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Dry Needling With And Without Repetitive Transcranial Magnetic Stimulation on Pain And Central Sensitization In Women With Myofascial Pain Syndrome

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Abstract

Myofascial pain syndrome(MPS) is characterized by trigger points and altered pain processing. In this single-blind randomized controlled trial, 28 women aged 18–35 years with upper trapezius MPS were randomized to dry needling (DN; n=14) or DN combined with repetitive transcranial magnetic stimulation (DN+rTMS; n=14). Following one intervention session, participants performed self-stretching exercises for four weeks. Blinded assessments were conducted at baseline, post-treatment, and at 2 and 4 weeks. Outcomes included the Central Sensitization Inventory(CSI), Neck Disability Index(NDI), pressure pain threshold(PPT), cervical range of motion, and pain intensity(VAS). A significant group×time interaction was found for PPT(P=0.023; partial η^2=0.115). PPT was higher in the DN+rTMS group at week 2(between-group difference, −0.59 kg/cm²; 95% CI, −0.94 to −0.24; adjusted P=0.002) and week 4(−0.79 kg/cm²; 95%

CI, −1.32 to −0.25; adjusted P=0.005). Significant interactions were also observed for left cervical rotation (P=0.038; partial η^2=0.102) and left lateral flexion(P=0.048; partial η^2=0.096). Other outcomes showed significant changes over time, but no significant group × time interactions. A single rTMS session added to DN may improve pressure pain sensitivity but does not appear to provide broader clinical benefits. Larger trials using repeated rTMS sessions are warranted.

Keywords: Myofascial pain syndrome, transcranial magnetic stimulation, central sensitization, dry needling

Introduction

Myofascial pain syndrome (MPS) is a painful condition that affects the muscular and fascial systems and is characterized by the presence of hyperirritable trigger points(TrP) located within a taut band of skeletal muscle fibers. This painful condition may cause disability[1]. The reported prevalence estimates among patients attending medical clinics range from 30% to 93% [2] with consistently higher rates reported in women[3]. Poor posture is a potential contributing factor to the development of hyperirritable trigger points. Prolonged poor posture, for example, as a result of unsupported forearm and flexed neck postures or prolonged cell phone use, may result in fatigue of the neck and shoulder muscles and the development of MPS, which is very common for the upper trapezius muscle[4, 5]. In turn, trigger points of this muscle are associated with cervical intervertebral joint dysfunctions and reduced cervical range of motion [6].

Furthermore, MPS features peripheral and central sensitization [7]. There is some preliminary evidence of elevated levels of inflammatory mediators, neuropeptides, catecholamines, and cytokines in a low-pH environment in the immediate vicinity of trigger points, which may impact muscle, nerve, and connective tissues, and cause an abnormal depolarization of primary afferent neurons [8, 9]. However, these studies by Shah and colleagues included only three subjects per group, which precludes drawing any definitive

conclusions, and, furthermore, there are serious concerns about the methodology used in these studies [10, 11].

Persistent painful stimuli may increase the excitability of dorsal horn neurons and contribute to receptive-field expansion and referred pain [12, 13]. Even in the absence of persistent peripheral input, these neurons can remain active, resulting in a lowered pain threshold and exaggerated responses to ordinary sensory stimuli [14]. Central sensitization is characterized by widespread hypersensitivity, greater pain intensity, increased disability, reduced pressure pain thresholds (PPT), and impaired proprioception and body awareness [15, 16].

In other words, evidence suggests that central sensitization can amplify trigger points activity and potentially establish a self-perpetuating cycle of pain. Central sensitization may be modulated by using advanced brain stimulation techniques, such as transcranial magnetic stimulation (TMS), which may stimulate the cortex, change cortical excitability, and modify synaptic connections[17, 18]. Transcranial magnetic stimulation is a safe and non-invasive technique that involves an electromagnetic coil to generate a magnetic field inside the skull. When TMS pulses are applied to the skull repeatedly, it is referred to as repetitive TMS (rTMS). Previous studies have shown that rTMS may lead to positive therapeutic effects in MPS, demonstrating an ability to reduce pain and increase motor evoked potentials, while its role as a biochemical modulator remains controversial [19, 20]

Basically, TrPs are managed through a variety of pharmacological and non-pharmacological approaches. One effective physiotherapy strategy for the management of trigger points is dry needling (DN). This technique involves inserting fine filament needles into muscular and connective tissues to improve neuromusculoskeletal pain and disability associated with trigger points [21]. Low to moderate quality evidence suggests DN may be effective for improving neck pain in the short-term [22, 23]. However significant mid-term effects on pain and neck mobility have not been demonstrated [24]. With trigger point DN, it is common to elicit local twitch responses (LTR), defined as sudden, involuntary contractions of muscle fibers when a needle penetrates a TrP. It is mediated through a spinal cord reflex that can also be

elicited by snapping palpation or pressure on a TrP [25]. A local twitch response is a critical objective clinical indicator that confirms accurate trigger point localization and successful deactivation during DN [26].

Research indicates that a higher LTR intensity is associated with greater therapeutic effects, including improved joint range of motion [27]. Evidence also suggests that adding self-stretching exercises may enhance treatment effects, as upper trapezius self-stretching has been shown to reduce muscle stiffness, tension and pain in younger adults [28, 29].

Despite these individual therapeutic benefits, a critical knowledge gap remains: no study has investigated whether combining peripheral deactivation of TrPs (via DN) with central neuromodulation of sensitized pain pathways via rTMS produces synergistic effects in MPS. Given the limited mid-term efficacy of DN alone[22] and the controversial results of rTMS as a standalone intervention[30, 31], it was hypothesized that combining these interventions would enhance treatment outcomes. Therefore, this single-blinded randomized controlled trial (RCT) aimed to evaluate the effects of combined rTMS and DN compared to DN alone in the treatment of trigger points in women with upper trapezius MPS.

Results

The intervention was delivered in a single session by the designated physiotherapist according to the predefined protocol. Adherence to the prescribed home exercises was not formally assessed. No relevant concomitant interventions were reported during the trial period. Twenty-eight women with upper trapezius myofascial pain syndrome (MPS) were randomly assigned to either dry needling (DN) or dry needling combined with repetitive transcranial magnetic stimulation (DN+rTMS), with 14 participants in each group. One participant in the DN group did not complete the week-4 assessment because of scheduling difficulties. For the affected outcomes, missing data were handled using the last observation carried forward, while the

available NDI and CSI data were retained. Participant flow is shown in Figure 2. The two groups were similar at baseline, with no significant differences in demographic or clinical characteristics (Table 1).

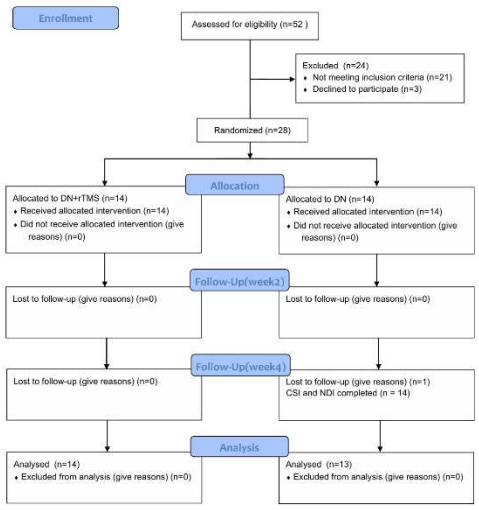


Figure 1- CONSORT flow diagram; DN, dry needling; rTMS, repetitive transcranial magnetic stimulation; CSI, central sensitization inventory; NDI, neck disability index

Table 1. Baseline demographic and clinical characteristics of the participants

Variable	DN Group (n=14)	DN+rTMS Group (n=14)	p-value
Age (years)	23.86 (2.25)	25.07 (3.65)	0.743†
Height (cm)	165.29 (6.65)	165.50 (4.64)	0.922
Weight (kg)	61.21 (12.36)	62.43 (11.10)	0.747†
BMI (kg/m²)	22.34 (3.88)	22.77 (3.67)	0.763
Flexion (°)	50.93 (5.31)	54.36 (7.65)	0.627†
Extension (°)	61.86 (9.67)	58.57 (8.58)	0.394†
Right rotation (°)	73.79 (8.06)	71.29 (10.30)	0.369†
Left rotation (°)	75.43 (12.86)	71.50 (8.77)	0.354
Right lateral rotation (°)	43.43 (5.89)	44.79 (5.37)	0.530
Left lateral rotation (°)	44.79 (6.96)	42.79 (5.96)	0.422
CSI (0–100)	39.93 (9.48)	37.71 (6.60)	0.747†
NDI (0–100)	21.14 (11.09)	22.00 (13.20)	0.854

VAS (0–10)	5.36 (1.74)	4.30 (1.64)	0.107
PPT (kg/cm²)	1.26 (0.46)	1.63 (0.71)	0.180†

Notes: Values are mean (SD). † p-value from Mann–Whitney U test. DN, dry needling; rTMS, repetitive transcranial magnetic stimulation; BMI, body mass index; VAS, visual analog scale; PPT, pressure pain threshold; CSI, Central Sensitization Inventory; NDI, Neck Disability Index.

Changes in outcomes over time by treatment group

The primary analysis examined the group × time interaction to determine whether outcomes changed differently in the DN and DN+rTMS groups. Descriptive data are presented in Table 2, and the repeated-measures analyses are summarized in Table 3. Mean scores and adjusted between-group comparisons at each assessment point are provided in Supplementary Table (S1 Table). Figure 3 shows the outcome trajectories over time.

Table 2. Descriptive statistics for all outcomes across assessment time points

Outcome	Group	Baseline	Immediately	Week 2	Week 4
VAS (cm)	DN	5.36 (1.74)	4.90 (1.54)	2.08 (1.45)	2.68 (1.90)
	DN+rTMS	4.30 (1.64)	4.41 (1.87)	2.11 (1.05)	1.68 (1.24)
PPT (kg/cm²)	DN	1.26 (0.46)	1.46 (0.62)	1.34 (0.31)	1.36 (0.27)
	DN+rTMS	1.63 (0.71)	1.54 (0.63)	1.93 (0.56)	2.15 (0.93)
CSI (score)	DN	39.93 (9.48)	NA	31.64 (13.71)	29.86 (13.00)
	DN+rTMS	37.71 (6.60)	NA	27.86 (5.26)	26.64 (7.90)
NDI (%)	DN	21.14 (11.09)	NA	13.14 (8.93)	17.86 (11.62)
	DN+rTMS	22.00 (13.20)	NA	14.29 (7.72)	14.00 (7.69)
Flexion (°)	DN	50.93 (5.31)	59.04 (6.08)	57.64 (6.07)	56.93 (5.40)
	DN+rTMS	54.36 (7.65)	64.21 (7.59)	58.79 (6.08)	60.64 (7.48)
Extension (°)	DN	61.86 (9.67)	68.29 (11.42)	66.64 (8.78)	69.29 (6.01)

	DN+rTMS	58.57 (8.58)	66.43 (10.27)	71.64 (9.64)	69.57 (9.80)
Right rotation (°)	DN	73.79 (8.06)	79.86 (6.11)	79.00 (7.47)	81.07 (7.05)
	DN+rTMS	71.29 (10.30)	77.43 (12.65)	82.00 (8.78)	83.14 (6.54)
Left rotation (°)	DN	75.43 (12.86)	83.86 (10.85)	81.86 (10.10)	82.21 (11.59)
	DN+rTMS	71.50 (8.77)	77.07 (9.48)	81.21 (7.46)	84.00 (5.92)
Right lateral flexion (°)	DN	43.43 (5.89)	51.93 (7.96)	45.71 (8.33)	43.71 (6.53)
	DN+rTMS	44.79 (5.37)	50.43 (5.39)	46.86 (5.39)	48.29 (4.60)
Left lateral flexion (°)	DN	44.79 (6.96)	53.93 (7.18)	46.79 (8.18)	45.64 (7.89)
	DN+rTMS	42.79 (5.96)	53.21 (5.35)	50.00 (3.96)	48.86 (4.87)

Note: Values are mean (SD). VAS, PPT, cervical flexion, cervical extension, right cervical rotation, left rotation, right lateral rotation, and left lateral rotation were assessed at baseline, immediately post-intervention, and at 2- and 4-week follow-up. CSI and NDI were assessed at baseline and at 2- and 4-week follow-up. DN, dry needling; rTMS, repetitive transcranial magnetic stimulation; VAS, Visual Analog Scale; PPT, pressure pain threshold; CSI, Central Sensitization Inventory; NDI, Neck Disability Index; NA, not assessed.

Table 3. Repeated-measures analysis of all outcomes

Outcome	Effect	F (df1, df2)	P value	Partial η^2
VAS (cm)	Group	F(1,26) = 2.37	0.136	0.084
	Time	F(3,75) = 36.42	<0.001	0.583
	Group × Time	F(2.66,69.09) = 1.04	0.380	0.038
PPT (kg/cm²)	Group	F(1,26) = 6.92	0.014	0.210
	Time	F(2.54,66.11) = 2.76	0.047	0.096
	Group × Time	F(2.54,66.11) = 3.37	**0.023**	0.115
CSI (score)	Group	F(1,26) = 1.07	0.311	0.039
	Time†	F(1.59,41.20) = 17.46	<0.001	0.402
	Group × Time†	F(1.59,41.20) = 0.08	0.878	0.003
NDI (%)	Group	F(1,26) = 0.03	0.855	0.001
	Time†	F(1.29,33.41) = 11.87	0.001	0.313
	Group × Time†	F(1.29,33.41) = 1.43	0.248	0.052

Flexion (°)	Group	F(1,26) = 3.92	0.059	0.131
	Time	F(3,78) = 13.31	<0.001	0.339
	Group × Time	F(3,78) = 0.66	0.582	0.025
Extension (°)	Group	F(1,26) < 0.001	0.990	<0.001
	Time	F(2.60,67.70) = 12.50	<0.001	0.325
	Group × Time	F(2.60,67.70) = 2.20	0.104	0.078
Right rotation (°)	Group	F(1,26) < 0.001	0.989	<0.001
	Time†	F(2.20,57.23) = 11.73	<0.001	0.311
	Group × Time†	F(2.20,57.23) = 1.42	0.250	0.052
Left rotation (°)	Group	F(1,26) = 0.56	0.463	0.021
	Time	F(3,78) = 15.22	<0.001	0.369
	Group × Time	F(3,78) = 2.95	**0.038**	0.102
Right lateral flexion (°)	Group	F(1,26) = 0.54	0.469	0.020
	Time	F(3,78) = 13.05	<0.001	0.334
	Group × Time	F(3,78) = 2.22	0.093	0.079
Left lateral flexion (°)	Group	F(1,26) = 0.22	0.645	0.008
	Time	F(3,78) = 24.96	<0.001	0.490
	Group × Time	F(3,78) = 2.75	**0.048**	0.096

Note: †Greenhouse–Geisser correction was applied because the assumption of sphericity was violated. For left rotation, right lateral flexion, and left lateral flexion, Mauchly's test did not indicate a violation of sphericity; therefore,

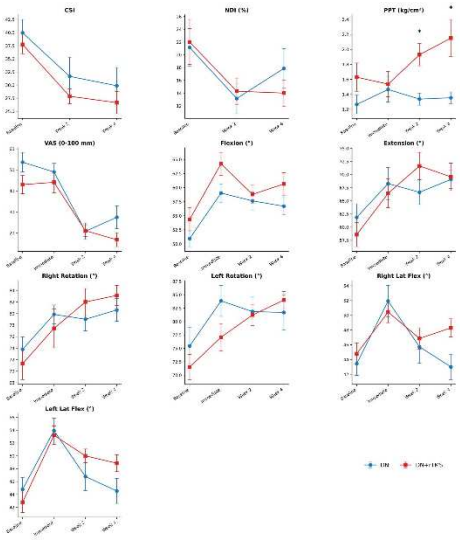


Figure 2- Mean (± SEM) scores over time for all outcomes in the DN and DN+rTMS groups. Abbreviations: CSI, Central Sensitization Inventory; NDI, Neck Disability Index; PPT, pressure pain threshold; VAS, visual analog scale. Assessments occurred at baseline, immediately post-intervention, and at weeks 2 and 4; CSI and NDI were not measured immediately. Error bars indicate SEM

sphericity-assumed results are reported. DN, dry needling; rTMS, repetitive transcranial magnetic stimulation; VAS, Visual Analog Scale; PPT, pressure pain threshold; CSI, Central Sensitization Inventory; NDI, Neck Disability Index.

A significant group × time interaction was found for PPT ($F = 3.37$, $P = 0.023$, partial $\eta^2 = 0.115$), indicating that PPT changed differently between the two groups. The effect was moderate. Compared with the DN group, the DN+rTMS group had higher PPT values at week 2 (between-group difference, -0.59 kg/cm²; 95% CI, -0.94 to -0.24; adjusted $P = 0.002$) and week 4 (-0.79 kg/cm²; 95% CI, -1.32 to -0.25; adjusted $P = 0.005$). No significant between-group differences were observed at baseline or immediately after treatment (Figure 3; S1 Table).

Significant group × time interactions were also found for left cervical rotation ($F = 2.95$, $P = 0.038$, partial $\eta^2 = 0.102$) and left cervical lateral flexion ($F = 2.75$, $P = 0.048$, partial $\eta^2 = 0.096$). Both effects were moderate. However, the adjusted comparisons at individual time points did not show significant differences between groups for either outcome (S1 Table). This suggests that the overall patterns of change differed between groups, but neither treatment was clearly superior at a specific follow-up time.

For pain, central sensitization, and disability, the two groups did not show different patterns of change. The group × time interactions were not significant for VAS ($P = 0.380$, partial $\eta^2 = 0.038$), CSI ($P = 0.878$, partial $\eta^2 = 0.003$), or NDI ($P = 0.248$, partial $\eta^2 = 0.052$). However, all three outcomes improved significantly over time, with large effects for VAS ($P < 0.001$, partial $\eta^2 = 0.583$), CSI ($P < 0.001$, partial $\eta^2 = 0.402$), and NDI ($P = 0.001$, partial $\eta^2 = 0.313$). In other words, participants in both groups improved during follow-up, but adding a single rTMS session did not lead to a clearly different pattern of improvement (Table 3; Figure 3).

The other cervical ROM outcomes also showed no significant group × time interactions for flexion ($P = 0.582$), extension ($P = 0.104$), or right rotation ($P = 0.250$). These movements improved over time in both groups, but their patterns of change did not differ significantly between treatments. Right lateral flexion also showed no significant interaction ($P = 0.093$). Although an adjusted between-group difference was observed at week 4 for right lateral flexion (-4.57°, 95% CI, -8.96 to -0.18; adjusted $P = 0.042$), this isolated finding was not considered evidence of a treatment effect because the overall group × time interaction was not significant (S1 Table).

Adverse events

No serious adverse events were reported. One participant in the DN+rTMS group experienced mild, transient scalp discomfort lasting less than 12 hours. No adverse events required medical intervention or led to study withdrawal.

Discussion

This randomized controlled trial examined whether adding a single session of rTMS to dry needling provides additional benefit over dry needling alone in women with upper trapezius MPS. The main finding

was that adding rTMS resulted in a different pattern of change in pressure pain sensitivity, with higher PPT in the DN+rTMS group at weeks 2 and 4. In contrast, there was no evidence of an additional treatment effect for pain, disability, or central sensitization–related symptoms, and the significant interactions observed for some cervical movements did not translate into significant between-group differences at individual time points.

Both groups showed substantial reductions in pain during follow-up, but the absence of a significant group × time interaction indicates that adding rTMS did not provide an additional analgesic benefit over DN alone. The magnitude of improvement within both groups was clinically relevant when considered against commonly reported thresholds for meaningful change in VAS pain. This pattern suggests that the improvement in pain was mainly associated with the DN-based intervention and the subsequent management provided to both groups, rather than with the addition of a single rTMS session. A possible explanation is that the improvement produced by DN alone left relatively little room for an additional effect from one rTMS session. Another possibility is that a single rTMS session may not provide a sufficient dose to produce a measurable additional effect on pain intensity. Disability also improved over time in both groups, without evidence of a different treatment trajectory. Thus, the present findings do not support an additional functional benefit from adding rTMS to DN. The improvement in NDI may reflect the reduction in pain and associated functional limitations following DN, together with the standardized self-stretching program provided during follow-up. The magnitude of change exceeded the commonly reported threshold for clinically meaningful improvement [32], indicating that the overall improvement was clinically relevant, but not specifically attributable to rTMS.

The clearest additional benefit of rTMS was seen for PPT. The group × time interaction was significant, and the DN+rTMS group had higher PPT than the DN group at both week 2 and week 4, with between-group differences of approximately 0.59 and 0.79 kg/cm², respectively. Interestingly, these differences were not seen immediately after treatment but emerged during follow-up. This raises the possibility that the additional effect of rTMS may develop over time rather than being evident immediately after treatment.

These between-group differences were larger than the previously reported threshold for clinically meaningful change in PPT in the upper trapezius. However, because this threshold was not established specifically for between-group differences in women with MPS, this comparison should be interpreted with some caution. Nevertheless, the fact that the between-group difference was present at both weeks 2 and 4 suggests that the effect was not simply a short-lived response immediately after treatment.

PPT is a quantitative measure of pressure pain sensitivity and provides information about how sensitive a person is to painful pressure [33]. However, a higher PPT should not be interpreted as direct evidence that central sensitization has been reduced. In this study, central sensitization–related symptoms were assessed separately using the CSI, and the CSI group × time interaction was not significant. Therefore, the most appropriate interpretation is that adding rTMS reduced pressure pain sensitivity rather than demonstrating a reduction in central sensitization itself.

One possible explanation for the additional improvement in PPT is that DN and rTMS may affect different aspects of the pain experience. DN primarily targets local myofascial nociceptive sources [34], whereas rTMS may influence brain networks involved in pain perception and descending pain modulation [35, 36]. Using both approaches together may therefore have produced a greater reduction in pressure pain sensitivity than DN alone. However, this is only a possible explanation, as we did not directly measure cortical excitability or descending pain inhibition in this study.

The CSI findings also call for a cautious interpretation. Although CSI scores improved over time, adding rTMS did not result in a greater reduction in CSI scores than DN alone. This may mean that a single rTMS session is not enough to change the broader range of symptoms captured by the CSI. It is also possible that changes in specific aspects of pain processing are not fully reflected by a self-report measure such as the CSI, particularly over a relatively short follow-up period. Previous studies involving repeated rTMS sessions have reported improvements in pain-related outcomes [19, 20] suggesting that the number of treatment sessions may be important if rTMS is intended to produce broader effects on pain processing.

Both groups showed immediate improvements in cervical ROM, which may reflect the reduction in trigger-point–related muscle tension and pain following DN. Although the DN+rTMS group appeared to maintain some of these improvements during follow-up, the between-group differences were not consistently significant at individual time points. Therefore, these findings should be interpreted cautiously and do not provide clear evidence that adding rTMS results in greater or more sustained improvements in cervical mobility. The improvements observed in both groups may have been partly related to reduced local muscle sensitivity and pain, which could allow participants to move more comfortably during daily activities and exercise. The additional effects of rTMS on pain processing may also have contributed to changes in movement over time, but this cannot be determined from the present data. Overall, any effect of rTMS on cervical mobility appears to be modest and may depend on the specific movement being assessed rather than representing a general improvement in ROM.

The relatively small sample size may also have limited our ability to detect smaller between-group differences. This may be particularly relevant for lateral flexion, where the direction of change favored DN+rTMS, although the between-group difference was not statistically significant. This finding should therefore be viewed as a possible signal that warrants further investigation rather than as evidence of a definite treatment effect.

The continued improvements during follow-up may also have been influenced by the standardized self-stretching program provided after the intervention. Because both groups received the same exercise program, it may have contributed to the improvements seen in both groups and makes it difficult to determine how much of the change in cervical ROM was specifically related to rTMS.

This study's main strengths were its randomized controlled design with blinded outcome assessment, use of validated outcome measures, assessment of pain, disability, mobility, and central sensitization, and inclusion of both immediate and 4-week follow-up evaluations. Its standardized intervention protocols also improve reproducibility. The main limitations were the small sample size, which may have reduced statistical power, and the follow-up period, which limits conclusions about long-term effects. The single-

session rTMS protocol may also have been insufficient, psychological factors were not measured, the sample included only women, and concurrent exercise was not systematically documented.

Overall, the findings suggest that a single session of rTMS combined with DN may provide an additional benefit for pressure pain sensitivity in women with upper trapezius MPS, although it did not demonstrate an additional effect on central sensitization as assessed by the CSI. Improvements in pain, disability, and cervical mobility in both groups occurred in the context of DN followed by a 4-week self-stretching program, suggesting that this combination may be useful for short-term management of MPS. Clinically, DN with continued self-stretching may be considered a practical treatment approach, while rTMS may be considered as an adjunct when reducing pressure pain sensitivity is a priority. However, the additional value of a single rTMS session remains uncertain, particularly for central sensitization. Future studies should examine repeated rTMS sessions, longer follow-up, and complementary measures of central sensitization to clarify its clinical role in MPS.

Methods

Study design, ethics, and sample size

This single-blind, parallel-group randomized controlled trial adhered to the CONSORT guidelines. Ethical approval was obtained from the Tehran University of Medical Sciences (Ethics Code: IR.TUMS.FNM.REC.1404.105), and the trial was prospectively registered with the Iranian Registry of Clinical Trials on September 15, 2025(IRCT20250908067180N1). All methods were performed in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants before participation in the study. Participants were recruited between September 17, 2025, and November 29, 2025.

The required sample size was calculated a priori using G*Power software (version 3.1.9.7), based on the expected change in Visual Analog Scale (VAS) scores reported in previous studies of dry needling and rTMS for myofascial pain syndrome [20, 37]. With a significance level of $\alpha = 0.05$ and 90% power ($1 - \beta = 0.90$), the analysis indicated that a total of 24 participants were required, with 12 participants in each group. Allowing for an anticipated 10% attrition, the sample was increased to 28 participants, resulting in 14 participants per group.

Participants

Participants were recruited and assessed at the National Brain Mapping Laboratory, University of Tehran, and the Faculty of Rehabilitation Sciences, Tehran University of Medical Sciences. Twenty-eight women aged 18–35 years with upper trapezius MPS were enrolled. Eligibility was assessed by an experienced physiotherapist after written informed consent. Inclusion required at least one active upper trapezius trigger point, neck pain ≥3 months with an average Visual Analog Scale (VAS) score ≥3/10, PPT≤2.5 kg/cm²[38, 39] , and a Central Sensitization Inventory(CSI) score >29. Participants were excluded if they were unwilling to complete follow-up, had a contraindication to DN, epilepsy, suspected or confirmed pregnancy, a cardiac pacemaker or other implanted electronic device, ferromagnetic or magnetically sensitive metal in the body, permanent head or neck piercings, tattoos near the stimulation site containing potentially ferromagnetic ink, or a history of surgery or significant trauma involving the head or upper extremities.

Randomization and blinding

After the baseline assessment, participants were randomly assigned in a 1:1 ratio to DN alone or DN combined with rTMS(DN+rTMS). A computer-generated random sequence with blocks of four was prepared using Randomizer.org. Allocation was concealed in sequentially numbered, opaque, sealed envelopes, which were opened only after eligibility and baseline assessment were completed.

Because of the nature of the interventions, participants and treating clinicians could not be blinded. The outcome assessor and statistician, however, remained blinded to group allocation throughout the study. The

assessor was not present during treatment sessions and had no access to the randomization schedule, and participants were asked not to reveal their allocation during follow-up assessments.

Interventions

All participants received one intervention session followed by the same standardized home-based upper trapezius stretching program for 4 weeks.

Self-stretching program: Immediately after the in-clinic intervention, all participants received standardized verbal and written instructions for a unilateral upper trapezius self-stretching exercise. Participants sat with the ipsilateral hand grasping the chair edge to stabilize the shoulder girdle, then used the contralateral hand to gently guide the neck into lateral flexion away from the stretched side until a mild-to-moderate stretch was felt along the lateral neck and shoulder. Each stretch was held for 10 seconds and repeated 10 times per set, performed once daily for 4 weeks (28 days). Adherence and performance were monitored using a self-reported daily exercise logbook.

Dry needling: DN was performed by a certified therapist with more than 5 years of clinical experience. Participants were positioned prone, with their hands under the forehead. Trigger points were identified by pincer palpation of the upper trapezius between the C7 spinous process and acromion, and the most painful trigger point was selected. A sterile single-use acupuncture needle (0.30 × 50 mm; Dong Bang Medical Co., Korea) was inserted perpendicular to the skin using a fast-in/fast-out technique and continued until local twitch responses ceased. No additional manual therapy or modality was provided to either group. The control group received both DN and self-stretching program.

Repepetive transcranial magnetic stimulation: Participants in the experimental group received the same DN procedure, immediately followed by one rTMS session. A physician monitored participants before stimulation. rTMS was delivered using a MagPro X100 stimulator with MagOptions software and a figure-eight coil (MCF-B70; MagVenture, Denmark) over the primary motor cortex (M1) ipsilateral to the needled side. The motor hotspot was identified using highest-amplitude motor-evoked potentials from the

contralateral first dorsal interosseous muscle, with surface EMG used to guide coil positioning (Figure1-A). Resting motor threshold was defined as the minimum intensity producing MEPs ≥50 μV in at least 5 of 10 consecutive trials. Stimulation was delivered at 10 Hz at 80% of resting motor threshold, using 20 trains of 50 pulses (1000 pulses total), with 55-second intervals between trains. The session lasted approximately 20 minutes. During stimulation, participants were seated in a comfortable reclining chair with their arms and hands resting relaxed on the armrests (Figure1-B). Stimulation was delivered at a frequency of 10 Hz at 80% of the resting motor threshold (RMT), using 20 trains of 50 pulses each, for a total of 1000 pulses per session. The inter-train interval was 55 seconds, and the total stimulation session lasted approximately

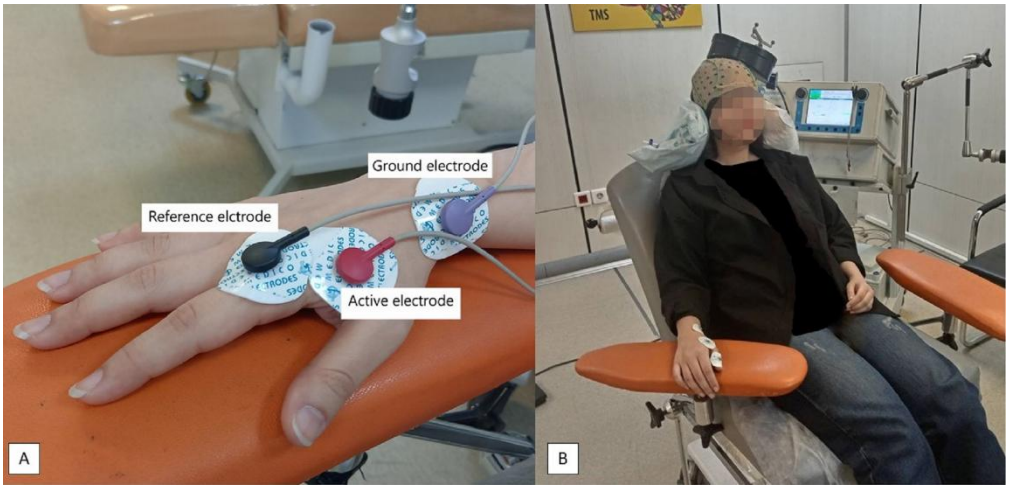


Figure 2- Mean (± SEM) scores over time for all outcomes in the DN and DN+rTMS groups. Abbreviations: CSI, Central Sensitization Inventory; NDI, Neck Disability Index; PPT, pressure pain threshold; VAS, visual analog scale. Assessments occurred at baseline, immediately post-intervention, and at weeks 2 and 4; CSI and NDI were not measured immediately. Error bars indicate SEM

20 minutes. [20]. During stimulation, participants were seated in a comfortable reclining chair with their arms and hands resting relaxed on the armrests (Figure1-B).

Outcome measure

Outcomes were assessed at baseline, immediately after treatment, and at 2- and 4-week follow-up. All assessments were performed by the same blinded assessor, who was not involved in treatment, randomization, or statistical analysis. Participants were asked to avoid analgesic or anti-inflammatory medication for 24 hours before each assessment.

Primary outcome measures

Pain intensity (VAS): Current pain intensity was measured using a 10-cm (100-mm) unnumbered horizontal line anchored by "no pain" at the left end (0 mm) and "worst pain imaginable" at the right end (100 mm). Participants marked a point on the line corresponding to their average neck pain intensity over the preceding 24 hours. The distance from the left anchor to the mark was measured and recorded as a quantitative score (mm). The VAS is a reliable tool with good test-retest reliability (ICC = 0.58– 0.93) [40]. The minimal clinically important difference (MCID) for the VAS in neck pain has been reported to be 15 mm [41].The VAS was assessed at all four time points.

Central sensitization inventory (CSI): Central sensitization was evaluated using the Persian version of the CSI, a validated self-reported questionnaire comprising two parts. Part A contains 25 items related to central sensitization symptoms (e.g., pain, fatigue, sleep disturbances, cognitive difficulties), each scored on a 5-point Likert scale (0 = never, 4 = always). Total scores for Part A range from 0 to 100, with higher scores indicating greater severity of central sensitization symptoms. Part B assesses whether the patient has been diagnosed with specific central sensitivity syndromes or related disorders (e.g., fibromyalgia, chronic fatigue syndrome, temporomandibular disorders). The Persian version of the CSI has demonstrated excellent test-retest reliability (ICC = 0.934; $P < 0.001$) and good internal consistency (Cronbach's $\alpha = 0.87$) [42]. The CSI was administered at baseline, 2-week follow-up, and 4-week follow-up only (not immediately post-intervention, as it reflects subacute and chronic symptom changes).

Pressure pain threshold (PPT): The PPT was assessed using a digital algometer (LUTRON FG-5020; Lutron Electronic Enterprise Co., Ltd., Taiwan) equipped with a 1-cm^2 rubber-tipped probe. With the participant seated comfortably on a chair, the algometer probe was placed perpendicularly (vertically) over the most painful trigger point identified in the upper trapezius muscle, between the C7 spinous process and the acromion process. Pressure was increased at a constant rate of approximately 1 kg/cm^2 per second. Participants were instructed to say "yes" at the first moment the sensation of pressure changed to pain. Each

measurement was performed twice with a 30-second rest interval between trials to prevent sensitization or habituation; the average of the two measurements was used for analysis [31]. The MCID for PPT in the upper trapezius muscle has been reported to be 0.21 kg/cm² in this population[43]. PPT was assessed at all four time points.

Secondary outcome measures

Neck disability index (NDI): Disability related to neck pain was assessed using the Persian version of the Neck Disability Index, a 10-item self-reported questionnaire evaluating neck pain-related functional status across domains including pain intensity, personal care, lifting, reading, headaches, concentration, work, driving, sleeping, and recreation. Each item is scored from 0 (no disability) to 5 (complete disability). Total scores (0–50) are converted to a percentage (0–100%) for reporting, with higher percentages indicating greater disability. The Persian version of the NDI has demonstrated high test-retest reliability (ICC = 0.90–0.97), strong internal consistency, and acceptable validity [44]. The MCID for the NDI has been reported to be 7.5% [32]. The NDI was administered at baseline, 2-week follow-up, and 4-week follow-up only.

Cervical range of motion (ROM): Active cervical ROM was assessed using a bubble inclinometer (Fabrication Enterprises Inc., NY, USA). The following six movements were measured in a standardized order: flexion, extension, right lateral flexion, left lateral flexion, right rotation, and left rotation. For flexion, extension, and lateral flexion measurements, participants sat upright on a chair with their hips and knees at 90° and feet flat on the floor and were instructed to move their head as far as possible in each direction without compensatory trunk movement. For rotation measurements, participants were positioned in supine lying with their head supported on a plinth and were asked to rotate their head as far as possible to each side. Each movement was performed twice, and the average of the two measurements was recorded for analysis. ROM was assessed at all four time points.

Adverse events

Adverse events were systematically monitored throughout the study. Participants were asked about any symptoms or discomfort (e.g., prolonged pain, dizziness, headache, scalp discomfort, excessive soreness, or mood changes) immediately after each intervention session and at each follow-up visit via structured interview. All adverse events, regardless of perceived causality, were recorded and graded for severity (mild, moderate, severe) and duration.

Statistical analysis

Analyses were performed using SPSS Statistics 26.0, with statistical significance set at $P < 0.05$. Normality was assessed using the Shapiro–Wilk test. Baseline characteristics were compared using independent-samples t tests for normally distributed variables and Mann–Whitney U tests otherwise. Primary analyses followed the intention-to-treat principle; for the participant lost to follow-up, missing values were handled using last observation carried forward, while available NDI and CSI data were retained. Changes over time were analyzed using two-way repeated-measures ANOVA, with group as the between-subject factor and time as the within-subject factor. The group × time interaction was prespecified as the primary test of whether outcomes changed differently between DN and DN+rTMS. Greenhouse–Geisser correction was applied when sphericity was violated. Significant main or interaction effects were examined using Bonferroni-adjusted pairwise comparisons. Partial eta-squared (η_p^2) was used to quantify effect size, and between-group mean differences were reported with 95% confidence intervals. Effect sizes of $\eta_p^2 = 0.01$, 0.06, and 0.14 were considered small, moderate, and large, respectively [45].

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Author contributions

Y.A. contributed to the conception and design of the study, data collection, data analysis, and drafting of the manuscript. Z.A. is Corresponding author contributed to the conception and design of the study, supervised the study, and critically revised the manuscript. K.M. contributed to the implementation of the study, data analysis, drafting of the Results section, preparation of the tables and figures, and critical revision of the manuscript. A.G. contributed to the implementation of the study and critically revised the manuscript. S.J. provided statistical consultation and contributed to the data analysis. J.D. contributed to the editing and revision of the manuscript. All authors reviewed and approved the final version of the manuscript

Data availability statement

All data generated or analyzed during this study are presented within the main manuscript and are also available in the supplementary information files. [S1 File1]c

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Conflict of interest statement

The authors declare no conflicts of interest.

Supporting information

S1 File : data. This file contains the complete data

S2 File : CONSORT checklist. This file indicates the location of each reporting item in the manuscript.

S3 File : checklist-for-initial-submissions. This file indicates the location of each reporting item in the manuscript.

S4 File : ethiccode-english . Ethics approval certificate issued by the relevant institutional ethics committee for the study.

S1 Table: Supplementary Table. Estimated marginal means and between-group comparisons at each assessment time point

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

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