No Effect of Acupuncture in the Relief of Delayed-Onset Muscle Soreness: Results of a Randomized Controlled Trial

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Background: Delayed-onset muscle soreness (DOMS) is a common symptom in people participating in exercise, sport, or recreational physical activities. Several remedies have been proposed to prevent and alleviate DOMS.

Design and Methods: A five-arm randomized controlled study was conducted to examine the effects of acupuncture on eccentric exercise-induced DOMS of the biceps brachii muscle. Participants were recruited through convenience sampling of students and general public. Participants were randomly allocated to needle, laser, sham needle, sham laser acupuncture, and no intervention. Outcome measures included pressure pain threshold (PPT), pain intensity (visual analog scale), and maximum isometric voluntary force.

Results: Delayed-onset muscle soreness was induced in 60 participants (22 females, age 23.6 ± 2.8 years, weight 66.1 ± 9.6 kg, and height 171.6 ± 7.9 cm). Neither verum nor sham interventions significantly improved outcomes within 72 hours when compared with no treatment control ($P > 0.05$).

Conclusions: Acupuncture was not effective in the treatment of DOMS. From a mechanistic point of view, these results have implications for further studies: (1) considering the high-threshold mechanosensitive nociceptors of the muscle, the cutoff for PPT (5 kg/cm^2) chosen to avoid bruising might have led to ceiling effects; (2) the traditional acupuncture regimen, targeting muscle pain, might have been inappropriate as the DOMS mechanisms seem limited to the muscular unit and its innervation. Therefore, a regionally based regimen including an intensified intramuscular needling (dry needling) should be tested in future studies, using a higher cutoff for PPT to avoid ceiling effects.

Key Words: mechanosensitive nociceptors, integrative medicine, neurophysiology, peripheral nociception

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INTRODUCTION

Muscle soreness is often induced by unaccustomed or eccentric exercise.[1] It has also been associated with the intake of specific medication[2] and is caused by inflammatory conditions.[3]

This condition is transient and people normally do not seek medical advice. Longer-lasting impairment can be found in people with reduced physical activity[4] or in elite athletes.[5]

The physiological basis of muscle contraction and damage draws on the relation between force, speed, and tension in a muscle fiber. Constant velocity lengthening produces a complex tension record, leading to a continued increase in tension throughout a given movement.[6] Beyond the plateau of the length tension curve, stretching the muscle works nonuniformly, elongating the weakest sarcomere first, which are those with the smallest number of cross-bridges.[6] This theory has been named "popped sarcomere," and repetitive stretches have been related to pronounced injury.[7] Besides mechanical trauma, microscopic disruptions are believed to lead to damaged cell membranes and, therefore, a loss of intracellular calcium homeostasis.[8] Several inflammatory processes are initiated, which in turn lead to fiber damage and cell death.[9] The breakdown products of the impaired muscle tissue excite nociceptors. Specifically, the transient receptor potential channels of the vanilloid type (TRPV1) and acid sensing ion channels have been suggested to play a central role in the processing of the stimuli.[10] In combination with an augmented mechanical response in muscle thin-fiber sensory receptors,[11] these neurophysiological observations are related to muscle tenderness and soreness. As an equivalent term, delayed-onset muscle soreness (DOMS) has been introduced.[12]

Symptomatic treatments include massage,[13,14] cryotherapy,[15,16] vibration,[17,18] nutriceutics[19] and others, but the evaluation of their effectiveness is inconsistent.[20,21] Analgesics seem to be effective in the short term, but inappropriate regarding their potential harms.[22] If necessary, topical administration is recommended.[23] Continued exercise also seems to be an effective treatment[24]; however, pain relief is transient and rapidly diminishes after exercise cessation.[25]

Complementary therapies have gained popularity over the last few decades and have appealed to patients. Acupuncture is now one of the most frequently used complementary therapies.[26] Acupuncture principles originate from a complex philosophical understanding of health and illness.[27] Nowadays, several neural,[28] immune,[29] and hormonal[30] pathways have been proposed to explain the mechanism behind acupuncture. Clinical evidence justifies its use as a therapeutic option in the treatment of pain and musculoskeletal conditions.[31] However, the evidence for acupuncture to relieve DOMS is inconsistent. Although some authors have shown a decrease in soreness perception,[32,33] others found either no clinically relevant effects in terms of pain and function[34,35] or only very small effects on pain.

We designed a 5-arm randomized controlled trial to investigate psychophysiological effects (ie, functional improvement and pain relief) of acupuncture in the treatment of DOMS. For the first time, we implemented a noninvasive placebo control [sham laser acupuncture (SLA)] to differentiate specific and nonspecific treatment effects.

METHODS

Study Design

The study is a single-center, double-blinded, randomized controlled trial aimed to investigate the effects of acupuncture on DOMS of the nondominant biceps brachialis muscle in healthy adults. Participants were assessed for study eligibility using the following exclusion criteria: pain, pregnancy, neuromuscular disease, severe neurological disease, cancer, coagulation disorder, mental illness, allergic contact dermatitis to nickel or other forms of acute dermatitis, severe bacterial or viral infection, cardiac disease, peripheral or central vascular disease, scar or wounds near the acupuncture points, regional skin transplants, and amputation of extremities with the lack of acupuncture points, regional sensibility disorders, chronic intake of analgesic, neuroleptics, antidepressants, corticoids, alpha2-blockers, and acupuncture within 2 weeks. Sixty participants agreed to participate and signed a written informed consent. After enrollment, muscle soreness was induced and participants were subsequently randomized to receive either verum acupuncture (VA), sham acupuncture (SA), laser acupuncture (LA), SLA, or no treatment (CON). Treatments were repeated every 24 hours, 3-times in total. Primary outcome measures were pressure pain threshold (PPT) over the biceps muscle belly and pain intensity. Secondary outcome was the maximum isometric voluntary force (MIVF) of the elbow flexors. Participants were followed up 72 hours after the induction of DOMS, and participants were told not to exercise during this time. The study has been approved by the Ethics Committee of the Goethe University of Frankfurt, Germany (reference 255/08) and is in agreement with the Declaration of Helsinki (Version Fortaleza 2012).

Randomized Treatment Allocation

Participants were randomly assigned to one of the 5 study groups using sequentially numbered opaque envelopes with a ratio of 1:1:1:1:1. The randomization sequence was generated by the Department of Sports Medicine, using the computer-based randomization program BiAS (Version 1.00; epsilon-Verlag GbR Hochheim, Darmstadt, Germany).

Sample Size Estimation

Sample size was estimated using the software BiAS. With α set at 5%, 11 participants were required in each group (total group size n = 55) to have 80% power to detect a difference in pain intensity of 1.6 points on the visual analog scale (VAS) (variance $\sigma 2 = 1.05$).[35]

Induction of Delayed-Onset Muscle Soreness

At baseline, DOMS of the nondominant elbow flexors was experimentally induced using a standardized exercise protocol. The nondominant biceps brachialis muscle was selected to provoke DOMS. All participants were seated at a preacher bench and performed isolated biceps curls with a dumbbell. At first, their individual 1 repetition maximum (1 RM; ie, the maximum weight lifted with 1 concentric contraction) was determined for the elbow flexors by loading the dumbbell with free weights in 0.5 kg increments. Participants were encouraged verbally to elicit their maximal effort. The 1 RM was then used to provoke DOMS through eccentric contractions. For this, the experimenter lifted the dumbbell until the subject's elbow was fully flexed, and the subject lowered the weight eccentrically as slowly as possible until the elbow was fully extended. This procedure continued until participants' subjective exhaustion.

Interventions

We used SA as a control for VA, and SLA as a control for LA. The CON group served as a control for all groups. Laser acupuncture is a control for invasive needle-dependent effects. Sham treatments (SA and SLA) control for treatment-dependent unspecific effects.[36]

All interventions were performed by MB, an expert acupuncturist (>360 hours of curricular teaching). Resting time was 20 minutes in all groups (including CON). Treatments started immediately after the induction of DOMS and were repeated after 24 and 48 hours (3 times in total).

Verum Acupuncture

Verum acupuncture semistandardized point selection based on expert opinion and curricular teaching of the German Society of Medical Acupuncture DÄGfA e.V., using sterile disposable, silicon-coated, steel needles (30.0 × 0.3 mm; Dongbang Acupuncture Inc, Chungnam, Korea). Acupuncture points are shown in Table 1.

Sham Acupuncture

Sham acupuncture was performed at 8 nontraditional sites of the body, and needles were stimulated manually (Table 1).

Laser and Sham Laser Acupuncture

Laser and Sham laser acupuncture were performed at the same acupuncture points as VA using a laserneedle system (3B laserneedle; 3B Scientific GmbH, Hamburg,

TABLE 1. Localization of Acupuncture Points

Verum Acupuncture Points		SA Points
Acupuncture Point	**Chinese Name**	
Basic points		
Bilateral		
LI 4	He Gu	P1: one cun radioproximal LI 4
LI 11	Qu Chi	P2: one cun proximomedial LI 11
LU 3	Tian Fu	P3: one cun proximal LU 3
LU 5	Chi Ze	P4: one cun proximomedial LU 5
GB 34	Yang Ling Quan	P5: one cun distal GB 34
SP 10	Xue Hai	P6: 2 cun medial SP 10
Unilateral		
mTrP 1	Ah Shi 1	P7: point within the deltoid muscle
mTrP 2	Ah Shi 2	
Individual points		
Ad libitum		

Verum acupuncture points: Western and Chinese nomenclature are given. Two mTrPs were treated unilateral at the nondominant arm. Individual points were chosen among all traditional acupuncture points. Sham acupuncture points: Anatomic description of used sham points, labeled P1 to P8. P1 to P6 were treated bilaterally, P7 to P8 were treated unilateral at the nondominant arm.

Cun, individual Chinese metric system; GB, gallbladder; LI, large intestibe; LU, lung; mTrP, myofascial trigger point; SP, spleen; 1 cun, 1 patients individual thumb width.

Germany). The device consists of several optical fibers that have a top section looking like a small needle. These "needles" were not inserted into the skin, but were fixed onto the skin at the above-defined sham points with special adhesive tape.

The laser device was operated by a laboratory member who was not involved in the study. It was switched on in both LA and SLA groups to provide visual and acoustic signals. The laser diodes were activated only in the LA group, and in the SLA group, the laser diodes remained switched-off. Participants and acupuncturist were told that the device emits invisible infrared laser light and had to put on protective glasses during the treatment. Participant positioning and treatment duration were identical to those during acupuncture and SA.

Blinding Procedure

Participants were acupuncture novices and were told that needle acupuncture and LA are equivalent treatment techniques. Acupuncturist and participants were not informed about the placebo laser condition to ensure double blinding. The acupuncturist attempted to give equal attention to all participants. The acupuncturist was not involved in the assessment of outcomes, and assessors were masked to group allocation.

Outcome Measures

Pressure pain threshold was assessed using a mechanical pressure algometer (pdt, Rome, Italy) at 7 equidistant points, perpendicular to the belly of the biceps brachii muscle on a thought line between the radial tuberosity and the coracoid process. Pressure was applied to each of these points with increasing force at a rate of approximately 1 $kg \cdot cm^{-2} \cdot s^{-1}$ until the participant reported a painful sensation, and the force value was recorded (kg/cm^2). An upper limit of PPT was set at 5 kg/cm^2 to avoid bruising. Each point was measured 3 times, with 10-second intervals between trials, and the mean of the second and third trials was used for the analysis. The reliability of this method has been shown previously.[37]

Maximum isometric voluntary force was measured using a strain-gauge force transducer (ASYS Sporeg, Offenbach, Germany). Participants were seated at a preacher bench with the elbow flexed at 90° and performed maximum isometric contractions against an inelastic strap that was placed around the wrist and connected to the force transducer (100 Hz sampling rate). Three trials were performed with contractions lasting 5 seconds, separated by 2 minutes rest intervals. Participants were encouraged verbally to elicit their maximal effort, and force was displayed on a visual display in real time providing immediate feedback. Peak strength values (N) were recorded, and the highest of the 3 repetitions was used for statistical analysis.

Pain intensity during active movement of the biceps muscle was assessed using a VAS ranging from 0 to 10 cm (with 0 indicating no pain and 10 experiencing the worst imaginable pain).

Statistics

Statistical analysis was conducted for comparison of the main and secondary outcome measures between the 5 study groups. Depending on the tests for normal distribution, the parametric method (ie, one-way analysis of variances) or nonparametric method (Kruskal–Wallis test) was used. Post hoc tests were performed by pairwise comparisons of the 5 study groups by unpaired t tests adjusted based on Bonferroni–Holm method (parametric) or by Dunn multiple comparison test (nonparametric). The baseline PPT data were used as a covariate in the repetitive measures analysis of PPT over time. Demographic data are presented as mean ± SD, and outcome measures as mean ± SEM.

Data analysis was performed with the SPSS statistical software system, version 21.0 (SPSS Inc, Chicago, IL).

RESULTS

Demographics and Baseline Data

Sixty participants (22 females and 38 males, age 23.6 ± 2.8 years, weight 66.1 ± 9.6 kg, and height 171.6 ± 7.9 cm) were included in the study and no dropout occurred. Measures at baseline were PPT = 4.2 ± 0.1 kg/cm^2, VAS = 0.0 ± 0.0 cm, and MIVF = 58.7 ± 2.8 N. Group data are presented in Table 2. Baseline differences were determined for age [df (4,59), F (3.623); P = 0.01] between the groups CON and SLA ($P < 0.01$) and for PPT [df (4), χ^2 = 13.66; $P < 0.01$] between groups CON and SLA ($P < 0.01$). The repeated-measures analysis of PPT was thus adjusted for baseline values. Neither sex nor age was detected as confounding factors.

Pressure Pain Threshold

The repeated-measures analysis of PPT did not reveal a difference between groups [df (4,414), F (0.899); P = 0.47;

TABLE 2. Demographics

	Group VA	Group SA	Group LA	Group SLA	Group CON
Demographics					
Gender, male or female (n)	4/8	4/8	5/7	3/9	6/6
Age (yrs)	23.1 ± 2.0	24.2 ± 3.5	23.2 ± 2.4	25.5 ± 2.8	21.6 ± 1.7[1]
Weight (kg)	65.8 ± 7.6	68.3 ± 10.6	66.1 ± 8.5	66.5 ± 10.1	63.7 ± 11.9
Height (cm)	172.3 ± 8.8	174.8 ± 7.4	171.7 ± 7.5	168.7 ± 7.2	170.6 ± 8.6
Baseline data					
PPT (kg/cm^2)	4.2 ± 0.1	4.2 ± 0.1	4.2 ± 0.1	4.0 ± 0.1	4.6 ± 0.1[2]
VAS (cm)	0.00 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0
MIVF (N)	55.3 ± 5.9	60.6 ± 5.9	54.8 ± 5.0	60.9 ± 7.8	62.1 ± 5.2

All 5 study groups are represented including the sample size and the gender ratio. Data are expressed as mean ± SD. Significant baseline differences were detected regarding (1) the difference in age between groups CON and SLA ($P < 0.01$) and (2) PPT between groups CON and SLA ($P < 0.01$).

Figure, A]. One day after induction of DOMS, the mean change of PPT was -0.53 ± 0.04 kg/cm^2 and returned to baseline 72 hours after DOMS (-0.23 ± 0.05 kg/cm^2). There was a main effect of time at 24, 48, and 72 hours when compared to baseline.

Visual Analog Scale

The pain intensity (VAS) between groups over time revealed no difference [*df* (4,55), *F* (1.654); $P = 0.17$; Figure, C]. One day after induction of DOMS, the mean VAS was 2.67 ± 0.21 cm, and 72 hours after DOMS, VAS = 2.16 ± 0.23 cm. There was a main effect of time at 24, 48, and 72 hours when compared to baseline.

Mean Isometric Voluntary Force

The MIVF between groups over time revealed no difference [*df* (4,55), *F* (0.283); $P = 0.89$; Figure, B]. One day after induction of DOMS, the mean MIVF was 45.23 ± 2.73 N, and 72 hours after DOMS, MIVF = 47.13 ± 2.79 N. There was a main effect for time at 24, 48, and 72 hours when compared to baseline.

DISCUSSION

We present the results of a study investigating the effects of different modes of acupuncture on symptoms and muscle function in experimentally induced muscle pain. Our DOMS model was successfully applied as evidenced by the increase in pain threshold, pain intensity, and functional impairment. Acupuncture was neither superior to sham treatments nor to CON. There were no differences between the 2 different acupuncture techniques, that is, needle or laser. These results are in line with other studies,[34,35] suggesting that acupuncture is not effective in the treatment of DOMS.

Confirming previous results, acupuncture fails to elicit detectable effects for DOMS. To date, there is no physiological mechanism that explains the underlying process of acupuncture and its relationship to psychological factors. It has therefore been recommended that treatment-related nonspecific effects should be distinguished from treatment-specific effects.[36] Nonspecific nonphysiological effects[38] are classified into setting, beliefs, expectations, credibility, and the patient-practitioner relationship. However, nonspecific physiological effects can be elicited when the patient is touched or when acupuncture points are palpated.[36] Therefore, we introduced 2 controls. The first involved needling of the skin at nontraditional (sham) sites. Needling of the skin, irrespective of the location, is known to release an array of analgesic and anti-inflammatory substances[28,39]; however, it has been suggested that needling at traditional sites leads to point-specific physiological effects, ideally larger than at sham points.[36] The second control, SLA, does not penetrate the skin and should therefore only result in the above-mentioned nonspecific physiological effects elicited by touching the skin. Both verum interventions, VA and LA, are known to activate similar neurophysiological analgesic pathways[28,40]: acupuncture by mechanical stimulation of skin and tissue, and laser by photobiomodulation. To our knowledge, there are no data on the relative effectiveness of both techniques. Besides peripheral signal transmission, spinal and supraspinal descending and inhibitory mechanism, such as the activation of inhibitory interneurons[41] or diffuse noxious inhibitory controls,[42] are supposedly involved. In the central nervous system, a broad range of neurotransmitters and other peptides have been found to be modulated, for example, endorphine, serotonin, or adrenocorticotropin.[43,44] In sum, all mechanisms are supposed to mediate acupuncture-induced analgesia.

The lack of acupuncture-induced effects in the relief of DOMS might be due to technical reasons. We chose a cutoff PPT <5 kg/cm^2 to avoid bruising as performed and suggested previously.[35,37,45] This cutoff may have led to measuring pressure detection thresholds rather than PPT. Almost half of the muscle fibers have low-threshold mechanosensitive units, which respond to weak stimuli such as deformation of the muscle tissue.[46] Muscle nociceptors instead are so called high-threshold mechanosensitive receptors (HTM). Their membrane may be equipped with transient receptor potential channels[47] similar to those proposed as a possible mechanism in the development of pain in DOMS. Hoheisel et al[48] showed that the activation of these HTM units is pressure dependent and requires a certain pressure threshold to be exceeded. This study and the studies from Hübscher and Barlas had cutoff values below 5 kg/cm^2 to avoid bruising. This is in

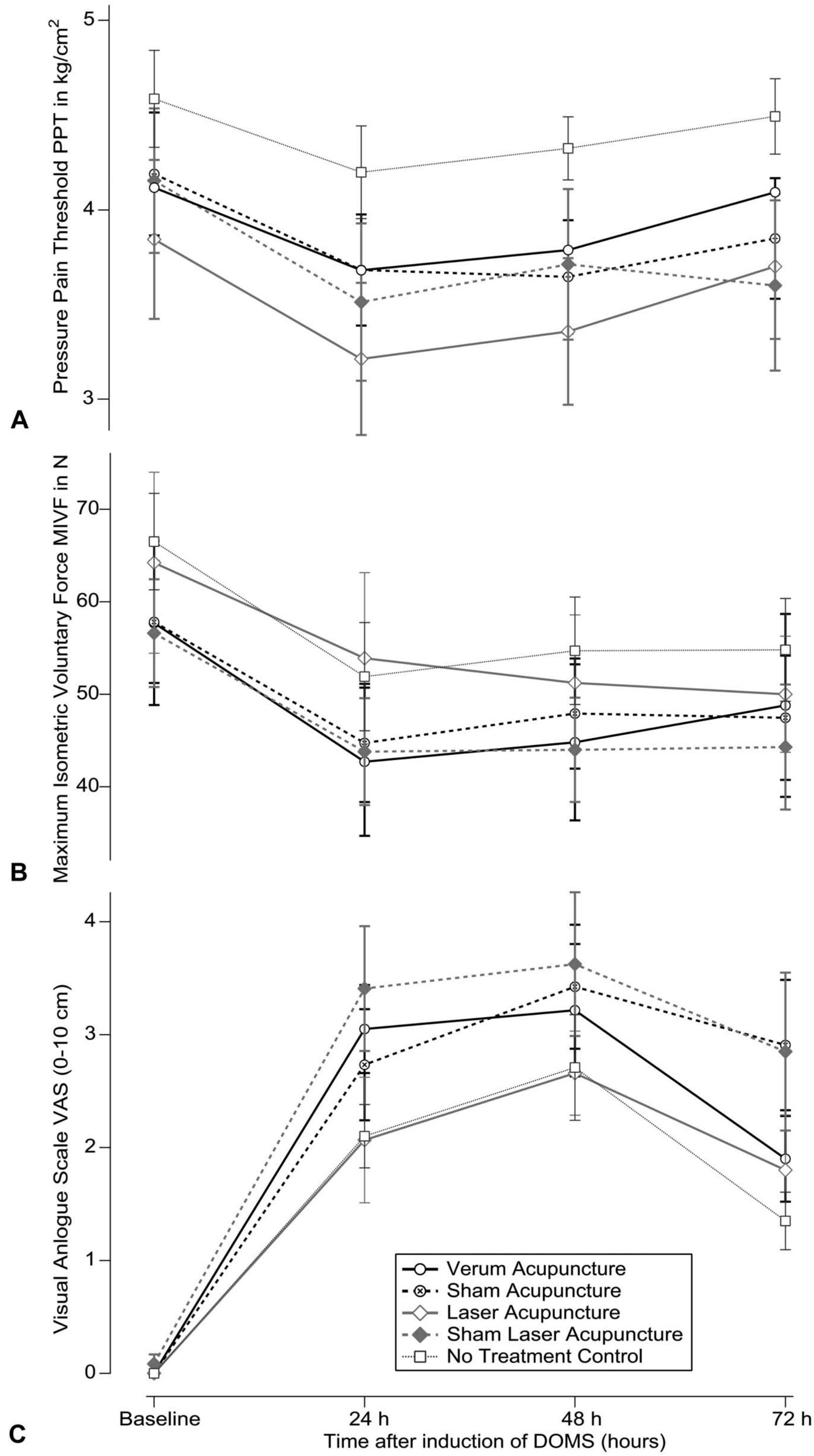

FIGURE. A–C, Display the outcome parameters PPT, MIVF, and VAS at baseline and 24, 48, and 72 hours after induction of DOMS. A, Mean change of the PPT in kg/cm². Baseline value is considered, Δ = 0. B, Course of the mean MIVF in Newton meter. C, Course of the mean VAS in centimeter. Data are expressed as mean ± SEM. There are no between-group differences, but overall change is significant (refer to the text).

accordance with a pilot study from Micklewright et al showing that soft tissue techniques failed at relieving DOMS[49] and with Frey Law et al[14] who showed deep tissue massage to be more effective than superficial touch in the reduction of experimental muscle pain. The hypothesis that acupuncture alters the PPT is supported by several experimental and clinical trials[50–53] and has lately been presented by Baeumler et al,[54] assuming that the PPT is the most affected sensory threshold and that effects on the mechanical pain sensitivity (detection) are less relevant.

Besides above discussed sensory thresholds, the underlying neuromechanism of DOMS and chronic pain are different. Pain defined by the International Association for the Study of Pain is "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage." Although pain is always a subjective sensation, nociception can be measured objectively.[55] The duration of pain, extent of cellular damage, and level of psychological distress interact to determine central sensitization and neural plasticity. Several acupuncture trials showed pain relief in chronic pain states,[31] and effects were also demonstrated in acute pain conditions where pain is believed to be influenced mainly at spinal levels, for example, postoperative pain[56] or tension-type headache.[57] Delayed-onset muscle soreness is a self-limiting process, predominantly generated locally at the muscle nociceptors. Therefore, previously described off-site effects of acupuncture (ie, treatment at distant acupuncture points) could be less pronounced.

A limitation of this study is the selection of the acupuncture points. The chosen points were located all over the body surface. Based on the above-mentioned theories regarding the possible mechanisms of acupuncture in the alleviation of DOMS, a greater proportion of local acupuncture points might be advisable to enhance local effects.

PRACTICAL APPLICATIONS

The chosen acupuncture regimen, physiologically inducing spinal and central analgesic pathways, was not effective in the relief of locally mediated muscular pain. The mechanism of DOMS is related to the increased excitability of muscular nociceptors. Increased excitability is restricted to the local muscle and of short-term duration. This suggests that local treatments (besides local acupuncture, eg, deep tissue techniques, local anesthetics, or electrostimulation) could be more effective. From a physiological point of view, future research and treatments should target local deep muscle tissue with strong-stimulating interventions.

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