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Abstract

Andersen, LL, Jay, K, Andersen, CH, Jakobsen, MD, Sundstrup, E, Topp, R, and Behm, DG. Acute effects of massage or active exercise in relieving muscle soreness: randomized controlled trial. *J Strength Cond Res* 27(12): 3352–3359, 2013—Massage is commonly believed to be the best modality for relieving muscle soreness. However, actively warming up the muscles with exercise may be an effective alternative. The purpose of this study was to compare the acute effect of massage with active exercise for relieving muscle soreness. Twenty healthy female volunteers (mean age 32 years) participated in this examiner-blind randomized controlled trial (ClinicalTrials.gov NCT01478451). The participants performed eccentric contractions for the upper trapezius muscle on a Biodex dynamometer. Delayed onset muscle soreness (DOMS) presented 48 hours later, at which the participants (a) received 10 minutes of massage of the trapezius muscle or (b) performed 10 minutes of active exercise (shoulder shrugs 10 × 10 reps) with increasing elastic resistance (Thera-Band). First, 1 treatment was randomly applied to 1 shoulder while the contralateral shoulder served as a passive control. Two hours later, the contralateral resting shoulder received the other treatment. The participants rated the intensity of soreness (scale 0–10), and a blinded examiner took measures of pressure pain threshold (PPT) of the upper trapezius immediately before treatment and 0, 10, 20, and 60 minutes after treatment 48 hours posteccentric exercise. Immediately before treatment, the intensity of soreness was 5.0 (*SD* 2.2) and PPT was 138 (*SD* 78) kPa. In response to treatment, a significant *treatment by time* interaction was found for the intensity of soreness ($p < 0.001$) and PPT ($p < 0.05$). Compared with control, both active exercise and massage significantly reduced the intensity of soreness and increased PPT (i.e., reduced pain sensitivity). For both types of treatment, the greatest effect on perceived soreness occurred immediately after treatment, whereas the effect on PPT peaked 20 minutes after treatment. In conclusion, active exercise using elastic resistance provides similar acute relief of muscle soreness as compared with that using massage. Coaches, therapists, and athletes can use either active warm-up or massage to reduce DOMS acutely, for example, to prepare for competition or strenuous work, but should be aware that the effect is temporary, that is, the greatest effects occurs during the first 20 minutes after treatment and diminishes within an hour.

Introduction

Muscle soreness is a common experience after unaccustomed physical exertion. For example, athletes may experience sore leg muscles after prolonged running, and nonathletes may experience sore back and neck muscles after strenuous physical labor. Delayed onset muscle soreness (DOMS)—soreness presenting 1–3 days after activity and gradually fading in 5–7 days—has been extensively referenced in the literature in relation to training and recovery ([4,7,10,16]). Researchers have suggested several causative factors of DOMS including lactic acid, muscle spasm, connective tissue damage, muscle damage, inflammation, enzyme efflux, and free radicals ([10,12]). Delayed onset muscle soreness is often attributed to eccentric muscle contractions known to more severely induce microinjury of the connective tissue and muscle fibers than static and concentric contractions ([7,10,16]).

Delayed onset muscle soreness temporarily impairs athletic performance, work ability, and physical functioning. For instance, reduced joint flexibility and loss of muscle strength are observed consequences of DOMS ([11]). Therapists frequently administer massage to athletes to aid recovery, warm-up for training or competition, and relieve muscle soreness ([6,8,14,22]). However, a skilled massage therapist may not always be available. Thus, the efficacy of simple and efficient complementary therapies to relieve DOMS needs to be explored.

Previous research can be categorized into prevention and treatment of DOMS. Research studies investigating the prevention of DOMS commonly include interventions such as massage ([28]), stretching ([23]), or low-intensity exercise ([26]) administered before or immediately after strenuous activity. Other studies have focused on the treatment of DOMS, that is, relieving pain symptoms 48–72 hours after activity using for instance massage techniques ([28]) or stretching ([23]). A Cochrane review concluded that stretching neither prevents nor relieves exercise-induced DOMS ([23]). Massage administered 48–72 hours after unaccustomed physical exertion appears to reduce DOMS, but few well-designed studies exist ([28]). A randomized controlled trial showed increased pressure pain threshold (PPT) after massage in adults with DOMS in the trapezius muscles ([19]). Actively warming up the muscles with physical exercise when DOMS is present is another possibility, which can easily be administered and implemented in many different settings. A study found that light concentric exercise had an acute analgesic effect on DOMS ([40]). However, randomized controlled trials directly comparing the effect of massage and active exercise for relieving DOMS are needed to provide better guidelines.

The aim of this study was to compare the acute effect of massage with active exercise for relieving DOMS presenting 48 hours after unaccustomed physical exertion. We hypothesized that both massage and active exercise would reduce DOMS compared with a control condition, and that active exercise would result in a similar relief of DOMS compared with that of massage.

Methods

Experimental Approach to the Problem

We performed an examiner-blinded randomized controlled trial (ClinicalTrials.gov NCT01478451) in a laboratory setting in Copenhagen, Denmark. Delayed onset muscle soreness was induced by eccentric contractions for the upper trapezius muscle on a Biodex dynamometer. When soreness presented 48 hours later, the participants (a) received 10 minutes of massage of the trapezius muscle or (b) performed 10 minutes of active exercise (shoulder shrugs 10 × 10 reps) with increasing elastic resistance (Thera-Band, Hygenic Corporation, Acron, OH, USA). First, 1 treatment was randomly applied to one shoulder while the contralateral shoulder served as a passive control. Two hours later, the contralateral resting shoulder received the other treatment. The participants rated the intensity of soreness (scale 0–10) and a blinded examiner took measures of PPT of the upper trapezius immediately before treatment and 0, 10, 20, and 60 minutes after treatment. Data were analyzed using repeated measures analysis of variance.

Subjects

Recruitment of the participants started in November 2011, and the study was completed in January 2012. Figure 1 shows the flow of participants through the trial. Inclusion criteria were (a) female and (b) age 18–67 years. Exclusion criteria were (a) hypertension >160/100 mm Hg, (b) musculoskeletal disease of the back or neck, (c) life-threatening disease, and (d) being unavailable during the study period. A total of 20 women were included in the study (Table 1).

Figure 1: Flow of participants through the study.

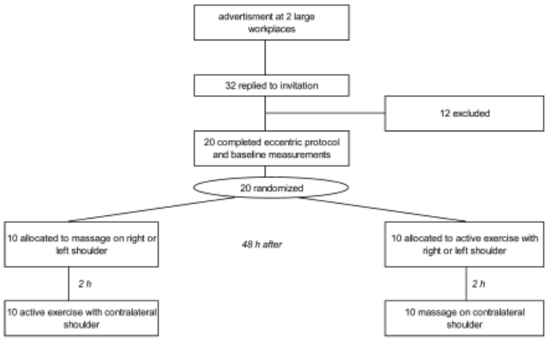

Table 1: Baseline demographics, outcome expectations, and clinical measurements (n = 20).*†

	Mean (SD) or percentage of participants
Demographics	
Age, y	32 (11)
Height, cm	169 (6)
Weight, kg	71 (15)
Number of women/men	20/0
Outcome expectations before study	
Massage causes (%) Less soreness	90
No change in soreness	5
More soreness	5
Active exercise with elastic resistance causes (%) Less soreness	55
No change in soreness	20
More soreness	25
Clinical measurements	
Before eccentric protocol Muscle soreness, scale 0–10	0.8 (1.1)
Pressure pain threshold trapezius, kPa	197 (75)
48-h After eccentric protocol, before treatment Muscle soreness, scale 0–10	5.0 (2.2)
Pressure pain threshold trapezius, kPa	138 (78)

*Outcome expectations before the study favored massage over active exercise (x2, p , 0.05).
†The eccentric protocol caused a significant increase in perceived soreness (p , 0.001) and decrease in pressure pain threshold (p , 0.001).

All the participants were informed about the objective and content of the project and gave written informed consent to participate in the study that conformed to The Declaration of Helsinki, and was approved by the Local Ethical Committee (H-3-2010-062). The trial was registered in ClinicalTrials.gov (NCT01478451) before the enrollment of the participants.

Procedures

For clarity, this section is divided into description of the randomization process, the protocol used to induce soreness, the treatments tested, the measurements used for quantification of soreness, and finally the statistical procedures.

Randomization

Using a computer-generated random numbers table, the participants were allocated to active exercise for the right or left shoulder followed 2 hours later by massage on the contralateral shoulder (n = 10), or to massage on the right or left shoulder followed 2 hours later by active exercise with the contralateral shoulder (n = 10). In this way, massage and active exercise were never performed on the same shoulder to avoid carryover effects from the first to the second round. In both situations, the passive shoulder served as control. In this way, data for active exercise, massage and control were obtained for all the participants, allowing for a balanced and paired statistical design. One author (L.L.A.) performed the randomization, and a physical therapist informed the participants of their respective allocation.

Induction of Soreness

Using a Biodex Medical isokinetic dynamometer (System 3 Pro, Brookhaven R&D Plaza, NY, USA), the participants performed eccentric contractions for the upper trapezius muscle during the first visit to the laboratory. The participant was standing erect with arms to the side and performed maximally resisted shoulder shrugs through a full range of motion. The participant relaxed the shoulders when the handle of the dynamometer traveled upward (i.e., the concentric phase) and resisted with maximal voluntary effort when the handle traveled downward (i.e., the eccentric phase). The participants performed 3 low- to moderate-intensity warm-up sets with 15 repetitions and then a total of 10 sets with 10–15 repetitions of maximal voluntary eccentric contractions: 10 repetitions at slow velocity ($30°\cdot s^{-1}$) during the first 4 sets, 15 repetitions at medium velocity ($60°\cdot s^{-1}$) during the next 4 sets, and 15 repetitions at high velocity ($90°\cdot s^{-1}$) during the final 2 sets. One minute of rest was given between each set. A computer screen provided visual feedback of the force output during all sets. Delayed onset muscle soreness presented 48 hours later. The participants were asked to refrain from physical exercise during the 48 hours after eccentric exercise.

Interventions

On the second visit to the laboratory, that is, 48 hours after the eccentric protocol, the participants were randomly assigned to receive one of the aforementioned combinations of massage and active exercise. The duration of 10 minutes for both treatments was chosen from a practical perspective, that is, to achieve a certain degree of warm-up yet not too long to fatigue the muscles and hinder implementation in most field settings.

For the massage protocol, an experienced massage therapist provided 10 minutes of massage on the right or left upper trapezius muscle while the contralateral shoulder was made to relax. The participant was lying prone on a massage couch. Massage involves various types of pressure, friction, and rubbing ([22]). In this study, the therapist used both petrissage, that is, kneading and friction, and effleurage, that is, a succession of light and deep stroking and gliding motions. The force used was adjusted according to the participant's level of soreness.

For the active exercise protocol, the participant performed unilateral shoulder shrugs with the Thera-Band elastic tubing, that is, elevating one shoulder while relaxing the contralateral shoulder. The participant was standing erect with 1 foot on the elastic tubing, which was elongated to 150% of resisting length. Within a 10-minute period, the participants performed 10 sets with 10 repetitions for a total of 100 repetitions. The participants used red elastic tubing during the first 3 sets, green elastic tubing during the next 3 sets, and blue elastic tubing during the final 4 sets, corresponding to 2-, 3-, and 4-kg resistances, respectively ([1]). Each set was completed in approximately 20 seconds allowing for 40 seconds of rest between sets.

Primary Outcomes

The primary outcomes determined 48 hours after the eccentric protocol were differences between the experimental shoulder compared with the control shoulder in (a) perceived soreness and (b) PPT of the upper trapezius muscle from immediately before treatment to 0, 10, 20, and 60 minutes after treatment (Table 2). For descriptive purposes and to habituate the participants with the test procedures, these measurements were also performed during the first visit to the laboratory before the eccentric protocol (Table 1).

Table 2: Between-treatment least square mean differences and 95% confidence intervals at the different time points.*†

	Time (min)	Active exercise vs. control	Massage vs. control	Massage vs. active exercise
NRS	Before	0.1 (0.5 to 20.3)	0.0 (0.4 to -0.4)	-0.1 (0.3 to -0.6)
	0	**-1.1 (-0.7 to -1.6)**	**-1.0 (-0.6 to -1.4)**	0.1 (0.6 to -0.4)
	10	**-0.8 (-0.4 to -1.2)**	**-0.7 (-0.3 to -1.1)**	0.1 (0.6 to -0.4)
	20	**-0.6 (-0.2 to -1.0)**	**-0.5 (-0.1 to -0.9)**	0.1 (0.5 to -0.4)
	60	**-0.5 (-0.1 to -0.9)**	-0.3 (0.1 to -0.7)	0.2 (0.6 to -0.3)
PPT	Before	-2 (9 to -13)	-1 (10 to -12)	1 (14 to -12)
	0	7 (18 to -4)	**17 (28 to 6)**	10 (22 to -3)
	10	**22 (34 to 11)**	**18 (29 to 7)**	-4 (9 to -17)
	20	**22 (33 to 11)**	**14 (26 to 3)**	-8 (5 to -21)
	60	**14 (25 to 3)**	**12 (23 to 1)**	-2 (11 to -14)

*NRS = numerical rating scale (0–10) of intensity of soreness; PPT = pressure pain threshold (kPa).
†Significant findings are marked in bold.

The participants were asked to rate perceived soreness of the left and right trapezius muscle on a numerical rating scale of 0–10, where 0 is “no soreness” and 10 is the “worst imaginable soreness.” The rating scale was horizontally oriented to represent a modified visual analog scale ([33]).

Using an electronic pressure algometer (Somedic, Hörby, Sweden), an examiner blinded to group allocation measured PPT of the left and right upper trapezius muscles. The contact area of the circular probe was 1 cm^2. Pressure was applied at a rate of 30 $kPa \cdot s^{-1}$ perpendicular to the skin at the 5 points in each side: at the midbelly of the muscle and 1 and 2 cm laterally and medially of this point. For the upper trapezius, the midbelly was determined as midway between the acromion to the seventh cervical vertebrae. The participant was instructed to clearly state when the sensation of “pressure” changed to “pain.” At each time point (immediately before and 0, 10, 20, and 60 minutes after the intervention), PPT was measured once at each of the 5 measurement sites in both the right and the left trapezius. Subsequently, PPT was expressed as the average value of the 5 sites for each shoulder at each time point. Previous studies have shown satisfactory to good test-retest reliability of PPT ([32,38]).

Outcome Expectations

Because outcome expectations can influence subjective pain ratings ([34]), we included the following question in the screening questionnaire: “To what extent do you believe that the following affects muscle soreness in the neck and shoulders?” (a) massage and (b) active exercise with elastic resistance. The response options were “causes less soreness,” “causes no change in soreness,” and “causes more soreness.”

Sample Size

Power calculations performed before the study showed that 20 participants in a paired design were necessary for testing the null hypothesis of equality of treatment at an alpha level of 5%, a statistical power of 80%, an *SD* of 1.5 and a minimally relevant difference in the intensity of soreness of 1 on a scale of 0–10 ([15]).

Statistics

Using the Mixed procedure of SAS (SAS institute, Cary, NC, USA, version 9.2), we performed a repeated measures 2-way analysis of variance to model the changes in (a) perceived soreness and (b) PPT. The independent variables *treatment* (massage, active exercise, control), *time* (immediately before and 0, 10, 20, and 60 minutes after treatment) and the interaction *treatment by time* were entered in the model as fixed effects. *Subject* (i.e., each individual participant) was entered in the model as a random effect. When a significant main effect or interaction was found post hoc tests were performed to locate differences. The values for each treatment at the different time point are reported as means (*SD*) and differences between treatments at each time point as least square means (95% confidence intervals), unless otherwise stated. The *p* values of <0.05 were accepted as statistically significant.

On an exploratory basis, we tested the influence of outcome expectations on the change in perceived soreness and PPT by entering *outcome expectations* ("causes less soreness," "causes no change in soreness," and "causes more soreness") and *time* (immediately before and 0, 10, 20, and 60 minutes after treatment) and *outcome expectations by time* in the analysis of variance stratified for treatment.

Finally, we calculated effect sizes as Cohen's *d* ([13]) at each time point (between-group differences divided by the pooled *SD*).

Results

Table 1 shows descriptive characteristics of the participants. At baseline, before the eccentric protocol (i.e., day 1), perceived soreness was 0.8 (1.1) on a scale of 0–10, and PPT was 197 (75) kPa. 48 hours later (i.e., day 3), immediately before treatment perceived soreness was 5.0 (2.2) and PPT 138 (78), showing induction of DOMS.

Complete data were obtained for all the 20 participants according to the randomization. A significant *treatment by time* interaction was found for perceived soreness ($p < 0.001$) and PPT ($p < 0.05$). Table 2 shows least square mean differences and 95% confidence intervals for perceived soreness and PPT between the treatments at the different time points. Compared with control, both active exercise and massage significantly reduced perceived soreness and increased PPT at most time points. No significant differences were observed between massage and active exercise at any time points, although compared with control, only massage showed significant effect on PPT at 0 minutes and only active exercise showed a significant effect on perceived soreness at 60 minutes.

Figure 2 illustrates the timewise change in perceived soreness and PPT. Perceived soreness adapted quickly, with the greatest effect observed immediately after treatment. Pressure pain threshold adapted more slowly, peaking 20 minutes after treatment.

Figure 2: Perceived intensity of soreness (numerical rating scale [NRS] 0–10) (A) and pressure pain threshold (PPT) (B) of the upper trapezius muscle immediately before (−10 minutes) and 0, 10, 20, and 60 minutes after 10 minutes of massage, active exercise, and passive control. Values are least square means andSE. § Active exercise significantly different from Control, p < 0.001–0.05. # Massage significantly different from Control, p < 0.001–0.05.

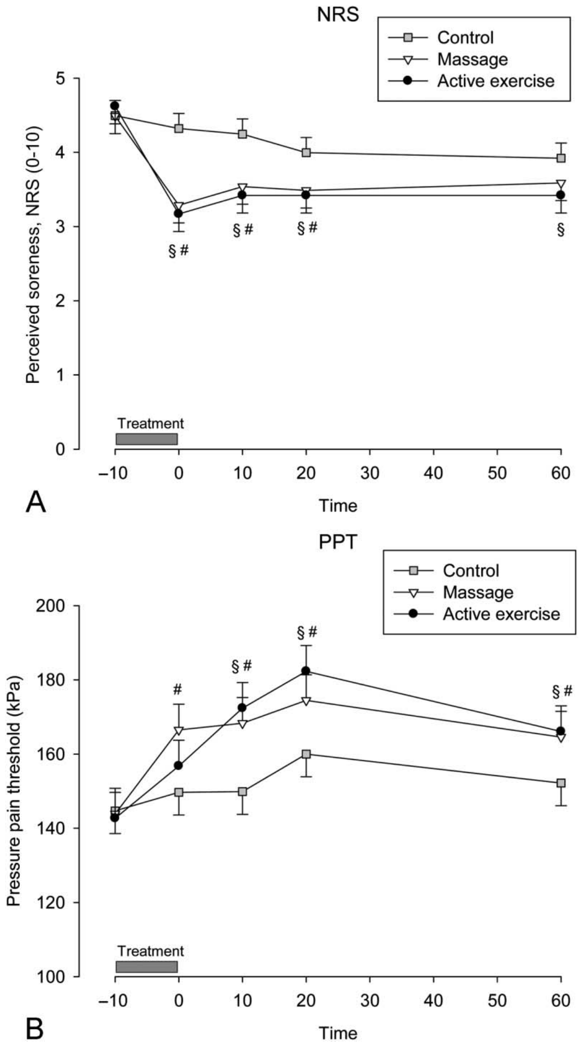

Table 3 shows effect sizes at the different time points. For intensity of soreness (pooled *SD* = 2.2), a moderate effect size was observed immediately after treatment leveling of to a small effect size after 20–60 minutes. For PPT (pooled *SD* = 78), effect sizes were small at all time points.

Table 3: Effect sizes for massage and active exercise, referencing control, at each time point after treatment.*

	Time (min)	Active exercise vs. control	Massage vs. control
NRS	0	0.52	0.47
	10	0.37	0.32
	20	0.26	0.23
	60	0.23	0.15
PPT	0	0.09	0.22
	10	0.29	0.24
	20	0.29	0.19
	60	0.18	0.16

*NRS = numerical rating scale (0–10) of intensity of soreness; PPT = pressure pain threshold (kPa).

Based on the screening questionnaire replies, outcome expectations were higher for massage than for active exercise (χ^2, $p < 0.05$, Table 1). Exploratory analyses showed that there was no significant *outcome expectation* *by time* interaction for perceived soreness and PPT for either treatment, that is, outcome expectations did not significantly influence the outcome.

There were no reported adverse events in response to massage or active exercise.

Discussion

This is the first randomized controlled trial to directly compare the timewise effect of massage with exercise for relieving muscle soreness. Our study showed acute reductions of soreness in women with DOMS in response to both active exercise and massage compared with a control condition. The magnitude and timewise change of soreness and PPT were comparable between the 2 treatments.

The eccentric protocol used in our study resulted in DOMS as evidenced by the markedly lowered PPT and increased perceived soreness at 48 hours. Many previous studies have used pressure algometry to obtain information on the level of muscle tenderness in musculoskeletal pain conditions ([2,36,39]). The levels of perceived soreness and PPT induced by the eccentric protocol in our study were comparable with the levels commonly observed in patients with chronic musculoskeletal disorders ([3,5,18,21,29,30,35]), and with the levels observed in athletes subjected to unaccustomed eccentric exercise ([10]). Thus, the eccentric protocol used in our study induced adequate levels of muscle soreness as compared with other study populations.

Previous studies have investigated the acute analgesic effects of exercise on muscle soreness. Zainuddin et al. investigated the effect of very light concentric exercise performed as 10 sets of 60 continuous elbow flexions (a total of 600 repetitions in 25 minutes) compared with no treatment on DOMS and muscle function 1, 2, 3, 4, and 7 days after strenuous eccentric exercise for the elbow flexors. In that study, muscle soreness was alleviated immediately after the light exercise bouts on days 1–4, whereas no effect on plasma markers of catabolism was observed at day 7. Thus, based on that study, the effect of light exercise on muscle soreness appears to be temporary without aiding recovery. However, to provide better practical guidelines, determining the duration of this temporary effect is important. Our study used a different timewise approach than Zainuddin et al. and measured soreness several times during the hour after treatment at 48 hours after eccentric exercise. Our study elaborates on the findings by Zainuddin by showing that the maximal benefit of exercise is achieved within the first 20 minutes after treatment. Also, the study by Zainuddin reported a decrease in muscle strength immediately after the light concentric exercise bouts consisting of 10 times 60 repetitions, suggesting that less volume may be preferred to avoid decrements in performance. In our study, we chose not to measure muscle strength continuously in the follow-up hour after treatment because such repetitive measurements can affect the perception of soreness and thus bias the results.

The intensity of active exercise for relieving DOMS may also be important. Andersen et al. showed that high-intensity strength training using resistance levels of 70–80% of 1 repetition maximum (∼10–15 kg during the shrug exercise) increased pain immediately after exercise in untrained women with trapezius myalgia, that is, chronic soreness of the trapezius muscle ([3]). In this study, the intensity during the shrug exercise was low to moderate, that is, progressing from red to blue thera-bands equivalent to 2–4 kg—during the 10 sets of 10 repetitions. In the study by Zainuddin, the intensity was likely lower than in our study, that is, the participants were able to perform 600 repetitions in 25 minutes ([40]). Thus, low to moderate intensities appear to effectively and safely relieve soreness, whereas high intensities may not.

Previous studies have also investigated the acute analgesic effects of massage on muscle soreness, but few well-designed randomized controlled trials exist ([28]). Frey Law et al. investigated in a randomized controlled trial the effect of deep-tissue massage applied to the forearm extensors (2-minute petrissage and 4-minute effleurage) compared with no-treatment or a sham intervention on DOMS at rest and during stretching 48 hours after strenuous eccentric exercise for the wrist extensors. In that study, the authors reported a decrease in stretching pain and PPT after deep-tissue massage compared with the no-treatment group, but no significant between-group difference in resting pain despite a numerical difference. In our study we found a significant positive effect of massage on resting muscle soreness. The number of subjects in each experimental group in the study by Frey Law was approximately the same as in our study, but in contrast to their study, we used a paired design allowing for greater statistical power per subject. Nevertheless, both studies support that massage can reduce symptoms of DOMS. Our study elaborates on the previous findings by showing that the maximal benefit of massage is achieved within the first 20 minutes after treatment and diminishes within an hour.

In adults with musculoskeletal pain, a change in pain intensity of 1 on a scale of 0–10 is considered the minimally relevant difference and a change of 2 is considered to be moderately clinically meaningful ([15]). In our study, soreness decreased on average by 1 on a scale of 0–10 compared with the control shoulder, equivalent to the minimal relevant difference. A clinical relevant change in PPT may be more difficult to define; therefore we included effect size calculations. According to Cohen, effect sizes of 0.20 are small, 0.50 moderate, and 0.80 large ([13]). In our study, effect sizes were moderate for the acute change in intensity of perceived soreness and small for change in PPT (Table 3). Thus, this study shows only small to moderate effects of massage and active exercise for relieving DOMS.

The effect of both massage and active exercise peaked immediately after treatment for perceived soreness and 20 minutes after treatment for PPT. The different timewise change in perceived soreness and PPT indicates that several mechanisms with different timewise influence could have acted in concert. Massage stimulates cutaneous receptors ([20]), potentially causing local lateral inhibition of pain feedback in the spinal cord. The stretch of and force applied to the muscle fibers from the different massage techniques also activate Ia afferents and Golgi tendon organs ([9,17]). The activation of these larger rapidly conducting nerve fibers could partially block the smaller, slower conducting nerve fibers detecting pain ([37]). Likewise, dynamic active exercise inherently activates various receptors such as Ia afferents, Golgi tendon organs, and cutaneous receptors. Thus, the gate control theory ([27]) may partly explain the acute reduction in soreness from both types of treatment. As another possible mechanism, massage also increases lymphatic drainage and squeezes out metabolic waste products and pain mediators such as histamines and bradykinins ([20,31]). Increased blood flow in response to active exercise may also provide washout of metabolites, and increased muscle temperature from the energy released during active exercise may make the sore muscles more compliant. By contrast, massage does not cause an elevation in muscle temperature ([24]). Thus, although the reduction in soreness was equivalent between massage and exercise, different mechanisms may have acted.

Placebo is a potential mechanism to influence subjective pain ratings ([25]). Before the study, 90% of the participants expected massage to reduce soreness and only 10% expected no effect or worsening from massage. By contrast, only 55% of the participants expected active exercise to reduce soreness and 45% expected no effect or worsening. Because the outcome expectations are known to influence subjective pain-related outcomes ([34]) placebo effects could have influenced especially the results of massage. However, exploratory analyses did not confirm a statistically significant influence of outcome expectations on the change in soreness in this study. Thus, it is conceivable that placebo effects only minimally influenced our results.

There are both strengths and limitations of our study. The randomized design and blinding of the examiner increase the validity of our results. The paired design allows for high statistical power with relatively few subjects, that is, 20 in this study. By contrast, power calculations showed that an unpaired design with 3 independent groups would require 36 in each group, that is, a total of 108 participants. Thus, economizing the number of participants using a paired design to compare the effect of massage and active exercise is both scientifically and ethically sound. However, a possible crossover effect from the experimental shoulder to the control shoulder may have underestimated the true treatment effect, causing only small to moderate effect sizes. This can be visualized in Figure 2, where the control shoulder also shows improvement over time. Thus, our estimates are likely conservative. Carryover effects from the first to the second test round can also underestimate true effect sizes, but because each shoulder received only one of the treatments while the other served as control this could only have minor impact on our results. Because DOMS most commonly occurs in response to unaccustomed physical exertion, we used untrained subjects. However, this also limits the generalizability of our findings, and future studies should compare the effectiveness of massage and exercise on soreness in trained athletes and in adults with chronic musculoskeletal disorders. Finally, future studies should include measures of muscle function and mechanisms of acute pain adaptation.

In conclusion, active exercise using elastic resistance provides similar acute relief of muscle soreness as compared with that by massage, and both treatments are superior to no treatment. For both types of treatment, the greatest effect on perceived soreness occurred immediately after treatment, whereas the effect on PPT peaked 20 minutes after treatment. Altogether, the greatest effects were observed within the first 20 minutes after treatment and diminished within an hour.

Practical Applications

Active exercise using low to moderate resistance and massage provided equal relief of muscle soreness with the greatest effects occurring during the first 20 minutes after treatment. The present knowledge provides more flexible treatment options for athletes, coaches and therapists needing to acutely relieve DOMS. For example, the coach can safely advise the athlete to do a gradual warm-up with active exercise rather than visiting the massage therapist when muscle soreness is present. We recommend using fairly light resistance during the first few sets of active warm-up and gradually increasing the resistance to tolerable levels during the later sets. However, athletes, coaches, and therapists should be aware that the effect is greatest during the first 20 minutes after treatment and diminishes within an hour. Thus, actively warming up the muscles relieves DOMS only temporarily and should be performed immediately before competition or strenuous work. Although not investigated in this study, stretching cannot be recommend for muscle soreness as a Cochrane review concluded that stretching neither prevents nor relieves exercise-induced DOMS ([23]).

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References

1. Andersen LL, Andersen CH, Mortensen OS, Poulsen OM, Bjornlund IB, Zebis MK. Muscle activation and perceived loading during rehabilitation exercises: Comparison of dumbbells and elastic resistance. Phys Ther 90: 538–549, 2010.
2. Andersen LL, Andersen CH, Sundstrup E, Jakobsen MD, Mortensen OS, Zebis MK. Central adaptation of pain perception in response to rehabilitation of musculoskeletal pain: Randomized controlled trial. Pain Physician 15: 385–394, 2012.
3. Andersen LL, Kjaer M, Sogaard K, Hansen L, Kryger AI, Sjogaard G. Effect of two contrasting types of physical exercise on chronic neck muscle pain. Arthritis Rheum 59: 84–91, 2008.
4. Armstrong RB. Mechanisms of exercise-induced delayed onset muscular soreness: A brief review. Med Sci Sports Exerc 16: 529–538, 1984.
5. Bajaj P, Bajaj P, Graven-Nielsen T, Arendt-Nielsen L. Osteoarthritis and its association with muscle hyperalgesia: An experimental controlled study. Pain 93: 107–114, 2001.

6. Brummitt J. The role of massage in sports performance and rehabilitation: Current evidence and future direction. N Am J Sports Phys Ther 3: 7–21, 2008.
7. Byrnes WC, Clarkson PM. Delayed onset muscle soreness and training. Clin Sports Med 5: 605–614, 1986.
8. Cafarelli E, Flint F. The role of massage in preparation for and recovery from exercise. An overview. Sports Med 14: 1–9, 1992.
9. Chalmers G. Re-examination of the possible role of Golgi tendon organ and muscle spindle reflexes in proprioceptive neuromuscular facilitation muscle stretching. Sports Biomech 3: 159–183, 2004.
10. Cheung K, Hume P, Maxwell L. Delayed onset muscle soreness: Treatment strategies and performance factors. Sports Med 33: 145–164, 2003.
11. Close GL, Ashton T, Cable T, Doran D, MacLaren DP. Eccentric exercise, isokinetic muscle torque and delayed onset muscle soreness: The role of reactive oxygen species. Eur J Appl Physiol 91: 615–621, 2004.
12. Close GL, Ashton T, McArdle A, MacLaren DP. The emerging role of free radicals in delayed onset muscle soreness and contraction-induced muscle injury. Comp Biochem Physiol A Mol Integr Physiol 142: 257–266, 2005.
13. Cohen J. Statistical Power Analysis for the Behavioral Sciences. Hillsdale, NJ: Lawrence Erlbaum Associates, 1988.
14. Drust B, Atkinson G, Gregson W, French D, Binningsley D. The effects of massage on intra muscular temperature in the vastus lateralis in humans. Int J Sports Med 24: 395–399, 2003.
15. Dworkin RH, Turk DC, McDermott MP, Peirce-Sandner S, Burke LB, Cowan P, Farrar JT, Hertz S, Raja SN, Rappaport BA, Rauschkolb C, Sampaio C. Interpreting the clinical importance of group differences in chronic pain clinical trials: IMMPACT recommendations. Pain 146: 238–244, 2009.
16. Ebbeling CB, Clarkson PM. Exercise-induced muscle damage and adaptation. Sports Med 7: 207–234, 1989.
17. Enoka RM, Hutton RS, Eldred E. Changes in excitability of tendon tap and Hoffmann reflexes following voluntary contractions. Electroencephalogr Clin Neurophysiol 48: 664–672, 1980.
18. Fernandez-de-las-Penas C, de la Llave-Rincon AI, Fernandez-Carnero J, Cuadrado ML, Arendt-Nielsen L, Pareja JA. Bilateral widespread mechanical pain sensitivity in carpal tunnel syndrome: Evidence of central processing in unilateral neuropathy. Brain 132: 1472–1479, 2009.
19. Frey Law LA, Evans S, Knudtson J, Nus S, Scholl K, Sluka KA. Massage reduces pain perception and hyperalgesia in experimental muscle pain: A randomized, controlled trial. J Pain 9: 714–721, 2008.
20. Goats GC. Massage—The scientific basis of an ancient art: Part 2. Physiological and therapeutic effects. Br J Sports Med 28: 153–156, 1994.
21. Greening J, Lynn B. Vibration sense in the upper limb in patients with repetitive strain injury and a group of at-risk office workers. Int Arch Occup Environ Health 71: 29–34, 1998.
22. Hemmings B, Smith M, Graydon J, Dyson R. Effects of massage on physiological restoration, perceived recovery, and repeated sports performance. Br J Sports Med 34: 109–114, 2000.
23. Herbert RD, de NM, Kamper SJ. Stretching to prevent or reduce muscle soreness after exercise. Cochrane Database Syst Rev 2011;CD004577.
24. Hinds T, McEwan I, Perkes J, Dawson E, Ball D, George K. Effects of massage on limb and skin blood flow after quadriceps exercise. Med Sci Sports Exerc 36: 1308–1313, 2004.
25. Hrobjartsson A, Gotzsche PC. Placebo interventions for all clinical conditions. Cochrane Database Syst Rev 2004; CD003974.
26. Law RY, Herbert RD. Warm-up reduces delayed onset muscle soreness but cool-down does not: A randomised controlled trial. Aust J Physiother 53: 91–95, 2007.
27. Melzack R. Recent concepts of pain. J Med 13: 147–160, 1982.
28. Moraska A. Sports massage. A comprehensive review. J Sports Med Phys Fitness 45: 370–380, 2005.
29. Nielsen PK, Andersen LL, Olsen HB, Rosendal L, Sjogaard G, Sogaard K. Effect of physical training on pain sensitivity and trapezius muscle morphology. Muscle Nerve 41: 836–844, 2010.
30. O'neill S, Manniche C, Graven-Nielsen T, rendt-Nielsen L. Generalized deep-tissue hyperalgesia in patients with chronic low-back pain. Eur J Pain 11: 415–420, 2007.
31. Paine T. The Complete Guide to Sports Massage. London, United Kingdom: A & C Black Publishing Ltd., 2000.

32. Persson AL, Brogardh C, Sjolund BH. Tender or not tender: Test-retest repeatability of pressure pain thresholds in the trapezius and deltoid muscles of healthy women. J Rehabil Med 36: 17–27, 2004.
33. Pincus T, Bergman M, Sokka T, Roth J, Swearingen C, Yazici Y. Visual analog scales in formats other than a 10 centimeter horizontal line to assess pain and other clinical data. J Rheumatol 35: 1550–1558, 2008.
34. Price DD, Milling LS, Kirsch I, Duff A, Montgomery GH, Nicholls SS. An analysis of factors that contribute to the magnitude of placebo analgesia in an experimental paradigm. Pain 83: 147–156, 1999.
35. Sterling M, Jull G, Vicenzino B, Kenardy J. Sensory hypersensitivity occurs soon after whiplash injury and is associated with poor recovery. Pain 104: 509–517, 2003.
36. Takala EP. Pressure pain threshold on upper trapezius and levator scapulae muscles. Repeatability and relation to subjective symptoms in a working population. Scand J Rehabil Med 22: 63–68, 1990.
37. Weerapong P, Hume PA, Kolt GS. The mechanisms of massage and effects on performance, muscle recovery and injury prevention. Sports Med 35: 235–256, 2005.
38. Ylinen J, Nykanen M, Kautiainen H, Hakkinen A. Evaluation of repeatability of pressure algometry on the neck muscles for clinical use. Man Ther 12: 192–197, 2007.
39. Ylinen J, Takala EP, Kautiainen H, Nykanen M, Hakkinen A, Pohjolainen T, Karppi SL, Airaksinen O. Effect of long-term neck muscle training on pressure pain threshold: A randomized controlled trial. Eur J Pain 9: 673–681, 2005.
40. Zainuddin Z, Sacco P, Newton M, Nosaka K. Light concentric exercise has a temporarily analgesic effect on delayed-onset muscle soreness, but no effect on recovery from eccentric exercise. Appl Physiol Nutr Metab 31: 126–134, 2006.

Keywords

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