS. Post hoc analysis of power indicated that statistical power ranged from 0.25 to 0.72.

Circumference

The responses over time were similar at all 4 circumference sites; as a result, we reported only the 4-cm measures (Table 1). The time effect was significant at 4 cm above the elbow joint ($F_{5,29} = 32.71, P < .001$). The 4-cm circumference measures immediately postexercise and at 24, 48, 72, and 96 hours were all significantly different from pretest measures (Table 1). There were no significant interactions between time and group ($F_{10,165} = 0.49, P = .90$). Neither were there significant differences in swelling at 4 cm among groups ($F_{2,33} = 1.38, P = .27$).

Perceived Soreness

There was a significant time effect for perceived soreness ($F_{5,29} = 102.13, P < .001$). Perceived soreness measures immediately postexercise and at 24, 48, and 72 hours were all significantly different from pretest measures. The 96-hour measures were not significantly different from the pretest measures (Table 2). There were no significant interactions between time and group ($F_{10,58} = 0.67, P = .75$). Neither were there significant differences in soreness among groups ($F_{2,33} = 0.49, P = .62$.).

Relaxed-Elbow Extension Angle

There was a significant time effect for relaxed-elbow extension angle ($F_{5,29} = 13.59, P < .001$). Relaxed-elbow extension angles immediately postexercise and at 24, 48, 72, and 96 hours were all significantly different from pretest measures (Table 3). There were no significant interactions between time and group ($F_{10,58} = 0.79, P = .63$). Neither were there significant differences in relaxed-elbow extension angle among groups ($F_{2,33} = 0.83, P = .45$).

Strength

There was a significant time effect for strength decreases ($F_{5,165} = 56.13, P < .001$). Strength decreases immediately postexercise and at 24, 48, 72, and 96 hours were all significantly different from pretest measures (Table 4). There were no significant interactions between time and groups ($F_{10,165} = 0.62, P < .79$). Neither were there significant differences in strength decreases among groups ($F_{2,33} = 0.14, P < .87$).

DISCUSSION

DOMS usually has a gradual onset within 24 hours postexercise, peaks in intensity at 24 to 72 hours, and then declines. Symptoms gradually subside within 10 days postexercise.[1,2]

Table 1. Mean Circumference (cm) 4 cm Above the Elbow Joint by Treatment Group and Time

Group	Pretest	Time Postexercise				
		Immediately	24 h	48 h	72 h	96 h
Twice daily	23.3 ± 2.0	24.0 ± 2.0	23.6 ± 2.0	23.6 ± 2.0	23.6 ± 2.2	23.6 ± 2.1
Once daily	22.5 ± 1.9	23.0 ± 1.8	22.7 ± 1.8	22.8 ± 1.9	22.8 ± 1.9	22.8 ± 1.9
Placebo	22.2 ± 1.3	22.8 ± 1.3	22.5 ± 1.2	22.5 ± 1.2	22.4 ± 1.2	22.4 ± 1.2
Time mean	22.7 ± 1.8	23.3 ± 1.7*	22.9 ± 1.8*	23.0 ± 1.7*	22.9 ± 1.8*	22.9 ± 1.8*

* Immediately, 24, 48, 72, and 96 hours postexercise means were all significantly different from pretest mean.

Table 2. Mean Perceived Soreness Level of Elbow Flexors by Treatment Group and Time

Group	Pretest	Time Postexercise				
		Immediately	24 h	48 h	72 h	96 h
Twice daily	0.0 ± 0.0	0.9 ± 0.8	2.7 ± 0.5	2.7 ± 0.9	1.4 ± 0.9	0.5 ± 0.5
Once daily	0.0 ± 0.0	1.2 ± 0.9	2.5 ± 0.8	2.6 ± 0.8	1.2 ± 0.8	0.2 ± 0.5
Placebo	0.0 ± 0.0	1.5 ± 1.1	3.0 ± 1.0	2.5 ± 0.9	1.5 ± 0.9	0.2 ± 0.5
Time Mean	0.0 ± 0.0	1.2 ± 1.0*	2.7 ± 0.8*	2.6 ± 0.8*	1.4 ± 0.9*	0.3 ± 0.5

* Immediately, 24, 48, and 72 hours postexercise means were significantly different from pretest mean.

Table 3. Mean Relaxed-Elbow Extension Range of Motion (degrees) by Treatment Group and Time

Group	Pretest	Time Postexercise				
		Immediately	24 h	48 h	72 h	96 h
Twice daily	164.3 ± 3.5	159.2 ± 3.8	160.0 ± 4.1	158.2 ± 2.7	160.2 ± 3.9	161.0 ± 3.6
Once daily	162.7 ± 3.5	160.7 ± 4.7	160.2 ± 4.4	159.8 ± 4.4	160.7 ± 4.8	161.4 ± 4.2
Placebo	162.2 ± 4.0	158.5 ± 5.7	158.6 ± 5.2	156.2 ± 5.9	158.6 ± 5.2	159.5 ± 5.0
Time mean	163.1 ± 3.7	159.5 ± 4.7*	159.6 ± 4.5*	158.1 ± 4.6*	159.8 ± 4.6*	160.6 ± 4.3*

* Immediately, 24, 48, 72, and 96 hours postexercise means were all significantly different from pretest mean.

Table 4. Mean 1RM (kg) for Elbow Flexion by Treatment Group and Time

Group	Pretest	Time Postexercise				
		Immediately	24 h	48 h	72 h	96 h
Twice daily	5.8 ± 1.0	3.9 ± 1.2	4.2 ± 0.6	4.4 ± 0.9	4.7 ± 0.7	4.9 ± 0.9
Once daily	5.4 ± 1.2	3.8 ± 1.4	4.1 ± 1.4	4.3 ± 1.4	4.7 ± 1.3	4.9 ± 1.3
Placebo	5.5 ± 0.9	4.2 ± 0.8	4.2 ± 0.7	4.5 ± 0.9	4.9 ± 0.9	5.1 ± 0.7
Time mean	5.6 ± 1.1	3.9 ± 1.1*	4.2 ± 0.9*	4.4 ± 1.0*	4.8 ± 1.0*	4.9 ± 1.0*

* Immediately, 24, 48, 72, and 96 hours postexercise means were all significantly different from pretest mean.

DOMS allowed us to assess the effectiveness of pulsed ultrasound treatment on swelling, perceived soreness, loss of relaxed-elbow extension, and loss of strength over 96 hours. We also examined the effects of an immediate application of pulsed ultrasound on preventing or significantly decreasing the symptoms of DOMS.

Prevention

With the immediate postexercise application of pulsed ultrasound to the elbow flexors, we hoped to prevent or significantly decrease the symptoms of DOMS. Even with the immediate treatment, the symptoms associated with DOMS were equally prevalent in all groups at 24 hours postexercise. We, like previous investigators[20,21] using modalities to prevent symptoms of DOMS, did not find any significant prevention of or decrease in symptoms of DOMS with a treatment given immediately postexercise. Ice massage, ice massage with exercise, and exercise alone have not significantly prevented or reduced soreness, strength, or range-of-motion losses associated with DOMS.[20] In another study,[21] when massage, microcurrent electrical stimulation, upper body ergometry, and a postexercise resting control group were compared, treatments applied immediately and 24 hours postexercise did not prevent soreness or strength loss. Conversely, Mickey et al[23] suggested that a 20-minute ice pack application followed by pulsed ultrasound (7 minutes at 20% duty cycle, 1

MHz, 1.0 W/cm^2) applied immediately postexercise and once daily for 3 days may be more effective than ice alone for the prevention and treatment of DOMS.

Treatment

DOMS is temporary, repairable damage to muscle.[1,11,33] We used pulsed ultrasound in this study because the mechanical effects, stable cavitation, and microstreaming are believed to aid tissue regeneration and healing.[34–36] Acoustic microstreaming and cavitation increase the diffusion of ions and metabolites across cell membranes and enhance the reparative process.[37] Changes in calcium permeability are associated with enhanced tissue healing.[37] Increased sodium permeability may reduce pain and spasm by altering neural activity.[37] Any significant evidence of circumference, perceived soreness, relaxed-elbow extension angle, or strength measures returning to pretest measures at a faster rate would have indicated healing and a treatment effect. We did not find any evidence of a treatment effect.

Circumference

Previous investigators[4,16,19] have claimed the degree of soreness DOMS produces is influenced by increased muscle pressure causing swelling within the exercised muscular area.

Other researchers[22,38,39] have shown that DOMS is not caused by increased muscle pressure and swelling. Swelling has been observed as a similar response in DOMS and acute inflammation, yet DOMS has been shown to be different from an acute inflammatory response.[28,33] When pulsed ultrasound has been endorsed[24,37,40] as successful in treating swelling, it was being used to treat an acute inflammatory response. We found that the treatments did not reduce swelling in DOMS.

Soreness

Our exercise protocol induced soreness in the elbow flexors in all the participants of our study. The time course of DOMS was consistent with other studies[18-22] using modalities on DOMS. Previous researchers[19] observed that pulsed ultrasound alleviated muscle soreness perception of DOMS at 48 hours. In our study, as in previous studies,[21,22] the mean values for perceived soreness at 24 hours and 48 hours were statistically the same for all treatment groups.

There were many differences between our study and the former study[19] that might have influenced soreness perception. Groups in our study had (a) multiple treatments (from 0 to 7 applications) at multiple times; (b) continual movement of the ultrasound transducer (1 MHz, 1.5 W/cm² temporal peak intensity, 7 minutes, 20% duty cycle); (c) a 5 × 10-cm treatment site on the upper extremity; and (d) strength measures based on a small muscle group (elbow flexors). Conversely, groups in the previous study[19] had (a) 1 treatment at 24 hours postexercise; (b) stationary positioning of the ultrasound transducer (1 MHz, 0.8 W/cm², 20 minutes, 20% duty cycle); (c) 2 36-cm treatment sites on the lower extremity; and (d) strength measures based on a large muscle group (quadriceps).

Relaxed-Elbow Extension Angle

Little research has been performed on range of motion and pulsed ultrasound. Continuous ultrasound, with its thermal effects, is normally used when an increase in range of motion is desired.[41] In our study, all groups significantly changed in relaxed-elbow extension angle immediately postexercise, and this change remained significant through the final assessment. The greatest mean loss (5°) in relaxed-elbow extension from pre-exercise measures was at the 48-hour postexercise assessment. We did not find pulsed ultrasound to significantly restore relaxed-elbow extension angle.

Strength

Pulsed ultrasound has been used in the past for stable cavitation and microstreaming to heal injured muscle. Loss of strength is a sign of injured muscle.[2-4,7,19] Hasson et al[19] observed that the percentage deviations from baseline for isometric contraction, maximum-extension torque, and knee-extension work were significantly less at 48 hours for subjects who received pulsed ultrasound compared with placebo treatment and control subjects. The authors concluded that pulsed ultrasound accelerates restoration of normal muscle performance and, thus, was effective in decreasing DOMS. Our results differed: for all groups, the 1RM strength values decreased equally and then slowly increased over the 5-day assessments, yet no group was able to achieve its original 1RM mean.

CONCLUSIONS

Pulsed ultrasound as used in our study did not significantly diminish the effects of DOMS on soreness perception, swelling, relaxed-elbow extension angle, or strength. Other protocols using ultrasound may be effective in reducing symptoms of DOMS. Further studies are needed, however, to establish this effectiveness.

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