

The effect of focused extracorporeal shock wave therapy on myofascial pain syndrome of trapezius

A systematic review and meta-analysis

Jun-Il Yoo, MD^a, Min-Kyun Oh, MD, PhD^b, Se-Woong Chun, MD^c, Shi-Uk Lee, MD, PhD^d, Chang Han Lee, MD^{b,*}

Abstract

Background: Myofascial pain syndrome (MPS) is commonly seen in clinical settings and negatively influences a patient's daily life. Recently, the application of extracorporeal shock wave therapy (ESWT) has been utilized as one of the treatment methods for MPS. The aim of this systematic review and meta-analysis was to summarize the current evidence for the short-term effect of ESWT on MPS of trapezius.

Methods: PubMed, EMBASE, Web of Science, and Cochrane Central Register of Controlled Trials were searched from the database inception to March 2019. Two reviewers independently screened articles, evaluated methodological quality, and extracted data. The primary outcome was post-interventional pain intensity.

Results: Randomized controlled trials (RCTs) were conducted to determine whether ESWT was used as the main treatment on MPS. The 5 studies reviewed in this meta-analysis were evaluated for changes in pain intensity. Compared with other treatments, focused ESWT in MPS was more effective in reducing the scores of visual analog scale (VAS) (standardized mean difference [SMD] = -0.48, 95% CI -0.74 to -0.22).

Conclusions: There is very low level evidence that focused ESWT is effective for short-term relief of neck pain in MPS. The limited sample size and poor quality of these studies highlight and support the need for large scale, good quality placebo controlled trials in this area.

Abbreviations: ESWT = extracorporeal shock wave therapy, MeSH = Medical Subjects Heading, MCID = minimally clinically important difference, MD = mean difference, MPS = myofascial pain syndrome, PPT = pressure pain threshold, RCT = randomized clinical trial, SMD = standardized mean difference, VAS = visual analog scale.

Keywords: extracorporeal shock wave therapy, meta-analysis, myofascial pain syndrome, randomized controlled trial, review

1. Introduction

Myofascial pain syndrome (MPS) is known to be a clinically common syndrome with characteristics including localized muscle tenderness, palpable intramuscular taut band, referred

pain, and muscle spasm following trigger point injections.^[1] MPS is frequently encountered in clinical settings, and accounts for the largest proportion of musculoskeletal diseases. The mechanisms underlying the etiology of MPS are not fully understood. Therefore, treatment approaches are mostly symptomatic. The primary objectives of the treatment are inactivation of the trigger point, loosening of spot nodule, and breakdown of the vicious cycle of pain-spasm-pain.^[2]

MPS treatments include invasive techniques such as trigger point injection and dry needling, and non-invasive techniques including electrical and exercise treatments. Electrical treatments consist of interference current therapy, ultrasound, and transcutaneous electrical nerve stimulation while exercise treatments include stretching, massages, taping, and so on.^[3-6]

Extracorporeal shock wave therapy (ESWT) was used in animal studies in the mid-1980s for the incidental observation of osteoblastic response pattern. In the early years of ESWT, therapy was used mainly for bone and the bony tendon attachments as well as in the treatment of calcific structures.^[7-9] Since then, ESWT has become a major area of interest particularly in MPS therapy.^[10] Several studies have demonstrated the efficacy of ESWT for pain relief and clinical improvement in patients with MPS despite unclear pathophysiology.^[11-16] The principle of ESWT is the production of mechanical energy by high air pressure. This energy is propagated in the tissues as the primary therapeutic effect, and the secondary effects refer to the biological effects which may lead to tissue repair and regeneration by

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^a Department of Orthopaedic Surgery, ^b Department of Rehabilitation Medicine, Gyeongsang National University School of Medicine and Gyeongsang National University Hospital, Jinju, Korea, ^c Department of Rehabilitation Medicine, Gyeongsang National University Changwon Hospital, 11 Samjeongjaro, Seongsan-gu, Changwon, Korea, ^d Department of Rehabilitation Medicine, Seoul National University Boramae Medical Center, Seoul, Korea.

* Correspondence: Chang Han Lee, Department of Rehabilitation Medicine, Gyeongsang National University School of Medicine and Gyeongsang National University Hospital, Jinju, Korea (e-mail: ychkhk1407@gmail.com).

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causing micro-functional and micro-structural changes.^[17] ESWT provides effective pain relief in musculoskeletal disease such as fracture nonunion, calcific tenosynovitis, and plantar fasciitis.^[5,18] Generally, shock waves can be classified as extracorporeal shock waves and radial shock waves. Extracorporeal shock waves are usually defined as focused type. Focused type is based on the use of single pressure pulses of micro-second duration, and these can be guided by ultrasound or radiographs to focus on a specific site. In contrast, radial type is a low to medium-energy shock wave that is pneumatically generated via acceleration of a projectile inside the handpiece of the treatment device and then transmitted radially from the tip of the applicator to the target zone.^[19] The application of radial ESWT in MPS has not been fully investigated. However, there is some evidence regarding the efficacy of radial ESWT for epicondylitis, plantar fasciitis, and calcific tendinitis.^[20,21] Considering the pathophysiology of MPS, accurate pulse of focused ESWT was used to treat MPS precisely based on the diagnostic criteria of pain recognition and referred pain in these studies.^[11–16] The studies adopted different clinical scales, with varied follow-up times, preventing a definitive conclusion of the effectiveness.^[11–16] Currently, no systematic review focusing solely on the treatment effect of ESWT for MPS has been published.

Furthermore, until now, few studies have systematically analyzed the effects of ESWT for MPS using randomized clinical trial (RCT). Therefore, the aim of the present systematic review and meta-analysis was to analyze the effects of ESWT on short-term relief of neck pain in RCTs involving MPS using a visual analog scale (VAS).

2. Methods

2.1. Literature search

This systematic review and meta-analysis was conducted according to the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and the guidelines of the Cochrane Handbook for Systematic Reviews of Interventions.^[22,23] This systematic review was registered in the PROSPERO database, an international prospective register of systematic reviews in health and social care (National Institute for Health Research, CRD42019093590). We searched electronic

databases (MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, and the Web of Science) sequentially from the database inception to March 2019. The searches were limited to RCTs or clinical trials, but without language restriction. We used the following search terms: “shock” (Medical Subjects Heading [MeSH]), “wave” (text word), “therapy” (MeSH), “shock wave therapy” (text word), “ESWT” (text word), “trigger” (text word), “point” (text word), “points” (MeSH), “trigger point” (text word), “trigger points” (MeSH), “pain” (MeSH), “myofascial pain” (text word), “syndromes” (MeSH), and “trapezius myofascial pain syndromes” (MeSH). These keywords were used as MeSH headings and free text words, respectively. The detailed search strategy employed in this study is shown in Table 1. Gray literature was searched via opengrey (opengrey.eu), and unpublished or ongoing trials were identified by electronically searching Pro-Quest Dissertations and databases, ClinicalTrials.gov, and National Research Register. We used snowballing technique to review references cited in domestic and international literature subscribed through electronic databases.

2.2. Inclusion and exclusion criteria

The systematic review was designed to answer the following focused question: “Is ESWT more effective for MPS than control group?” PICOS (Population/patient/participants/problem, Intervention, Comparison, Outcome, Study design) method was used to define the eligibility criteria as follows: P (population) refers to patients (of all genders) over 18 years of age diagnosed with MPS and excluded previous back surgery, spondylolisthesis, facet joint arthropathy, neurological pain; I (intervention) included ESWT; C (comparison) was with persons receiving control treatments which were included a placebo; O (outcome) was the value of VAS measured; and S (study design) comprised RCT. Eligible articles were included if they

- (1) followed RCT design;
- (2) included patients who were diagnosed with MPS based on Simon’s criteria^[24];
- (3) used ESWT as an intervention; and
- (4) had at least a single outcome measure of either VAS or other parameter that can be replaced by VAS to assess pain intensity.

Table 1

Detailed search strategies for each database. Mesh terms, search terms, and combinations of the 2 were used for each database search.

Database	Detailed search strategies	Records founded
MEDLINE/PUBMED	((("shock"[MeSH Terms] OR "shock"[All Fields]) OR ("extracorporeal shockwave therapy"[MeSH Terms] OR ("extracorporeal"[All Fields] AND "shockwave"[All Fields] AND "therapy"[All Fields]) OR "extracorporeal shockwave therapy"[All Fields]) OR ("shock"[All Fields] AND "wave"[All Fields] AND "therapy"[All Fields]) OR "shock wave therapy"[All Fields]) OR ESWT[All Fields] AND (("trigger points"[MeSH Terms] OR ("trigger"[All Fields] AND "points"[All Fields]) OR "trigger points"[All Fields] OR ("trigger"[All Fields] AND "point"[All Fields]) OR "trigger point"[All Fields]) OR ("trigger points"[MeSH Terms] OR ("trigger"[All Fields] AND "points"[All Fields]) OR "trigger points"[All Fields]) OR (myofascial[All Fields] AND ("pain"[MeSH Terms] OR "pain"[All Fields])) OR ("myofascial pain syndromes"[MeSH Terms] OR ("myofascial"[All Fields] AND "pain"[All Fields] AND "syndromes"[All Fields]) OR "myofascial pain syndromes"[All Fields]))	103
EMBASE	("shock"/exp OR shock OR "wave"/exp OR wave OR "therapy"/exp OR therapy OR eswt) AND point AND ("trigger"/exp OR trigger) AND points AND myofascial AND ("pain"/exp OR pain) AND syndromes	103
Web of Science	Topic: (shock wave therapy or ESWT) and (trigger point* or myofascial pain*)	18
Cochrane Central Register of Controlled Trials	(shock or shock wave therapy or ESWT) and (trigger point or trigger points or myofascial pain or myofascial pain syndromes)	23

Ultimately, 247 records were found, 103 from MEDLINE/PubMed, 103 from EMBASE, 23 from the Cochrane Library, and 18 from the Web of Science.

Studies were further selected according to the inclusion criteria listed in Section 2 (Fig. 1).

ESWT = extracorporeal shock wave therapy, Medical Subjects Heading.

Exclusion criteria were

- (1) studies without data/results;
- (2) literature or systematic review, narrative review, and case reports; and
- (3) studies involving animal subjects.

2.3. Study selection and data extraction

Each identified article was independently screened by title and abstract by the 2 authors (C.H. and J.I.) to remove duplicate entries and studies that failed to meet the inclusion criteria. In order to avoid exclusion of potentially relevant articles, abstracts providing unclear results were included in the full-text analysis. Discrepancies in data extraction were resolved after a discussion between the 2 reviewers. A third reviewer (M.K.) adjudicated when necessary. Full-text articles of the remaining studies were assessed according to previously defined inclusion and exclusion criteria, and eligible articles were selected. The review authors were not blinded to authors, institutions, or the publication. References of the included articles were further checked manually.

Two of the authors (C.H. and J.I.) independently extracted the following data from each included article into predesigned data collection forms on Microsoft excel:

- (1) study identification: first author's name, year of publication, study design, and country;
- (2) population (participants): sample size, mean age, and numbers of male and female participants;
- (3) diagnosis and duration of symptom;
- (4) intervention group: details of ESWT interventions such as intensity and frequency with control group;
- (5) primary outcome measures: VAS was used as a substitute for Patient Global Assessment scale in the study by Gur et al.^[12]

Discrepancies were resolved by the third examiner (M.K.).

2.4. Risk of bias in individual studies

Two of the authors (C.H. and J.I.) independently evaluated the risk of bias in the enrolled studies using the Cochrane Risk-of-Bias Tool.^[25] Following the Cochrane Risk-of-Bias Tool, we assessed each study for 5 areas: selection, performance, detection, attrition, and reporting bias. We also evaluated additional 5 areas related to crossover design following the Cochrane Handbook.^[23]

2.5. Data synthesis and statistical analysis

In the studies by Cho,^[11] Gur,^[12] Ji,^[14] Jeon,^[13] Kiraly,^[16] and colleagues, the change in VAS was evaluated using meta-analysis (Table 2). The meta-analysis of 5 studies involved pain on VAS as the outcome measure. We aggregated the data obtained from 5 studies reporting focused ESWT effects in the form of mean (standard deviation) to produce an overall mean effect (standardized mean difference [SMD] and mean difference [MD]). VAS score was summarized as mean plus/minus standard deviation, when provided or calculated. For outcomes presented as means with ranges, means, and standard errors were calculated from the sample size, median, range and/or interquartile range, or confidence intervals (CI).^[23,26] The standardized mean effect size was calculated using R version 3.0.2.^[27] For

VAS score, a standardized treatment effect was calculated and the results were expressed as SMD and 95% CI. I^2 test and Q statistic were used to assess heterogeneity.^[28] A P value of Q statistic $<.05$ was defined as an indicator of heterogeneity, and low, moderate, and high values of the I^2 statistic were assigned to 25%, 50%, and 75%, respectively.

The change of pressure pain threshold (PPT) was evaluated at the studies by Ji^[14] and Jeon^[13] and colleagues. However, the devices for the assessment of altered PPT were not same. Units of threshold also differed from each other. Therefore, the change in PPT was analyzed descriptively. The study by Lee^[15] colleagues considered 3 treatment groups which were made up of 3 treatment groups (proprioceptive neuromuscular facilitation, ESWT, and trigger point injection). However, all the groups received hot pack therapy for 20 minutes and ultrasound for 5 minutes as well as their respective treatments. We decided that it was wrong to use the data of this study to produce an overall mean effect of focused ESWT. So this study was analyzed descriptively and the VAS, PPT, neck disability index, and Constant-Murley Scale were conducted for the evaluation of pain and function. The PPT, neck disability index, and Constant-Murley Scale except the VAS were assessed for the evaluation of pain and function in the study by Cho^[11] colleagues. In the study by Kiraly^[16] and colleagues, neck disability index was evaluated via descriptive analysis. Further, 2 studies^[29,30] demonstrating the efficacy of radial ESWT were analyzed descriptively because radial ESWT differed from focused ESWT in transmission of shock wave (Table 2).

3. Results

3.1. Identification of eligible studies

The literature search identified 251 publications. After eliminating duplicates, 208 articles were selected; 193 of these were excluded after screening their title and abstract screening. The remaining 8, involving trials with 371 patients, were evaluated because they met our inclusion criteria (Fig. 1).

3.2. Study design and population

Table 2 summarized the characteristics of study participants. The included studies were published between 2012 and 2019. All of included studies were RCTs with different follow-up period from 1 week to 3 months. The 8 studies included a total of 371 patients with MPS. Among them, 5 studies included a total of 194 patients who underwent the focused ESWT (n=96) and control (n=98) treatment for MPS. The remaining 1 study^[15] was analyzed descriptively and the other 2 studies^[29,30] reported the efficacy of the radial ESWT.

3.3. ESWT compared with control treatment: results of meta-analysis

The 5 studies included in the meta-analysis provided 5 effect sizes that evaluated the effect of focused ESWT on VAS. The time point of assessment was 2 weeks in 2 trials.^[13,14] The assessment in the other 2 trials was carried out for 3 weeks.^[12,16] The rest trial was carried out for 4 weeks.^[11] Subjects treated with focused ESWT showed a reduction of VAS (SMD = -0.48, 95% CI -0.74 to -0.22) compared with subjects who were taken a control treatment, heterogeneity for I^2 value was lower than moderate ($\tau^2=0.0843$; $I^2=48.1\%$; $P=.103$) (Fig. 2).

Table 2
Characteristics of the included studies.

Study (design and country)	n (M/F)	Mean age (yr) [*]	Diagnosis	DS (mo) [*]	Groups	Follow-up	Outcome measure
Gur 2013 ^[12] (RCT, Turkey)	59 (14/45)	35.07 ± 12.23 [†] 37.00 ± 11.51 [‡]	MPS	33.83 ± 31.38 [†] 35.34 ± 31.50 [‡]	F-ESWT: 1000 × 0.25 mJ/mm ² 3 times at 3-d intervals US	3 wk 3 mo	PGA (->VAS)
Lee 2013 ^[15] (RCT, Korea)	33 (NR)	51.61 ± 8.3 [†] 51.92 ± 7.53 [§] 52.67 ± 7.58 [¶]	MPS	NR	F-ESWT: 1000 × NR (5Hz) 8 times (2 times/wk in 4wk) with hot pack and ultrasound therapy PNF with hot pack and ultrasound therapy TPI with hot pack and ultrasound therapy	4 wk	VAS PPT CMS NDI
Ji 2012 ^[14] (RCT, Korea)	20 (3/17)	32.82 ± 12.71 [†] 34.00 ± 15.56	MPS	NR	F-ESWT 1000 × 0.056 mJ/mm ² 700 impulse (taut band) 300 impulse (surrounding to the taut band) 4 times (2 times/wk in 2 wk) Control: 0.001 mJ/mm ²	2 wk	VAS PPT
Jeon 2012 ^[13] (RCT, Korea)	30 (22/8)	40.86 ± 13.07 [†] 45.00 ± 15.46 [‡]	MPS	NR	F-ESWT: 1500 × 0.1 mJ/mm ² (rate of 240 wave) 3 times with a week's interval TPI with TENS	1 wk 2 wk	VAS PPT McGill pain questionnaire ROM of neck
Cho 2012 ^[11] (RCT, Korea)	36 (NR)	47.06 ± 13.53 [†] 47.67 ± 10.49 48.08 ± 12.24 [#]	MPS	NR	F-ESWT: 1000 × 0.12 mJ/mm ² 12 times (3 times/wk in 4 wk) Stabilization Combined	4 wk	VAS PPT CMS NDI
Kiraly 2018 ^[16] (RCT Hungary)	61 (7/54)	57.26 ± 14.31 [†] 62.62 ± 9.62 ^{**}	MPS	NR	F-ESWT: 2000 × 0.25 mJ/mm ² (10 Hz) 1000 impulse (taut band) 1000 impulse (surrounding to the taut band) 3 times with a week's interval Low-level laser	3 wk 15 wk	VAS NDI
Luan 2019 ^[29] (RCT, China)	62 (19/43)	32.47 ± 10.58 [†] 33.09 ± 12.78 ^{††}	MPS	8.30 ± 3.10 [†] 8.91 ± 2.73 ^{††}	R-ESWT: 2000 × 0.1 mJ/mm ² 1500 impulse (taut band) 500 impulse (surrounding to the taut band) 3 times with a week's interval Dry needling	1 mo 3 mo	VAS PPT NDI Shear-wave ultrasound elastography
Manafnezhad 2019 ^[30] (RCT, Iran)	70 (21/49)	37 ± 9.1 [†] 39.2 ± 7.2 ^{††}	MPS	NR	R-ESWT: 1000 × 60 mJ/mm ² (16 Hz) 3 times with a week's interval Dry needling	1 wk 2 wk 3 wk	VAS PPT NDI

CMS = Constant-Murley scale, DS = duration of symptoms, F = female, F-ESWT = focused extracorporeal shock wave therapy, M = male, MPS = myofascial pain syndrome, NDI = neck disability index, NR = not reported, PGA = Patient Global Assessment, PPT = pressure pain threshold, PNF = proprioceptive neuromuscular facilitation, R-ESWT = radial extracorporeal shock wave therapy, RCI = randomized clinical trial, ROM = range of motion, TPI = trigger point injection, VAS = visual analog scale.

^{*} Values are mean ± SD.

[†] ESWT group.

[‡] Control group.

[§] PNF group.

[¶] TPI group.

^{||} Stabilization exercise group.

[#] Combined (ESWT with stabilization exercise) group.

^{**} Low-level laser group.

^{††} Dry needling.

3.4. ESWT compared with control treatment: results of descriptive analysis

Ji et al.^[14] reported that focused ESWT was more effective than control treatment in patients with MPS. The comparison of PPT indicated that the pressure threshold (N) was significantly increased in the focused ESWT group from 40.4 ± 9.94 to 61.2 ± 12.16, which remained unchanged in the control group. In the study conducted by Jeon et al.,^[13] the

pain threshold (lb/cm²) was increased from 6.86 ± 1.35 before first therapy, to 11.43 ± 0.27 after first therapy, and 12.57 ± 0.72 after third therapy, while trigger point injection with transcutaneous electrical nerve stimulation group increased the pain threshold (lb/cm²) from 6.20 ± 1.92 before first therapy, to 8.80 ± 0.48 after first therapy, and 9.60 ± 2.19 after third therapy, and the changes between the groups were significantly different (*P* = .045).

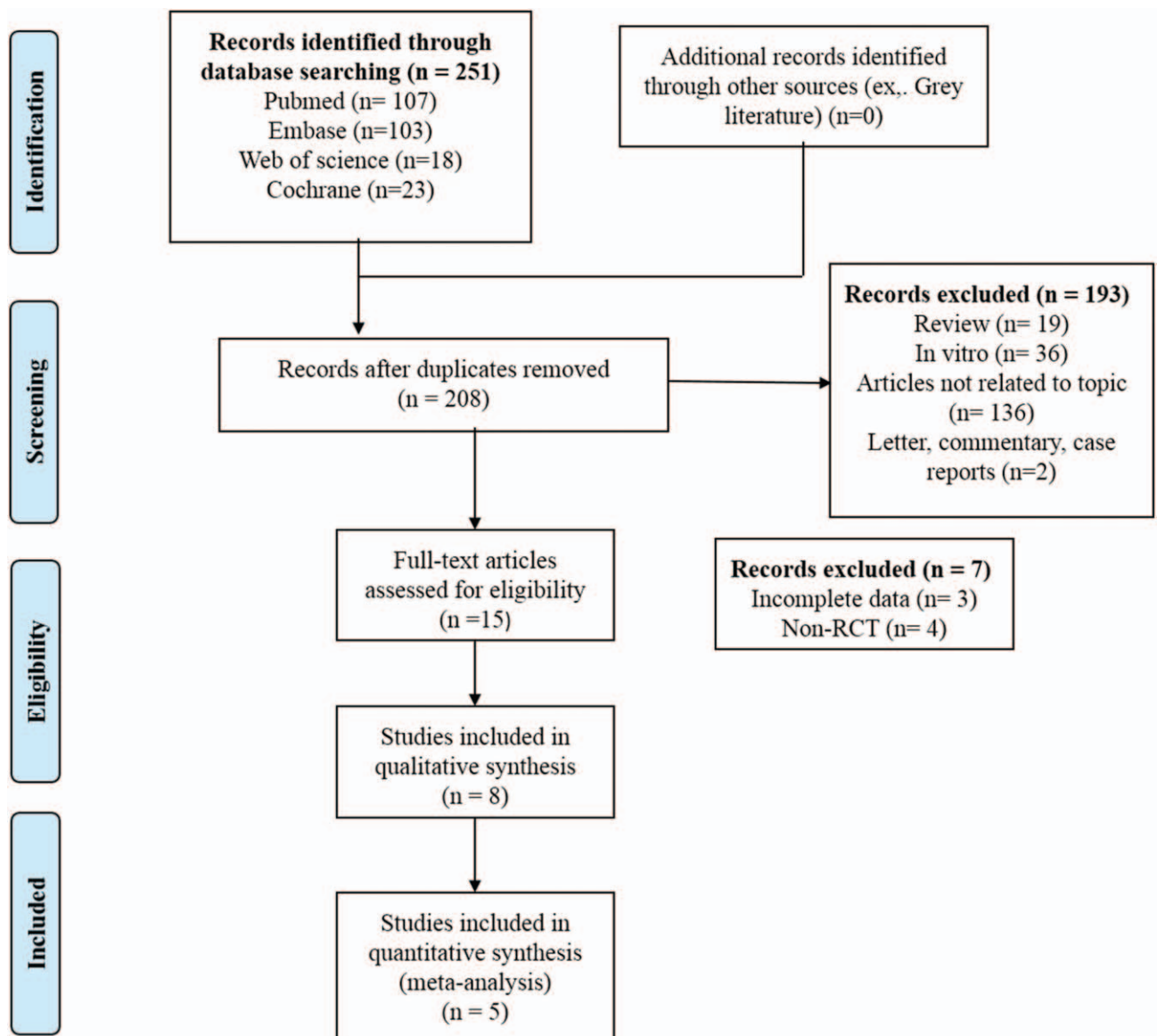


Figure 1. PRISMA flow of information through the different phases of meta-analysis.^[22]

The study by Lee^[15] colleagues were analyzed descriptively. The evaluation of pain and function was conducted through the VAS, PPT, neck disability index, and Constant-Murley Scale. Lee et al^[15] reported that focused ESWT therapy was more effective for pain relief (i.e., in case of VAS) than in other treatments (proprioceptive neuromuscular facilitation and trigger point injection). Proprioceptive neuromuscular facilitation treatment enhanced neck function. Trigger point injection treatment reduced pain, but had limited role in enhancing the functional activities. Cho et al^[11] examined the effects of focused ESWT, stability exercise, and their combined treatment. The combined treatment was more effective in reducing the pain compared with the individual treatments (only focused ESWT and stability exercise). Functional status and quality of life were measured by neck disability index before and after 3 weeks and 15 weeks by Kiraly^[16] and colleagues. Neck function was improved signifi-

cantly in both groups at 3 weeks and 15 weeks. However, patients with focused ESWT demonstrated significantly better changes than patients with low-level laser therapy (the mean between-group differences at 3 weeks = 0.660, 95% CI = -1.933 to 3.253 and the mean between-group differences at 15 weeks = 1.072, 95% CI = -2.110 to 4.254).

The studies by Luan^[29] and Manafnezhad^[30] and colleagues were also analyzed descriptively because the studies were different from the 5 included studies^[12-16] that were used for meta-analysis in transmission of shock wave. The 2 studies used radial ESWT and dry needling in the upper trapezius. The evaluation of pain and function was conducted using the VAS, PPT, and neck disability index. Both radial ESWT and dry needling were effective for pain relief and in improving the function for patients with MPS. There were no significant differences in the radial ESWT group and dry needling group.

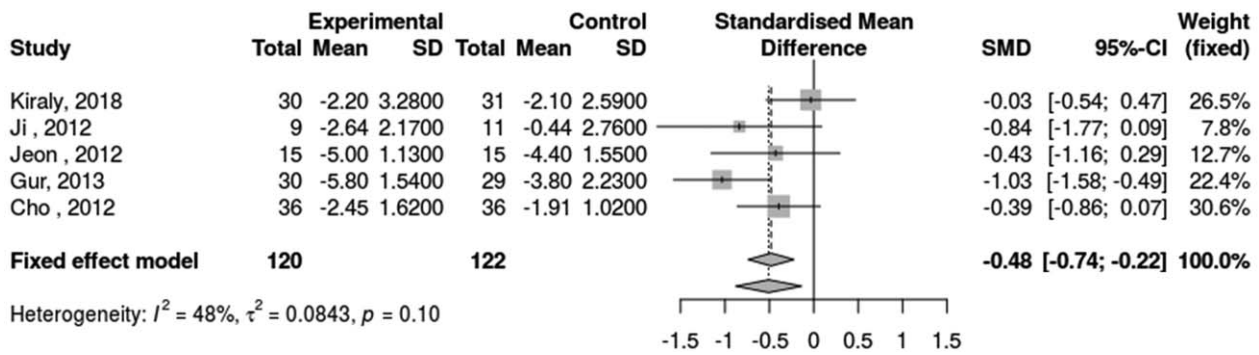


Figure 2. Forest plot of overall effects of ESWT on MPS based on VAS score for standardized mean difference.

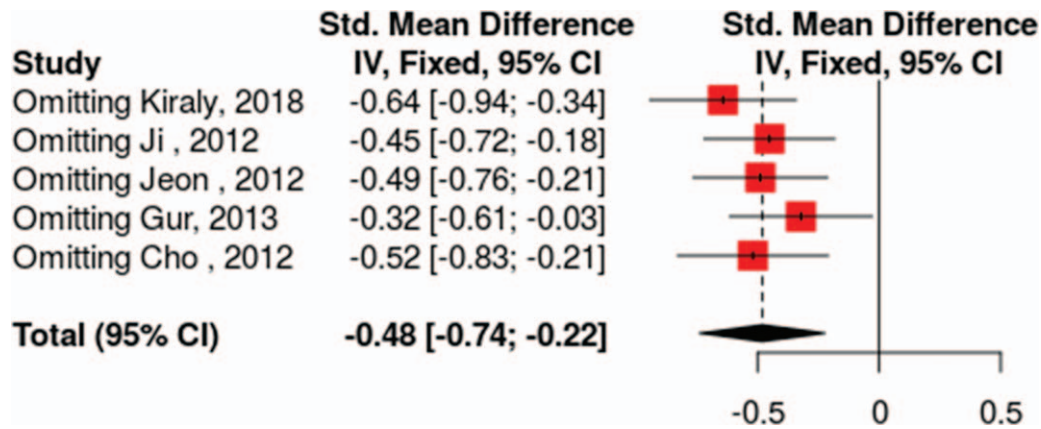


Figure 3. Sensitivity analyses.

3.5. Sensitivity analyses

We performed sensitivity analyses to determine the effect of focused ESWT on VAS (Fig. 3).

The odds ratios, SMD, and rankings did not change considerably. Excluding research and overall tendency did not change significantly.

3.6. Risk of bias within individual studies

The quality assessment of RCTs in the studies was conducted using the Cochrane Risk-of-Bias Tool, as summarized in Table 3. The baseline characteristics of all studies were not significantly different between the intervention and the control groups. Random sequence generation was deemed adequate in all trials. However, allocation concealment was high risk in 1 study.^[14] Blinding of outcome assessment was unknown in 4 trials.^[12-15] Since the number of included studies was less than 10, funnel plot analysis was not performed^[31].

4. Discussion

There are a few treatment options available for patients with MPS. Among them, ESWT was effective in patients with MPS.^[11-15] The pathophysiology of MPS involves an abnormal increase in acetylcholine triggering a continuous release and uptake of calcium ions, leading to muscle ischemia as a result of sustained shortening of sarcomeres and release of sensitizing substances. The

vicious cycle is completed when the nociceptors are sensitized and muscle ischemia is aggravated.^[32,33] Since ESWT has been applied in musculoskeletal diseases including MPS, its effective mechanisms still remain a mystery; pain and inflammation relief are attributed to modulatory effects on nitrogen monoxide and vascular growth factor. ESWT can be used to stimulate angiogenic factors and microvascular regeneration ESWT decreases pain as well as increasing pain tolerance in MPS.^[13] A few hypotheses have been proposed based on the cellular and molecular effects of ESWT on MPS.^[33,34] According to De Sanctis et al,^[35] ESWT improves capillary blood circulation in chronic ischemic zones and alters the pain signaling in ischemic tissues caused by calcium influx. The referred pain in MPS is caused by easy induction of central sensitization, because peripheral muscle nociceptor threshold is lower than that in other systems.^[36] ESWT may interrupt the cascade of referred pain by inhibiting peripheral muscle nociceptors and reducing the levels of substance P.^[14]

A number of trials showed conflicting results. In this systematic review and meta-analysis, we identified 8 RCTs investigating the effect of ESWT on MPS in 441 subjects. The principle finding of our meta-analysis was that VAS scores were significantly lower in subjects treated with focused ESWT than in control groups (SMD = -0.48) under the fixed model. In the descriptive analysis, the study by Cho^[11] and colleagues reported that focused ESWT therapy was more effective than other treatments for pain.

For neck pain, Van der Westhuizen et al^[37] have calculated the minimally clinically important difference (MCID; i.e., the

Table 3
Risk of bias assessment of included studies.

Study	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome	Selective reporting	Other bias
Gur 2013 ^[12]	L	L	UN	UN	UN	UN	L
Ji 2012 ^[14]	L	H	L	UN	UN	UN	L
Jeon 2012 ^[13]	L	UN	UN	UN	UN	UN	L
Cho 2012 ^[11]	L	UN	UN	L	L	UN	L
Lee 2013 ^[15]	L	UN	UN	UN	UN	UN	L
Kiraly 2018 ^[16]	L	L	UN	L	UN	UN	L
Luan 2019 ^[29]	L	L	UN	L	UN	UN	L
Manafnezhad 2019 ^[30]	L	L	UN	L	UN	UN	L

H=high risk; L=low risk; UN=unclear risk.

smallest change in a measurement that signifies an important improvement in a symptom) for the VAS in patients with MPS. The authors postulated that an improvement of 2.48 cm in the VAS of patients represents an MCID. The VAS is a horizontal line, 10 cm in length, with 0 cm labeled “no pain” and 10 cm labeled “worst pain I have ever had”. Patients mark the point on the line based on their perception of their current state.^[38] The VAS was used in all studies to compare pain before and after treatment. In our meta-analysis, we found that the average change on the VAS was lower than MCID value for MPS in the treatment groups. When considering control group, a single control group in Gur et al^[12] underwent ultrasound therapy, and the other control group in the Jeon et al^[13] had trigger point injection and transcutaneous electrical nerve stimulation therapy. A stabilization exercise was used in the control group in the study conducted by Cho et al.^[11] Also, low-level laser therapy was used in the control group in the study conducted by Kiraly et al.^[16] Therefore, the SMDs in 4 studies were small. The average change of the VAS lower than MCID may have been caused by effects of other treatments in the 4 studies.

We showed that the pressure threshold (N) was significantly increased in the focused ESWT group compared to the control group in the studies by Ji^[14] and Jeon^[13] and colleagues. Further, the study by Kiraly^[16] and colleagues revealed that patients with focused ESWT demonstrated significantly better changes than those exposed to low-level laser therapy based on the neck disability index. This review found sufficient evidence to support that focused ESWT had significant clinical effects on MPS.

Additionally, the studies by Luan^[29] and Manafnezhad^[30] and colleagues were analyzed descriptively because they differed from the 6 included studies^[11–16] involving transmission of shock wave. Radial ESWT was used for upper trapezius in these 2 studies. Both radial ESWT and dry needling were effective for pain relief and in improving function for patients with MPS. There were no significant differences in the radial ESWT group and the dry needling group. It can be contemplated that reduction of pain spasm-induced decrease in blood flow and enhanced blood flow to the active trigger point was mediated via cavitation effects and direct pressure release by dry needling, which decreased the pain intensity and increase the PPT.^[39]

In this study, we conducted a strict and extensive literature search to present an up-to-date review of the literature. However, this study has several limitations. First, only 5 studies were included in meta-analysis. However, all of the included studies were RCTs, and we performed the quality assessment of the risk of bias to overcome this limitation. Second, we examined only VAS to determine the effect of ESWT in our meta-analysis. An

additional RCT study using another measurement is needed. Third, our meta-analysis cannot provide the long-term effect (more than 4 weeks) of ESWT. Furthermore, the characteristics of the 5 studies were similar in terms of gender and age. Therefore, subgroup sensitivity analysis could not be performed in this study. Future RCTs should demonstrate the effect of ESWT on age and gender.

In conclusion, there is very low level evidence that focused ESWT is effective for short-term relief of neck pain in MPS. The limited sample size and poor quality of these studies highlight and support the need for large scale, good quality placebo controlled trials in this area.

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Author contributions

Conceptualization: Yoo JI, Lee CH.

Data curation: Yoo JI, Oh MK.

Formal analysis: Yoo JI.

Investigation: Oh MK, Lee SU.

Methodology: Yoo JI.

Supervision: Chun SW.

Validation: Chun SW.

Writing-original draft: Yoo JI.

Writing-review & editing: Lee CH.

Chang Han Lee orcid: 0000-0001-8351-5226.

References

- Sciotti VM, Mittak VL, DiMarco L, et al. Clinical precision of myofascial trigger point location in the trapezius muscle. *Pain* 2001;93:259–66.
- Kim H. Myofascial pain syndrome. *J Kor Acad Fam Med* 2001;22:147–54.
- Tough EA, White AR, Cummings TM, et al. Acupuncture and dry needling in the management of myofascial trigger point pain: a systematic review and meta-analysis of randomised controlled trials. *Eur J Pain* 2009;13:3–10.
- Rickards LD. The effectiveness of non-invasive treatments for active myofascial trigger point pain: a systematic review of the literature. *Int J Osteopath Med* 2006;9:120–36.
- Müller-Ehrenberg H, Licht G. Diagnosis and therapy of myofascial pain syndrome with focused shock waves (ESWT). *Ann Rehabil Med* 2005;5:1–6.
- de las Peñas CF, Campo MS, Carnero JF, et al. Manual therapies in myofascial trigger point treatment: a systematic review. *J Bodyw Mov Ther* 2005;9:27–34.

- [7] Spindler A, Berman A, Lucero E, et al. Extracorporeal shock wave treatment for chronic calcific tendinitis of the shoulder. *J Rheumatol* 1998;25:1161–3.
- [8] Seil R, Rupp S, Hammer D, et al. Extrakorporale stoßwellentherapie bei der tendionosis calcarea der rotatorenmanschette: vergleich verschiedener behandlungsprotokolle. *Zeitschrift für Orthopädie und ihre Grenzgebiete* 1999;137:310–5.
- [9] Rompe J, Hopf C, Küllmer K, et al. Low-energy extracorporeal shock wave therapy for persistent tennis elbow. *Int Orthop* 1996;20:23–7.
- [10] Dejung B, Gröbli C, Colla F, et al. Triggerpunkt-therapie (trigger point therapy). Bern: Hans Huber Verlag; 2003.
- [11] Cho Y-S, Park S-J, Jang S-H, et al. Effects of the combined treatment of extracorporeal shock wave therapy (ESWT) and stabilization exercises on pain and functions of patients with myofascial pain syndrome. *J Phys Ther Sci* 2012;24:1319–23.
- [12] Gur A, Koca I, Karagullu H, et al. Comparison of the efficacy of ultrasound and extracorporeal shock wave therapies in patients with myofascial pain syndrome: a randomized controlled study. *J Musculoskelet Pain* 2013;21:210–6.
- [13] Jeon JH, Jung YJ, Lee JY, et al. The effect of extracorporeal shock wave therapy on myofascial pain syndrome. *Ann Rehabil Med* 2012;36:665–74.
- [14] Ji HM, Kim HJ, Han SJ. Extracorporeal shock wave therapy in myofascial pain syndrome of upper trapezius. *Ann Rehabil Med* 2012;36:675–80.
- [15] Lee J-H, Han E-Y. A comparison of the effects of PNF, ESWT, and TPI on pain and function of patients with myofascial pain syndrome. *J Phys Ther Sci* 2013;25:341–4.
- [16] Kiraly M, Bender T, Hodosi K. Comparative study of shockwave therapy and low-level laser therapy effects in patients with myofascial pain syndrome of the trapezius. *Rheumatol Int* 2018;38:2045–52.
- [17] Wang CJ. Extracorporeal shockwave therapy in musculoskeletal disorders. *J Orthop Surg Res* 2012;7:11.
- [18] Bauermeister W. Diagnosis and therapy of myofascial trigger point symptoms by localization and stimulation of sensitized nociceptors with focused ultrasound shockwaves. *Medizinisch Orthopädische Technik* 2005;5:65–74.
- [19] Shrivastava S. Shock wave treatment in medicine. *J Biosci* 2005;30:269–75.
- [20] Akinoglu B, Kose N. A comparison of the acute effects of radial extracorporeal shockwave therapy, ultrasound therapy, and exercise therapy in plantar fasciitis. *J Exerc Rehabil* 2018;14:306–12.
- [21] Malliaropoulos N, Thompson D, Meke M, et al. Individualised radial extracorporeal shock wave therapy (rESWT) for symptomatic calcific shoulder tendinopathy: a retrospective clinical study. *BMC Musculoskelet Disord* 2017;18:513.
- [22] Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med* 2009;6:e1000100.
- [23] Higgins JP, Green S. *Cochrane Handbook for Systematic Reviews of Interventions*. Vol 4. 2011; John Wiley & Sons,
- [24] Simon D. *Travell & Simon's Myofascial Pain and Dysfunction: The Trigger Point Manual. Upper Half of Body*. Vol 1. 1999; Lippincott-Williams & Wilkins Philadelphia,
- [25] Higgins JP, Altman DG, Gotzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ* 2011;343:d5928.
- [26] Wan X, Wang W, Liu J, et al. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC Med Res Method* 2014;14:135.
- [27] Schwarzer G. *Meta: Meta-Analysis with R R package version 3.0-1*. 2013.
- [28] Higgins JP, Thompson SG, Deeks JJ, et al. Measuring inconsistency in meta-analyses. *Br Med J* 2003;327:557.
- [29] Luan S, Zhu ZM, Ruan JL, et al. Randomized trial on comparison of the efficacy of extracorporeal shock wave therapy and dry needling in myofascial trigger points. *Am J Phys Med Rehabil* 2019.
- [30] Manafnezhad J, Salahzadeh Z, Salami M, et al. The effects of shock wave and dry needling on active trigger points of upper trapezius muscle in patients with non-specific neck pain: a randomized clinical trial. *J Back Musculoskelet Rehabil* 2019.
- [31] Cooper HM. *Synthesizing Research: A Guide for Literature Reviews*. Vol 2. 1998; Sage,
- [32] Ottomann C, Hartmann B, Tyler J, et al. Prospective randomized trial of accelerated Re-epithelization of skin graft donor sites using extracorporeal shock wave therapy. *J Am Coll Surg* 2010;211:361–7.
- [33] Shah JP, Gilliams EA. Uncovering the biochemical milieu of myofascial trigger points using in vivo microdialysis: an application of muscle pain concepts to myofascial pain syndrome. *J Bodyw Mov Ther* 2008;12:371–84.
- [34] Wang FS, Yang KD, Chen RF, et al. Extracorporeal shock wave promotes growth and differentiation of bone-marrow stromal cells towards osteoprogenitors associated with induction of TGF- β 1. *J Bone Joint Surg Brit Vol* 2002;84-B:457–61.
- [35] De Sanctis MT, Belcaro G, Nicolaidis AN, et al. Effects of shock waves on the microcirculation in critical limb ischemia (CLI) (8-week study). *Angiology* 2000;51:S69–78.
- [36] Giamberardino MA, Costantini R, Affaitati G, et al. Viscero-visceral hyperalgesia: characterization in different clinical models. *Pain* 2010;151:307–22.
- [37] Van der Westhuizen JH. The Relative Effectiveness of Kinesiotape Versus Dry Needling in Patients with Myofascial Pain Syndrome of the Trapezius Muscle 2012.
- [38] McCormack HM, David JdL, Sheather S. Clinical applications of visual analogue scales: a critical review. *Psychol Med* 1988;18:1007–19.
- [39] Balllyns JJ, Shah JP, Hammond J, et al. Objective sonographic measures for characterizing myofascial trigger points associated with cervical pain. *J Ultrasound Med: Off Journal Am Inst Ultrasound Med* 2011;30:1331–40.