

The effectiveness of acupuncture for pain reduction in delayed-onset muscle soreness: A systematic review

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ABSTRACT

Objective

To systematically review the literature on acupuncture for delayed-onset muscle soreness (DOMS) and report upon study quality and treatment outcomes.

Design

Systematic review.

Data sources

Searches were conducted in the following electronic databases from their inception to 31 March 2018: CINAHL, MEDLINE, Allied and Complementary Medicine (AMED) and SPORTDiscus. Reference lists of all included studies and relevant reviews were hand-searched for additional studies.

Eligibility criteria for selecting studies

Randomised controlled trials (RCTs) that evaluated the effectiveness of acupuncture in DOMS in adults measuring the pre-specified primary outcome (pain) were included.

Data collection and analysis

Data was extracted using pre-defined extraction forms and the Standards for Reporting Interventions in Clinical Trials of Acupuncture (STRICTA) checklist. Quality of studies was evaluated based on the Cochrane risk of bias assessment.

Results

Five RCTs investigating laboratory-induced DOMS in the upper limbs with a total sample size of 182 healthy participants were included. Of the included studies, three reported superiority of acupuncture over no treatment in DOMS pain reduction as measured by visual analogue scale, pressure pain threshold or electrical pain threshold, while two studies yielded non-significant results. All studies demonstrated risk of bias in one or more areas, commonly lack of blinding of participants and personnel.

Summary/conclusions

There is conflicting to limited evidence to support the effects of acupuncture on the relief of pain associated with DOMS. The findings were confounded by methodological limitations and reporting insufficiency. More rigorous, high-quality and well-reported RCTs are required to further evaluate the effectiveness of acupuncture for DOMS.

INTRODUCTION

Delayed-onset muscle soreness (DOMS) describes symptoms experienced after unaccustomed exercise involving significant eccentric contractions (EC), which result in exercise-induced muscle damage (EIMD)¹. It is characterised by dull, aching pain during palpation or movement of the involved muscles, but not at rest², and is associated with muscle weakness, loss of range of motion, swelling and stiffness³. The impact of DOMS on athletes' performance has been extensively documented^{4,5,6} and includes reduced endurance⁶, strength and power^{5,6}, altered joint kinematics⁵ and an increased risk of injury^{5,6}. Commonly, it peaks between 24-72 hours after unaccustomed EC⁷, and usually subsides within five to seven days⁷.

The extent of muscle damage and the duration of DOMS symptoms vary with training conditions⁸ and individual factors⁹, including exercise intensity, duration, velocity⁸ and muscle stiffness⁹. It is experienced by many athletes following high-intensity or unfamiliar EC⁵, such as downhill running⁵, resisted cycling⁵ and team sports⁶. The current concept of mechanism is that high tensile force from EC results in muscle damage and a subsequent inflammatory response¹. The inflammatory products sensitise nociceptors within muscle fibres, causing pain sensations associated with DOMS¹. This is accompanied by leakage of creatine kinase (CK) and an increase in serum CK levels, which peak 48 hours after exercise¹⁰. However, a recent study² observed that mechanical hyperalgesia occurred in rats after eccentric contractions, without obvious muscle damage or inflammation, prompting the

authors to propose an alternative mechanism involving two different neurotrophic factors².

Although DOMS does not require medical intervention, it can adversely impact laboratory-based performance in various ways^{4,5,6}. Reduction in endurance has been reported due to impairments of movement economy, glycogen repletion and biomechanics⁶, and combined with observations of reduced strength and power^{5,6}, may put athletes at greater risk of injury^{5,6}. Physiotherapeutic interventions, including cold water immersion¹¹, contrast water therapy¹¹, exercise¹², stretching¹², massage¹², and acupuncture¹³, may have a role in reducing the effect of DOMS. Acupuncture, which involves the insertion of fine needles into the body¹⁴, is used in contemporary healthcare for a range of symptoms, including pain¹⁵. Acupuncture needles may be inserted at traditional acupuncture points, which are described throughout the body¹⁶, or at *ah shi* points, which are referred to hyperirritable painful spots without a pre-defined location¹⁷.

Although acupuncture appears to have originated from Traditional Chinese Medicine (TCM), researchers with a Western view of health have demonstrated that it produces physiological effects through local axon reflexes, segmental, extra-segmental and central neuromodulation¹⁵. Whilst the exact variable(s) that influence these effects remains equivocal, the analgesic properties of acupuncture make it a potential treatment for DOMS. However, to establish whether an intervention is effective, randomised controlled trials (RCT's) and subsequent systematic reviews are required¹⁸.

Systematic reviews of RCTs are considered the highest level of evidence in the hierarchy of research designs investigating the effectiveness of interventions¹⁸. Systematic reviews^{12,13} investigating the effectiveness of physiotherapeutic modalities for DOMS, including massage^{12,13}, low-intensity exercise^{12,13}, cryotherapy^{12,13}, and stretching^{12,13}, have been unable to provide treatment recommendations due to the poor methodology and heterogeneous results of available studies. One systematic review¹³ that included 30 RCTs investigating the effectiveness of various physiotherapy treatments on experimentally induced DOMS did not support the use of acupuncture; however, the review only included two acupuncture trials.

Another systematic review¹⁹ concluded that acupuncture at traditional acupuncture and *ah shi* points is effective, based upon two high quality studies^{20,21}. To assess the included RCTs, they used the Physiotherapy Evidence Database (PEDro) scale, which measures methodological quality of clinical trials using 10 items, with each item being attributed a score of one or zero²². Whilst PEDro is commonly used in published systematic reviews²², there are discrepancies between the PEDro scores graded by the reviewers and those available in the PEDro database, which suggests variability in the interpretation of its scoring criteria. Also, the use of quality scales such as PEDro to appraise clinical trials is problematic, as they tend to combine aspects of reporting quality with aspects of trial conduct and apply summarisation weighting that is difficult to justify²³. A trial with a high PEDro score does not necessarily imply that it is free from bias in areas such as

randomisation and blinding of participants, thus drawing conclusions based on a summary score might lead to biased findings²². The Cochrane risk of bias (RoB) assessment tool has been developed to address the shortcomings of quality scales and is the preferred tool for study quality assessment within the Cochrane Collaboration²³.

Given that conflicting findings for individual studies and systematic reviews in acupuncture for DOMS exist, and that quality appraisal for one of these systematic reviews is inconsistent with the PEDro database, an updated systematic review with alternative RoB assessment is warranted. The objective of this study was to systematically review the literature on acupuncture for DOMS, and report upon study quality and treatment outcomes for pain.

METHODS

This systematic review was undertaken and reported in accordance with the PRISMA statement²⁴.

Articles were included within this study if they: (1) were RCTs of human subjects over the age of 18; (2) published in English in a peer reviewed journal; (3) evaluated acupuncture for the management of DOMS; and (4) reported a primary outcome measure for pain.

The following studies were excluded: (1) randomised crossover trials (due to the uncertain washout period of acupuncture);²⁵ (2) studies where acupuncture

was used as a co-intervention; and (3) those which did not have a primary outcome measure that assessed pain.

The following electronic databases were searched independently by GK and CC from their inception to 31 March 2018 for eligible studies: CINAHL, MEDLINE, Allied and Complementary Medicine (AMED), EMBASE and SPORTDiscus. For those articles that met the inclusion criteria, reference lists were hand-searched for additional studies. The electronic search strategy is available in the online supplemental information (appendix 1). All articles were screened for eligibility by title, then abstract, then full text, by both authors. If it was unclear by the title or abstract whether the study met the inclusion criteria, the full text was obtained for review. Studies were included through mutual agreement. No disagreements arose.

Data was extracted using customised forms as shown in tables 1 and 2 to summarise the study, participants, outcomes and acupuncture interventions according to the revised Standards for Reporting Interventions in Clinical Trials of Acupuncture (STRICTA) checklist²⁶. Data was extracted by GK and then verified by CC. The Cochrane RoB assessment tool²⁷ was used for quality assessment by both reviewers. Discrepancies were discussed and the final judgement for each paper required consensus from both reviewers.

Due to the substantial heterogeneity of included studies and inadequacy of data reporting, pooling effect size by meta-analysis was inappropriate; therefore, a narrative synthesis was performed. Results were considered statistically significant if $p \leq 0.05$. The strength of evidence was summarised on

a scale that was developed by the Cochrane Collaboration back review group, which ranges between no evidence to strong evidence²⁸. Consistent findings among multiple higher quality RCTs indicates strong evidence²⁸, moderate evidence implies consistent findings amongst multiple lower quality RCTs (or a single higher quality RCT)²⁸. A solitary lower quality RCT suggests limited evidence and inconsistent findings in multiple RCTs indicates conflicting evidence²⁸. Finally, no evidence can be demonstrated if there are no RCTs²⁸.

RESULTS

A total of 233 records were retrieved from the initial search, with a further 18 records identified after performing hand-searches of reference lists. After removing duplicates, 195 records were screened in which 186 records were excluded based on the title and abstract, and four by full text, yielding five eligible studies. Figure 1 shows the PRISMA flow diagram of the literature search.

Table 1 summarises the included studies. They were published between 2000 and 2016 in Japan (n=30²¹; n=22²⁹), Northern Ireland (n=48)³⁰, Finland (n=22)²⁰ and Germany (n=60)³¹. There were 182 participants, of which 85 (46.7%) were female and 97 (59.3%) were male. They ranged between 18 and 40 years of age. Participants were described as healthy^{21,29,30,31} or physically active²⁰. Four studies^{20,21,29,30} recruited participants from university students or staff, while one³¹ did not mention the source of participants.

All studies investigated laboratory-induced DOMS of the upper limb. Four studies^{20,21,30,31} provoked DOMS by EC of the non-dominant elbow flexor with the use of one pre-determined repetition maximum (1RM). However, the protocols employed were slightly different: two studies^{20,30} used three sets of contractions of 1RM separated by 30 sec intervals; two studies^{21,31} used one set of ECs. The remaining study²⁹ targeted extensor digital muscles by isometric contraction.

For primary outcomes, four studies measured muscle soreness using a 0-10cm visual analogue scale (VAS)^{20,21,31} or a computerised VAS³⁰ in different muscle states: full elbow flexion²¹, assisted elbow flexion and extension²⁰, active movement³¹ and unspecified³⁰. Four studies measured mechanical pain threshold (MPT),^{20,30} pressure pain threshold (PPT)^{29,31} or electrical pain threshold (EPT)²⁹. MPT/PPT was measured by applying pressure of gradually increasing intensity using a pressure algometer to detect the minimum level of stimulus that provoked a painful sensation. Three studies set a cut-off point of 5kg/cm²^{20,31} or 40N (corresponding to 4.08kg)³⁰ to avoid bruising. One study²⁹ did not mention the use of cut-off points. EPT was measured by a pulse algometer in which a needle was inserted stepwise at 0.5-1.0mm increments to measure the EPT of skin, fascia and muscle alongside ultrasonic echo imaging. For secondary outcomes, one study³⁰ evaluated range of motion (ROM) including elbow flexion, extension and relaxed angle and two studies^{20,31} evaluated maximum isometric voluntary force (MIVF).

The points at which outcome measurements were taken varied across studies. All studies took baseline measurements. One study³⁰ measured outcomes prior to each treatment over five days. Another study²⁰ compared outcomes before and immediately after treatment over three days and measured the final outcome on day four. Itoh, Ochi and Kitakoji²¹ measured outcomes immediately, one to three days and seven days after the one-off acupuncture treatment. Itoh, Minakawa and Kitakoji²⁹ measured outcome two days following exercise, and then immediately after a one-off acupuncture treatment. Fleckenstein *et al.*³¹ conducted measurements at 24, 48 and 72 hours after DOMS induction but did not specify if this was before or after treatment.

No dropouts occurred in three studies^{29,30,31}. One study²¹ reported four dropouts among 30 participants while the remaining study²⁰ did not mention the dropout rate.

Table 2 outlines the STRICTA quality appraisal for each study. Four studies^{20,21,29,30} used manual acupuncture, and one³¹ used manual and laser acupuncture. Only one study³¹ specified the style of acupuncture used.

All five studies needled at *ah shi* points, and three studies targetted traditional acupuncture points in addition^{20,30,31}. One study³⁰ provided treatments over four consecutive days after DOMS induction. Two studies^{20,31} provided treatment three times – immediately, and 24 hours and 48 hours after DOMS induction. In the remaining studies, participants received only one treatment, which was given 10 minutes²¹ and two days²⁹ after DOMS induction

respectively. Needle retention time ranged from 10 minutes²¹ to 30 minutes²⁹. The response elicited, i.e. *de qi* sensation (a needle provoked sensation of soreness and numbness)¹⁶, was reported in one study²⁰.

The setting of treatment was only available in one study³¹. Three studies mentioned qualifications of acupuncturists, ranging from three years of training and one to ten years of clinical experience^{21,29} to 360 hours of teaching experience³¹. One study²⁰ reported use of a “skilled and experienced acupuncturist” while another³⁰ did not mention their background. All studies compared acupuncture intervention with no treatment. Two studies^{20,30} used superficial needling at non-tender traditional acupuncture points and locations not corresponding to traditional acupuncture points as a sham control. Itoh, Ochi and Kitakoji²¹ compared acupuncture at tender and non-tender points with insertion depth remaining unchanged. Fleckenstein *et al.*³¹ compared verum acupuncture with sham acupuncture (not at traditional acupuncture points), laser acupuncture and sham laser acupuncture. Itoh, Minakawa and Kitakoji²⁹ compared acupuncture at different insertion depths and in different dermatomes. All studies failed to report adverse events associated with treatment.

Table 1. Characteristics and results of included studies

Trial	Country, participants and age range	Target muscle/DOMS induction method	Outcome measure	Comparison groups	Statistical test/level of significance (p)	Mean ± standard deviation	Results
Barlas <i>et al.</i> ³⁰	Northern Ireland 48 healthy university student and staff (24F/24M) 18-40	Non-dominant biceps brachii 3 sets of eccentric contractions of 1RM until exhaustion separated by 30s rest interval	1. VAS (state of muscle unspecified) 2. MPT 3. ROM (elbow flexion, extension and relaxed angle) Measured pre-treatment over 5 days	1. Treatment group A: needling at traditional acupuncture points (n=12) 2. Treatment group B: needling at four most tender points (n=12) 3. Placebo group: superficial needling at four non-tender, non-traditional acupuncture points (n=12) 4. No treatment (n=12)	Parametric (one-way ANOVA) p=0.05	NR; data was presented in graphs and text	VAS – No consistent significant difference (p≥0.05) MPT – No significant difference (p≥0.05) ROM – No significant difference (p≥0.05)

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Trial	Country, participants and age range	Target muscle/ DOMS induction method	Outcome measure	Comparison groups	Statistical test/ level of significance (p)	Mean ± standard deviation	Results
Hubscher <i>et al.</i> ²⁰	Finland 22 healthy, physically active sport students (12F/10M) 22-30	Non-dominant biceps brachii 3 sets of eccentric contractions of 1RM until exhaustion separated by 30s rest interval	1. VAS (during assisted elbow flexion and extension) 2. MPT 3. MIVF Measured pre- and post-treatment over 3 days and measured the final outcome on day 4	1. Real acupuncture: deep needling at traditional acupuncture and tender points (n=7) 2. Sham acupuncture: superficial needling at non-tender, non-traditional acupuncture points (n=8) 3. No treatment (n=7)	Non-parametric (Kruskal-Wallis) p=0.05	NR; data was presented in graphs and text	VAS – Significant difference between group 1 and group 2 and group 1 and group 3 at 72 hours after DOMS induction (both p≤0.05) MPT – No significant group differences could be observed at any of the time points (p≥0.05) MIVF – No statistical significance (p≥0.05)

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Trial	Country, participants and age range	Target muscle/ DOMS induction method	Outcome measure	Comparison groups	Statistical test/ level of significance (p)	Mean ± standard deviation	Results
Itoh, Ochi and Kitakoji ²¹	Japan 30 healthy student from acupuncture school (13F/17M) 18-22	Non-dominant biceps brachii 1 set of eccentric contractions of 1RM until subjective exhaustion	VAS (during full elbow flexion) Measured outcomes before DOMS induction, immediately, 1-3 days and 7 days after a one-off acupuncture treatment	1. Tender point group: needling at tender points (n=10) 2. Non-tender point group: needling at non-tender, non-traditional acupuncture points (n=9) 3. No treatment (n=7)	Parametric (unpaired <i>t</i> test) p=0.05	Tender point group: Immediately after treatment: 0.6±0.9cm 3-days post treatment: 0.4±0.5cm Non-tender point group: Immediately after treatment: 1.7±2.6cm 3 days post-treatment: 1.2±1.3cm No treatment: Immediately after treatment: 4.2±2.7cm 3 days post-treatment: 2.4±2.3cm	Significant difference in VAS between group 1 and 3 immediately (p≤0.005) and 3 days after treatment (p≤0.005) No significant difference in VAS between no treatment and non-tender point groups

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Trial	Country, participants and age range	Target muscle/DOMS induction method	Outcome measure	Comparison groups	Statistical test/ level of significance (p)	Mean ± standard deviation	Results
Itoh, Minakawa and Kitakoji ²⁹	Japan 22 healthy university students (14F/8M) 18-28	Extensor digitorum 3 sets of loaded exercises with 5 minutes resting period: keeping a horizontal position of the third finger with a movable weight attached, until exhaustion	1. PPT 2. EPT of skin, fascia and muscle Measured outcome 2 days following DOMS induction and then immediately after a one-off acupuncture treatment	1. Muscle acupuncture group: acupuncture at tender point of ipsilateral muscle at depth of 10mm (n=6) 2. Skin acupuncture group: acupuncture at tender point of ipsilateral muscle at depth of 3mm (n=6) 3. Non-segmental muscle group: acupuncture at tender point of non-segmental muscle (n=6) 4. No treatment (n=6)	Parametric (one-way ANOVA) p=0.05	PPT immediately after treatment Muscle group: 652.3±77.1 Skin group: 445.0±89.6 Non-segmental group: 335.0±60.6 No treatment: 328.7±63.0 EPT of fascia immediately after treatment Muscle group: 0.64±0.20mA Skin group: 0.33±0.13mA Non-segmental group: 0.31±0.09mA No treatment: 0.09±0.12mA EPT of skin immediately after treatment Muscle group: 0.80±0.32mA Skin group: 0.64±0.25mA Non-segmental group: 0.85±0.28mA No treatment: 0.55±0.64mA EPT of muscle immediately after treatment Muscle group: 1.02±0.24mA Skin group: 1.09±0.40mA Non-segmental group: 0.89±0.36mA No treatment: 1.19±0.30mA	PPT – significant difference between group 2 and group 4 (95% CI 19.5-203.0, p≤0.05); significant difference between group 1 and group 4 immediately after treatment (95% CI 226.0-410.2, p≤0.001) EPT – significant difference in values of the fascia between group 1 and group 4 immediately after treatment (p≤0.05)

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Trial	Country, participants and age range	Target muscle/ DOMS induction method	Outcome measure	Comparison groups	Statistical test/ level of significance (p)	Mean ± standard deviation	Results
Fleckenstein <i>et al.</i> ³¹	Germany 60 healthy adults (22 F/38 M) 23.6 ± 2.8	Non-dominant biceps brachii 1 set of eccentric contractions of 1RM until subjective exhaustion	1. VAS (during active movement of muscle) 2. PPT 3. MIVF Measured before DOMS induction, and 24, 48 and 72 hours after	Verum acupuncture (VA): needling at semi-standardised traditional acupuncture points (n=12) Laser acupuncture: laser at same points as VA (n=12) Sham acupuncture (SA): needling at non-traditional acupuncture points (n=12) Sham laser acupuncture: switched on laser at same points as SA (n=12) No treatment (n=12)	Parametric (one-way ANOVA) and non-parametric (Kruskal-Wallis) P=0.05	Mean±SD for each group at different time NR; data was presented in graphs and text	VAS - No significant difference (p≥0.05) PPT - No significant difference (p≥0.05) MIVF - No significant difference (p≥0.05)

EPT, electrical pain threshold; MIMF, maximum isometric voluntary force; MPT, mechanical pain threshold; NR, not reported; PPT, pressure pain threshold; ROM, range of motion; RM, repetition maximum; VAS, visual analogue scale

Table 2. Acupuncture interventions in included studies (revised STRICTA items).

Studies	Barlas <i>et al.</i> ³⁰	Hubscher <i>et al.</i> ²⁰	Itoh, Ochi and Kitakoji ²¹	Itoh, Minakawa and Kitakoji ²⁹	Fleckenstein <i>et al.</i> ³¹
1a) Acupuncture style	NR	NR	NR	NR	German Society of Medical Acupuncture
1b) Rationale for treatment	NR	Points selected based on Lin & Yang (1999) study	NR	NR	Point selection based on expert opinion and curricular teaching of the German Society of Medical Acupuncture
1c) Treatment variation*	Fixed	Fixed	Fixed	Fixed	Partially individualised
2a) Number of needle insertions	4	Unclear	3	1	Unclear
2b) Points used in real acupuncture treatment	Group 1 – PC2, LI11, LU5, LI4 Group 2 – Tender points	<i>Ah shi</i> (tender spots), GB34, LU3, LU5, LI11	3 most tender points	Maximum tender point	LI4, LI11, LU3, LU5, GB34, SP10, MTrP 1 (<i>ah shi</i> 1), MTrP 2 (<i>ah shi</i> 2),
2c) Insertion depth	Group 1 – 2.5 to 3cm Group 2 – 1.75 to 2cm	NR	1 to 2cm	3mm/10mm	NR
2d) Response elicited	NR	<i>de-qi</i>	NR	NR	NR
2e) Needle stimulation	MA	MA	MA	MA	MA/LA
2f) Retention time	20 min	15 min	10 min	30 min	NR
2g) Needle size/ length/ type/ manufacturer	0.25mm/ 3.75cm/ stainless steel/ Scarborough Ltd	0.3mm/ 30mm/ sterile disposable needles/ Moxom Medical GmbH	0.18mm/ 40mm/ stainless steel/ Seirin	0.18mm/ 40mm/ stainless steel/ Seirin	0.3mm/ 30mm/ sterile disposable, silicon-coated, steel needles/ Dongbang Acupuncture Inc

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Studies	Barlas <i>et al.</i> ³⁰	Hubscher <i>et al.</i> ²⁰	Itoh, Ochi and Kitakoji ²¹	Itoh, Minakawa and Kitakoji ²⁹	Fleckenstein <i>et al.</i> ³¹
3a) Number of sessions	4	3	1	1	3
3b) Frequency/ duration of treatment sessions	Over 4 consecutive days/ 20 min each	Immediately, and 24, 48hrs after DOMS induction /15 min each	10 min after DOMS induction/ 10 min	2 days after DOMS induction / 30 min	Immediately, and 24, 48hrs after DOMS induction/ NR
4a) Details of other interventions	N/A	N/A	N/A	N/A	N/A
4b) Setting and content of treatment	NR	NR	NR	NR	Participant were told needle acupuncture and laser acupuncture are equivalent treatment techniques.
5) Practitioner background	NR	Skilled and experienced acupuncturist	Acupuncturists with 3 years of acupuncture training and 1-10 years of clinical experience	Author with 3 years of acupuncture training and 10 years of clinical experience	Expert acupuncturist with 360 hrs of curricular teaching
6) Control interventions	Placebo group (non-traditional acupuncture, non-tender points)	Sham acupuncture (superficial needling without stimulation at non-traditional acupuncture, non-tender points)	Non-tender point group (non-tender, non-traditional acupuncture points). Point locations were not clearly specified.	NR	Sham acupuncture (non-traditional acupuncture points)/ Sham laser acupuncture (switched off laser). Details of needling were not reported

*Treatment variation was categorised into three types based on the levels of individualisation; “fixed” means all patients receive the same treatment at all session, “partially individualised” means using standard set of points combined with individualised points, and “individualised” means each patient receives a unique set of treatments based on diagnosis and treatment response.

De qi, needle-provoked sensation of soreness and numbness; LA, laser acupuncture; MA, manual acupuncture; NR, not reported; STRICTA, Standards for Reporting Interventions in Controlled Trials of Acupuncture; TCM – Traditional Chinese Medicine

Risk of bias in included studies

Figure 2 summarises the risk of bias of each trial in each domain.

Four studies^{20,21,29,31} used random sequences generated by computer programmes, and one study³⁰ was rated “unclear” as the randomisation method was not described. Allocation concealment was only employed in one study³¹ using sequentially numbered opaque envelopes.

Blinding of participants was only considered as low risk if appropriate credibility measures, such as a credibility questionnaire, demonstrated that both the acupuncture and control groups were perceived as equivalent by participants³². No studies conducted credibility tests to assess blinding of participants although all studies attempted to blind participants by comparing acupuncture with different control procedures, therefore, all were rated “high risk” for blinding of participants. One study³¹ attempted to further ascertain blinding by only recruiting acupuncture novices while one study²¹ recruited students from an acupuncture school, which could have unblinded participants to group allocation. No studies mentioned the blinding of acupuncturists, therefore all were considered at high risk of bias for this domain.

Four studies^{20,21,29,31} employed independent assessors for outcome measurement, therefore were considered at low risk of bias for this domain. One study³⁰ was considered unclear as relevant information was not provided. Three studies^{29,30,31} had no participant dropouts. The risk of bias in one study²⁰ was unclear as the number of participants completed and analysed in each

group was not reported. One study²¹ had a high risk of bias as “intention to treat” analysis was not performed with data on four withdrawals. Selective outcome reporting was not found in any studies therefore all were considered low risk of bias. Another bias was identified in one study²⁹, in which two of the 22 participants originally recruited were asked to repeat the study because there were insufficient participants, which could have unblinded the participants to their group allocation.

Effects of intervention

The statistical tests adopted included both parametric (one-way ANOVA^{29,30,31} and unpaired *t* test²¹) and non-parametric tests (Kruskal-Wallis test^{20,31}). All studies set the level of significance at $p=0.05$. However, only two studies^{21,29} presented the mean and standard deviation (SD), with the others^{20,30,31} presenting data through graphs and descriptions.

All studies^{20,21,30,31} measuring VAS demonstrated an increase in scores after DOMS induction, followed by an amelioration after two to four days, implying that the DOMS induction procedure was successful. However, the extent of soreness induced was likely to be different between studies due to variations in DOMS induction methods and subjective perception of exhaustion. Furthermore, three studies^{20,30,31} failed to report the VAS scores and instead presented the data using graphs and text.

Two studies^{20,21} reported acupuncture to be superior to no treatment; one study²⁰ reported at 72 hours after DOMS induction (mean \pm SD not reported;

$p \leq 0.05$) and the other²¹ demonstrated a significant reduction in VAS score immediately after acupuncture (acupuncture group 0.6 ± 0.9 cm vs. no treatment: 4.2 ± 2.7 cm, $p \leq 0.005$) and three days post-treatment (acupuncture group 0.4 ± 0.5 cm vs. no treatment 2.4 ± 2.3 cm, $p \leq 0.005$). However, only one²⁰ study showed a significant difference between acupuncture and sham groups at 72 hours after DOMS induction (mean \pm SD not reported; $p \leq 0.05$). In comparison, two studies^{30,31} reported no significant difference between groups (mean \pm SD not reported, $p \geq 0.05$).

Four studies^{20,29,30,31} measured MPT/PPT, in which decreasing values represent an increase in tenderness. All studies reported a decrease in MPT/PPT as a result of the DOMS induction procedure. Positive results were only observed in one study,²⁹ in which there was significant difference in PPT immediately after treatment between the skin acupuncture group (insertion depth 3 mm) and no treatment group (445.0 ± 89.6 vs. 328.7 ± 63.0 , respectively; $p \leq 0.05$); and significant difference between the muscle acupuncture group (insertion depth 10 mm) and no treatment group (652.3 ± 77.1 vs. 328.7 ± 63.0 , respectively; $p \leq 0.001$).

One study²⁹ measured EPT and reported that fascia EPT values were significantly higher ($p = 0.05$) in the muscle acupuncture group (insertion depth 10 mm; 0.64 ± 0.20 mA) than those in the no treatment group (0.09 ± 0.12 mA) immediately after treatment.

Overall two studies^{20,21} demonstrated complete resolution of pain, one²¹ reported that VAS returned to baseline in all groups seven days after treatment, and the other²⁰ showed full recovery of MPT in all groups on day four of the experiment.

Using the Cochrane study quality scale, these findings indicate the evidence base for acupuncture treatment of DOMS is conflicting to limited. All studies failed to provide evidence that the outcome assessor and participant were blinded, with only one study³¹ considered to have a low risk of bias in all other categories. Furthermore, outcomes for pain varied, with three studies^{20,21,29} finding reduced pain, and two^{30,31} finding no differences, when compared to no intervention.

DISCUSSION

Quality of evidence

No studies were considered free from bias, resulting in a score of conflicting to limited quality. All but one RCT³¹ had unclear allocation concealment and at least one more methodological flaw. All studies aimed to investigate whether a specific independent variable, such as needle insertion, needle insertion depth, or location of needle insertion, impacted DOMS pain. However, although blinding of participants was attempted by comparing an acupuncture intervention with sham acupuncture^{20,21,29,30,31} and/or the use of acupuncture novices³¹, no studies conducted credibility assessments to evaluate successful blinding of participants. It is important to establish whether a sham intervention is indistinguishable from the true treatment,³³ and if this had been included, credibility could have been ruled out as a variable potentially impacting DOMS pain,

In keeping with most published acupuncture RCTs³⁴, the studies included within this systematic review failed to completely fulfil the STRICTA criteria. The included studies reported on 11-13 of the 17 criteria, and interestingly the two most recently published studies^{29,31} performed the worst. This prevents the reader from being able to accurately replicate the intervention, or ascertain whether the acupuncture approach was most appropriate. For example, four studies^{21,29,30,31} failed to report needle responses elicited by acupuncture, which may influence therapeutic effect¹⁶. Inadequate treatment could underestimate the effects of acupuncture, leading to false negatives³⁵.

Finally, three studies^{20,30,31} failed to publish adequate statistics for appropriate scrutiny, instead opting for statements such as 'not significant', or providing graphs without means or standard deviations. Only one study³¹ mentioned the sample size calculation which was based on a level of significance of 0.05 and power of 80%. Greater transparency through data display is considered essential in accurate reporting, and the lack of data and power calculations in the included studies prevents this systematic review from drawing any firm conclusions regarding the effect of acupuncture on DOMS pain.

Effectiveness of acupuncture for DOMS pain

This review showed there is conflicting to limited evidence to support the use of acupuncture for the relief of pain associated with DOMS. Three out of the five included studies reporting superiority of acupuncture over controls^{20,21,29}, with one of these studies failing to provide adequate data²⁰. Neither study that found acupuncture to be equal to control interventions^{30,31} provided adequate data in the form of means and standard deviations. Furthermore, all studies used laboratory-induced DOMS with healthy participants, and therefore did not measure return to sports or subsequent performance. These measures would have provided a clinically relevant context and thus more meaningful data.

Whilst the acupuncture method and frequency of delivery did not differ greatly between studies, there were several design features that could have affected outcomes. All included studies used subjective exhaustion to determine DOMS induction, which could have resulted in substantial variability of baseline measures between participants and between studies. Therefore, incorporating

a post-exercise baseline criterion requiring moderate or severe DOMS-related pain before randomisation may have increased the sensitivity³⁶.

In addition, any effects associated with acupuncture may be observed immediately after treatment, or after multiple treatments³⁷. Three studies^{20,21,29} within this review, which found acupuncture to be superior to controls, measured both immediate and cumulative effects, two of which^{21,29} demonstrated significant differences between the acupuncture and control groups immediately after treatment, and two also found benefits at 72 hours post treatment^{20,21}. However, the two studies^{30,31} presenting non-significant results evaluated cumulative effects only. Any future RCTs should measure both immediate and cumulative effects to provide an understanding of the duration of effect, if any, that could be expected from acupuncture.

Finally, the outcome measures adopted in these studies varied. PPT measures the minimum pressure required to provoke pain, whereas VAS measures the pain level in response to a stimulus that exceeds the pain threshold. Studies^{38,39} measuring VAS and PPT in DOMS have concluded there is no significant correlation between these two variables. They are believed to measure different aspects of DOMS³⁸, making direct comparisons between VAS and PPT difficult. Furthermore, variations in the time at which VAS measurements are taken can influence VAS scores. An RCT³⁶ comparing the efficacy of a topical gel in relieving DOMS observed there was a smaller effect size for pain on standing than pain with walking. It has been suggested that pain with movement appears to have higher sensitivity than pain at rest as the

latter may not be obvious enough to allow discrimination of the analgesic effect³⁶. Given that a sporting environment is the most relevant context for DOMS studies, it would seem most appropriate to measure pain during movement, and use a VAS instead of PPT as this is more likely to be used in the clinical setting to measure day-to-day pain.

Compared to studies that failed to meet the inclusion criteria for this systematic review, inconsistent and heterogeneous findings appear to be the norm, with two studies^{40,41} finding acupuncture to be more effective than a control, and one study finding that acupuncture did not significantly reduce post-exercise VAS among 20 male cyclists⁴². Furthermore, this review was able to include five studies and use a robust quality appraisal tool, which compares favourably to the two existing systematic reviews for DOMS^{13,19} including two to four studies, neither of which have used the Cochrane quality assessment scale. However, we can neither recommend nor discourage the use of acupuncture for DOMS, given the heterogeneous methods and findings of the included studies.

Although DOMS is usually accompanied by various muscle function changes after unaccustomed EC³, the relationship between muscle soreness and those changes is still unknown⁴³. It has been suggested that loss of muscle strength is not likely caused by psychological inhibition related to the sensation of soreness⁶. Consequently, it is unclear whether reduction in muscle soreness would lead to recovery of muscle strength or athletic performance. Among the included studies, only one²⁰ recruited physically active sports people while the

others used healthy individuals. All studies were conducted in a controlled laboratory setting instead of training environments. Furthermore, given that the clinical implications of reducing the effects of DOMS is likely to be of most interest to professional athletes, the method of DOMS production should more closely mimic a sporting setting, and should include a measure of athlete preparedness for return to activity. This could be combined with measures of athletic performance, such as exertional effort and the time taken to return to full training, which would provide a more clinically relevant study.

The limitations to this study are:

1. Only studies published in English were selected; unpublished and grey literature was not included, thus it is possible that some relevant trials may have been excluded.
2. Protocols of the included studies were not searched and assessed, so bias from selective reporting cannot be fully ascertained. Retrieval of missing primary data by contacting authors was not performed, so the risk of bias present in the included studies could be due to reporting deficits or actual methodological flaws.
3. Meta-analysis was not performed due to heterogeneity of study design and outcome measures.

Conclusion

Based on this review, the evidence for acupuncture analgesia in DOMS is conflicting. Limitations of the studies reviewed were evident with respect to

participant blinding, reporting of the acupuncture interventions, adverse events and data presentation. More rigorous and well-reported RCTs including a measure of athlete preparedness for return to activity in a sporting environment are required to further evaluate the effectiveness of acupuncture for DOMS.

FOOTNOTE

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