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EFFECT OF PULSED ULTRASOUND VERSUS PLACEBO ON MUSCLE SORENESS PERCEPTION AND MUSCULAR PERFORMANCE

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ABSTRACT. The purpose of this study was to compare the analgesic effect of pulsating ultrasound treatment and placebo on delayed onset of muscle soreness produced by an eccentric exercise bout. In addition, the effect of pulsed ultrasound on muscular performance following an eccentric exercise bout was studied. Eighteen untrained subjects were randomly assigned to: 1) ultrasound (A) [$N=6$] over the areas of concentrated muscle soreness, i.e. proximal vastus lateralis and distal vastus medialis; 2) placebo ultrasound (B) [$N=6$]; and 3) no therapeutic intervention (C) [$N=6$]. Baseline data were recorded for maximum isometric knee extension contraction (MVC), maximum knee extension torque (MT), knee extension work (W), and soreness perception (SP). All values were subsequently reassessed 24 and 48 hours after intense muscular activity. Immediately following the 24 hour reassessment the A group received ultrasound treatment, the B group received placebo ultrasound, while the C group received no treatment. Percent deviation from baseline of SP, MVC, MT and W were significantly less for A than B and C ($p<0.05$) at 48 hours post muscle soreness bout. These data indicate that pulsed ultrasound accelerates restoration of normal muscle performance, and thus is effective in decreasing delayed onset of muscle soreness. The mechanism for decreasing soreness perception in the muscle is unknown, but may be related to decreasing intramuscular pressure and/or decreasing the inflammatory response.

Key words: eccentric exercise, muscle soreness, performance, ultrasound.

Two of the more common adverse side-effects resulting from physical training and rehabilitation are muscular pain and soreness. At least two types of muscle pain and soreness have been identified that can occur during or following exercise. Muscle pain occurring during an exercise bout of high intensity is believed to be related to ischemia and increased muscle lactate (7). This type of muscle discomfort requires no therapeutic intervention. Muscle soreness development following exercise incorporating eccentric or "lengthening" contractions is believed to be related to muscle and connective tissue damage (3, 4, 13, 23, 29). This muscle discomfort has been described in the literature as "delayed onset" (DOMS), and is usually perceived approximately 24 hours after the exercise bout (1, 30). Muscle soreness may linger for an additional 24 to 48 hours depending upon the severity of the exercise activity (1, 30). Tissue damage is unavoidable during types of training incorporating heavy load eccentric muscle contractions (3), and is followed by an inflammatory response with cellular infiltration of lymphocytes and granulocytes (2, 28). In conjunction with tissue injury is an influx of fluid into the muscle resulting in an elevation of intramuscular pressure (15, 16). Group IV sensory neurons that terminate in the muscle connective tissue between myofibers may be sensitive to increased osmotic pressure and thus carry the sensation of dull diffuse pain associated with DOMS (6, 26).

Therapy for inflammation and DOMS currently employs the use of topical application of thermal agents (25) and orally administered analgesics and antiinflammatories (24, 27). Pulsed ultrasound has been advocated to enhance tissue regeneration (8, 9, 33); reduce inflammation (10, 11, 17); and decrease pain (12, 20, 34). However, the therapeutic use of pulsed ultrasound in reduction of DOMS has not been documented. This is unfortunate since pulsed ultrasound may decrease muscle edema and reduce intracompartmental pressures. Thus, the purpose of this investigation was to determine the effect of pulsed ultrasound on muscle soreness perception and muscular performance.

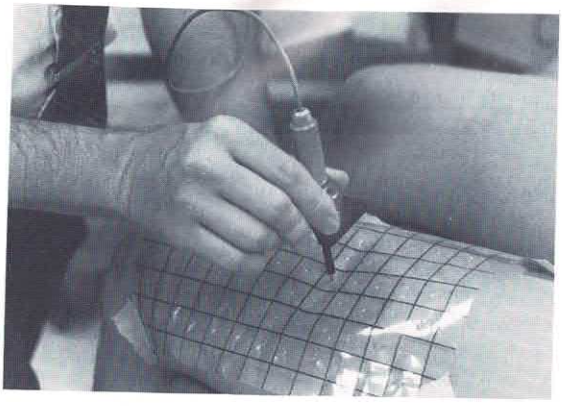


Fig. 1. Instrumentation utilized to determine muscle soreness.

METHODS

Subjects

Eighteen subjects (age 20–35), free of orthopaedic limitations and not actively involved in a weight-training program nor ingesting anti-inflammatory medications participated in this investigation. All subjects were familarized with the experimental procedures and possible risks involved, and provided written informed consent that had been approved by the Committee on Human Experimentation. Prior to initiation of the study all subjects were evaluated for cardiorespiratory fitness on the basis of blood pressure and EKG changes associated with submaximal exercise (approximately 80% of maximum heart rate) utilizing a cycle ergometer and the Astrand-Rhyming technique (5). In addition, a careful orthopaedic evaluation of the lower extremities was performed.

Procedures

Subjects reported to the laboratory on three different occasions throughout the study, each time in a fasted state. On the first visit, the subjects were randomly assigned to one of the three groups. Each group had six subjects. The three programs employed for this study were: 1) pulsed ultrasound (A); 2) placebo ultrasound (B): ultrasound performed without power; and 3) control (C): No treatment. A double-blind procedure was utilized throughout the investigation, in which the physical therapist providing treatment was unaware of which subject received A or B treatment. On the initial visit, the subjects' baseline muscle performance and muscle SP were determined prior to the muscle soreness bout.

The muscle soreness exercise bout consisted of stepping up on a bench with the right leg (concentric) and lowering the body weight down (eccentric) with the left leg. The height of the bench was 110% of the lower leg length (floor to knee joint line) and the subject carried an additional load of 10% of body weight. The exercise bout lasted 10 min at a stepping frequency of 15 cycles/min (21). Following the exercise bout the subjects were instructed as to what activities were to be avoided (massage, exercise, thermal modalities, caffeine ingestion, smoking or anti-inflammatory drug use) during the study.

For the second visit, subjects reported 24 hours post exercise, and muscle performance and muscle SP were re-evaluated. Each of the three groups then received their respective treatment. The A group received ultrasound at an intensity of 0.8 watts/cm, pulsed 1:4 ratio (2 milliseconds on, 8 milliseconds off), at a frequency of 1.0 MHz (Mettler Electronics Corp, Sonicator 706, Anaheim, CA). This treatment intensity has been demonstrated to elicit both an anti-inflammatory effect and fluid streaming in tissue (9, 35). The ultrasound therapy lasted for 20 min at each 36 cm site (distal head of vastus medialis and proximal head of vastus lateralis). These were the two areas of most intense muscle soreness perception in all subjects. The ultrasound head was held stationary and insonated 28.3 cm of the targeted area. The B group underwent the exact same procedure, but with the ultrasound unit being shut off during the treatment cycle. The C group did not receive any therapeutic treatment.

On the third visit, 48 hours post exercise, muscle performance and muscle SP were again evaluated.

Measurements

Muscle performance was evaluated each day utilizing the Omnitron dynamometer (Hydrafitness Industries, Belton, TX) and the Cybex II isokinetic dynamometer (Lumex, Inc., Ronkonkoma, NY). The Omnitron was used to assess maximum knee extension torque [MT] (measured at low velocity/high resistance; setting 10–5 repetitions, with the average determined as MT) and knee extension work [W] (measured at high velocity/low resistance; setting 2–20 repetitions, with the total determined as W). The subject was placed in the Omnitron unit so that the axis of the knee joint was directly in line with the axis of the goniometer. The subject was instructed to give maximum efforts for each repetition and informed to flex and extend the knee through the entire range of motion as forceful and rapidly as possible. Data was collected for W on both knee joints with 15 min of recovery before data collection of MT. The Cybex II was utilized to evaluate maximum isometric knee extension contraction [MVC] (measured at a knee angle of 60 degrees of flexion, with the subjects' knee positioned in line with the axis, and pelvis and thigh securely stabilized). Three measurements were taken with a resting period of 5 min between contractions, with the average determined as MVC (21).

Muscle soreness perception (SP) was evaluated each day in the following fashion. A polyurethane sheet marked with a grid of intercepts 2 cm apart, was attached to the anterior thigh of the subject (trimmed to cover the entire quadriceps musculature) with the skin marked to ensure constant positioning in subsequent evaluation. A round-ended metal probe (2 mm tip diameter) was attached to a load cell (SensorMedics Model UL4–50, Anaheim, CA) and strain gauge (Gould-Statham Model UTC3, Dayton, OH). The probe instrument was interfaced to the R511A SensorMedics Dynagraph via a voltage/pulse/pressure coupler (SensorMedics Model 9853A, Anaheim, CA). The amplified force signal was displayed on an oscilloscope (Hewlett-Packard Model 1741A, Colorado Springs, CO) and recorded (R511A SensorMedics Dynagraph Chart Recorder, Anaheim, CA) for further analysis. At each test site, a gradually increasing force was applied upto a maximum of 50 Newtons (Fig. 1). The subject was asked to verbally indicate when the sensation of pressure changed to one of discomfort. The amount of force (Newtons) was then recorded. If no indication of discomfort was reported upto 50 N, soreness was not considered to be present at the site. The

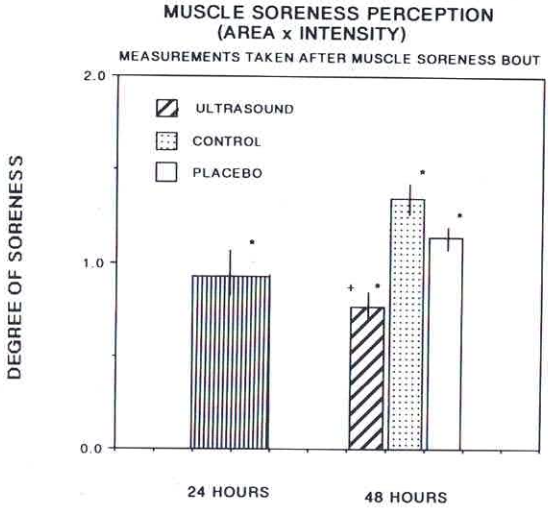


Fig. 2. Muscle soreness perception (area × intensity) of the quadriceps. Data are reported as mean ±SD. * denotes a difference between baseline and other time measures, + denotes a difference between ultrasound, and the control and placebo treatments at 48 hours ($p<0.05$).

degree of muscle soreness was defined as the inverse of the amount of force applied to the targeted area needed to elicit a change in the subject's perception of pressure to that of soreness. The mean intensity for each subject was the summated values divided by the number of individual areas testing positively for muscle soreness. Although this measure is a combination of objective and subjective data, the test–retest correlation was relatively high in pilot data ($r=0.91$). The area of muscle soreness was defined as the estimate of the amount of the quadriceps muscle that had muscle soreness. This value was obtained by testing at each 2 cm site, and dividing the number of areas testing positively by total testing sites. A standard pattern of testing the quadriceps requiring 7 to 10 min to perform was developed (21, 22). Testing SP was always initiated at the medial-distal quadriceps and proceeded in a direction of left to right until the lateral border was reached. Testing then continued from right to left on the next proximal row. This "switch back" testing was performed until the final proximal row was evaluated. Each site tested was 2 cm away from neighboring tested sites. The proximity of testing sites may influence pain threshold, however test/retest pilot data indicate a high reliability in this method. The muscle SP for each subject was then calculated (product of intensity and area).

Statistics

For this experiment, a two-factor factorial design was employed. Factor one was the measurement day, while factor two was the treatment group. To determine the effects of the treatment, days of recovery, and their interaction on the muscle SP and muscle performance variables a two-way ANOVA, adjusted for repeated measures across measurement day (split plot) was utilized. Significance was established at $p<0.05$.

RESULTS

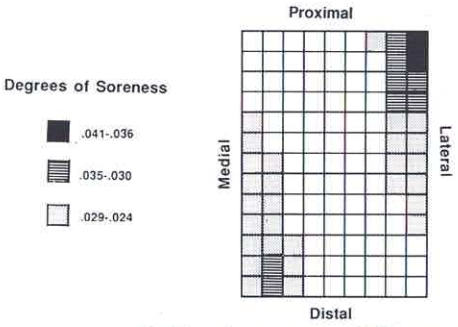
The result for muscle SP is given in Fig. 2. No muscle soreness was present in any of the eighteen subjects before performing the muscle soreness exercise bout. The muscle SP was significantly greater ($p<0.05$) at 24-hours than prior to the muscle soreness bout for all groups. There was no significant difference between groups at 24 hours. The location of the muscle soreness was consistant within all subjects. The involved areas were: 1) distal head of vastus medialis and 2) proximal head of vastus lateralis. The rectus femoris was spared (Fig. 3). The muscle SP was less for the A group than B or C ($p<0.05$) at 48 hours. The A group muscle SP decreased slightly from 24 to 48 hours (non-significant) 0.78 to 0.74. The B and C group muscle SP significantly increased from 24 to 48 hours (0.92 to 1.35 and 0.77 to 1.14, respectively).

The results for muscle performance are given in Figs. 4, 5 and 6. The results are depicted as percent change (decline) from baseline measurements. MVC, MT and W were all significantly less at 24 hours compared to baseline for all groups ($p<0.05$). There were no significant difference between groups at 24 hours (Figs. 4, 5 and 6). Following therapeutic intervention, the muscular performance of the A group at 48 hours was significantly greater than the B or C groups ($p<0.05$). MVC for the A group was 8.3% below baseline as compared to 16.7% and 20.3% for B and C groups respectively (Fig. 4). MT for the A group was 4.9% below baseline versus 18.4% (B) and 23.1% (C) (Fig. 5). The A group W was 8.0% below baseline as compared to the B group (16.1%) and C group (23.4%) (Fig. 6). However, muscular performance of the A group was still significantly less than baseline for MVC, MT and W (Figs. 4, 5 and 6).

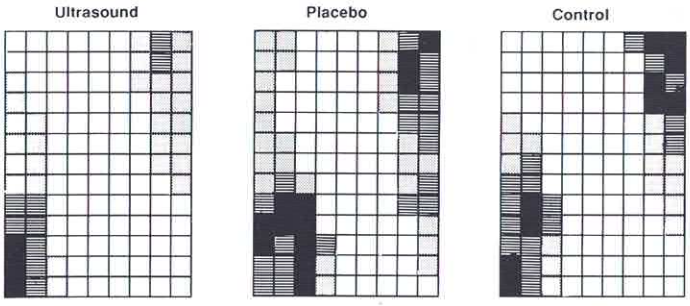
DISCUSSION

Pulsed ultrasound has been utilized for tissue regeneration, inflammation reduction, and pain modulation. It appears that tissue regeneration and the anti-inflammatory response may be related to the vigorous mechanical streaming of fluid elements within the treated tissue during the pulsed ultrasound procedure (9, 12, 35). However, the physiological basis of pain modulation, utilizing pulsed ultrasound treatment is unknown, but may also be related to mechanical oscillation of tissue and fluid streaming within muscle compartments. This streaming may alter vascular permeability (19) and thus lessen the pressure gradient

A. The quadriceps area examined



B. Muscle soreness, 24 hours post exercise



C. Muscle soreness, 48 hours post exercise

Fig. 3. Location of muscle soreness over time. Areas affected were vastus medialis (distal) and vastus lateralis (proximal) with rectus femoris spared.

across the myomysium. Other mechanisms of action have been postulated for decreasing pain, such as modification of the release of prostaglandin and histamine (18, 32). However, in these studies, pulsed ultrasound was delivered early (minutes or hours after trauma) when the inflammatory response was acute and vigorous.

In previous investigations examining the effectiveness of various therapeutic modalities on delayed onset muscle soreness (21, 22), evidence supports the notion that a mechanical based therapeutic intervention (concentric muscle contraction with alternating agonist antagonist action) at 24 hours post soreness bout appears to be superior to anti-inflammatory intervention (dexamethasone) for normalizing muscle performance and decreasing progression of muscle soreness perception. Results from the present investigation appear to further support the hypothesis that DOMS and muscle edema may be most beneficially affected by a mechanical therapeutic modality.

Elevated intracompartmental pressures and muscle edema are a direct result of inflammation in response to damaged connective and muscle tissue. This relationship brings up questions as to when is the best time to treat an individual to minimize muscle discomfort. The inflammatory response begins quite early (within several hours) after initial tissue damage (2, 31). Therefore, it seems reasonable to assume that if

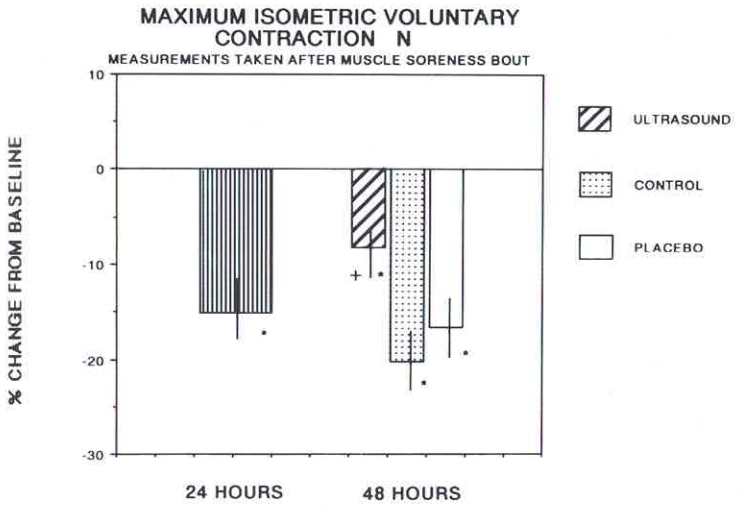


Fig. 4. Maximum voluntary contraction (isometric) of the quadriceps (expressed as a % change from baseline measures for the ultrasound, placebo, and control groups). Data are reported as mean ±SD. * denotes a difference between baseline and other time measures, + denotes a difference between ultrasound, and the control and placebo treatments at 48 hours ($p<0.05$).

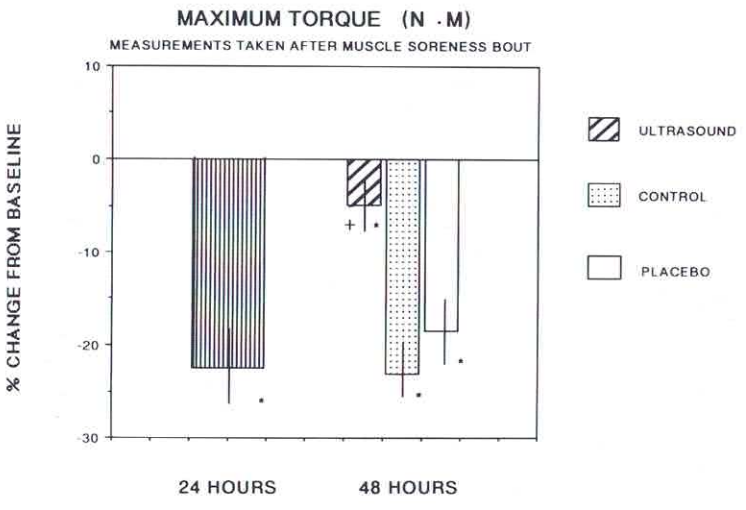


Fig. 5. Maximum torque production [power] (at high resistance) of the quadriceps (expressed as a % change from baseline measures for the ultrasound, placebo, and control groups). Data are reported as mean ±SD. * denotes a difference between baseline and other time measures, + denotes a difference between ultrasound, and the control and placebo treatments at 48 hours ($p<0.05$).

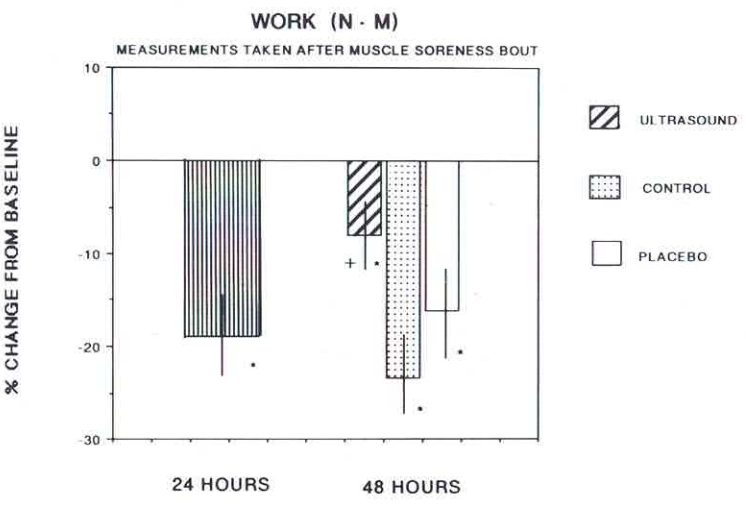


Fig. 6. Work output (at low resistance) of the quadriceps (expressed as a % change from baseline measures for the ultrasound, placebo, and control groups). Data are reported as mean ±SD. * denotes a difference between baseline and other time measures, + denotes a difference between ultrasound, and the control and placebo treatments at 48 hours ($p<0.05$).

controlling initial inflammation is the goal, then an anti-inflammatory drug or proven modality should be administered immediately after the offending exercise bout. Besides early intervention, pre-exercise prophylactic utilization of anti-inflammatory drugs does occur in both the clinical and sports-athletic arena. However, objective data does not exist to currently warrant this practice. In most cases, patients do not complain about muscle discomfort or seek intervention until a day or two after the activity. By this time the initial inflammatory stage is completed, muscle edema and elevated intracompartmental pressures are present, and presumably the repair process is underway (14). Therapeutic intervention during this time period (24 to 48 hours) should be primarily directed toward decreasing muscle edema, but also minimizing any further inflammation.

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