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Effects of Repetitive Peripheral Magnetic Stimulation and Exercise on Pain, Neck Disability Index, and Muscle Fatigue in Chronic Neck Pain Patients

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This study examined the effects of repetitive peripheral magnetic stimulation (rPMS) and exercises on pain, neck disability, and muscle fatigue in chronic neck pain patients. Eighteen subjects were randomly assigned to experimental and control groups. The experimental group received rPMS combined with exercise therapy, and the control group applied general physical therapy and exercise therapy. Both groups received treatment time of 20 minutes per day, five times a week, for a total of 4 weeks. The subjects were evaluated by a visual analog scale (VAS), neck disability index, and muscle fatigue. In the experimental group, a significant decrease was observed in both VAS and NDI after treatment ($p<.05$), and there was significant difference compared to the control group ($p<.05$). In both the experimental group and control groups, significant improvement was observed in the muscle fatigue after therapy ($p<.05$), and there was no significant difference in the muscle fatigue compared to the control group ($p>.05$). The results suggest that rPMS combined with exercise effectively reduces pain, improves functional ability, and alleviates neck muscle fatigue in patients with chronic neck pain.

Keywords : repetitive peripheral magnetic stimulation, magnetic field, exercise, pain, neck disability index, muscle fatigue, chronic neck pain

1. Introduction

Chronic neck pain refers to discomfort or pain in the cervical region persisting for more than three months, often impairing physical performance and diminishing overall quality of life [1]. It represents the second most prevalent musculoskeletal disorder after low back pain, affecting approximately 20–50% of adults, with 10–20% of these cases progressing into chronic stages [2]. Epidemiological studies have also reported that about 15% of the adult population experiences neck pain annually. The prevalence of chronic neck pain has steadily risen in recent years, largely due to prolonged use of electronic devices such as smartphones and computers, extended periods of poor posture, stress, and reduced physical activity [3]. Beyond physical discomfort, chronic neck pain contributes to broader socioeconomic challenges including increased healthcare expenditure, decreased work productivity, and diminished quality of life. According to the World Health Organization, both neck and low back pain are among the leading causes of global disability [4].

The primary pathophysiological mechanism underlying chronic neck pain involves muscular imbalance around the cervical and shoulder regions. Forward head posture frequently results in excessive activation of the upper trapezius and sternocleidomastoid muscles, accompanied by reduced activity of the deep cervical flexors. This imbalance perpetuates a cycle of muscular hypertonicity and pain [5]. Overactive muscles restrict local blood flow, accelerate metabolic waste accumulation, and heighten muscle fatigue, which subsequently promotes trigger point formation and intensifies pain responses, ultimately contributing to an elevated neck disability index [6]. Therefore, therapeutic interventions addressing muscular imbalance are essential for effective management.

A wide range of physiotherapeutic approaches have been employed for chronic neck pain, including transcutaneous electrical nerve stimulation (TENS), thermotherapy, ultrasound, exercise, and manual therapy. Among these, exercise therapy remains one of the most effective and widely recommended strategies. Stretching exercises enhance flexibility and vascular supply, while strength training contributes to postural stabilization and correction

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of muscle imbalance, which are key etiological factors in chronic neck pain [7]. Exercise therapy has also been shown to promote recovery from muscle fatigue, elevate pain thresholds, improve postural alignment, and reduce the risk of recurrence. However, the degree of benefit often varies depending on patient compliance, and individuals with severe pain may struggle to perform exercises consistently during the initial stages of rehabilitation [8].

Repetitive magnetic stimulation (rMS) has recently gained attention as a noninvasive modality capable of regulating peripheral nerve excitability and muscle activity, and its clinical use in neuromuscular rehabilitation is expanding. Specifically, repetitive peripheral magnetic stimulation (rPMS) facilitates muscle relaxation, improves local blood flow, modulates neural function, and alleviates pain symptoms. Because rPMS can reach deep tissues without encountering skin resistance and causes minimal discomfort, patient compliance is typically high [9, 10]. Moreover, the application of rPMS before exercise may potentiate the effects of physical training by inducing immediate muscle relaxation and preparing the tissues for movement. Previous research has demonstrated the therapeutic benefits of rPMS across a variety of musculoskeletal and chronic pain conditions [11]. Nonetheless, there remains a paucity of studies examining the combined use of rPMS and exercise therapy specifically for patients with chronic neck pain.

Accordingly, the present study aimed to evaluate the combined effects of rPMS and exercise therapy on muscle fatigue, the Neck Disability Index (NDI), and pain intensity as measured by the Visual Analogue Scale (VAS) in individuals with chronic neck pain. Through this investigation, we sought to establish objective evidence supporting an effective, evidence-based, and noninvasive treatment approach for patients suffering from chronic cervical pain.

2. Materials and Methods

2.1. Participants

This study included 20 patients diagnosed with chronic neck pain by a specialist at neurosurgery and orthopedic clinics located in D City. Participants were eligible if they had experienced persistent cervical pain for longer than three months and exhibited no signs of neurological impairment. Individuals were excluded if they had sustained acute cervical trauma, undergone prior spinal surgery, presented with neuromuscular disorders, or were taking medications that could influence electromyographic activity. Additionally, patients who were pregnant or lactating, had pacemakers or implanted electrical devices in the body, and had suspected malignancy or thrombosis were excluded, which are contraindications to magnetic field therapy. Before enrollment, all participants were fully informed of the research objectives, procedures, and potential risks, and each provided written consent for voluntary participation in accordance with ethical guidelines.

2.2. Study design

A total of twenty eligible participants were randomly assigned to one of two groups: An experimental group (receiving Repetitive Peripheral Magnetic Stimulation and exercise therapy) and a control group (receiving general physical therapy combined with identical exercise therapy). Two participants withdrew due to treatment discontinuation, leaving nine in each group who completed the study protocol. Pre- and post-intervention assessments were conducted to determine treatment efficacy (Fig. 1). To minimize bias, ensuring a double-blind randomized controlled design. Random assignment was achieved using a computer-generated random sequence to generate a random number table. Furthermore, participants and evaluators were blinded to the experimental details to ensure a double-blind study design. Since therapists must provide different treatments to each group, blinding was

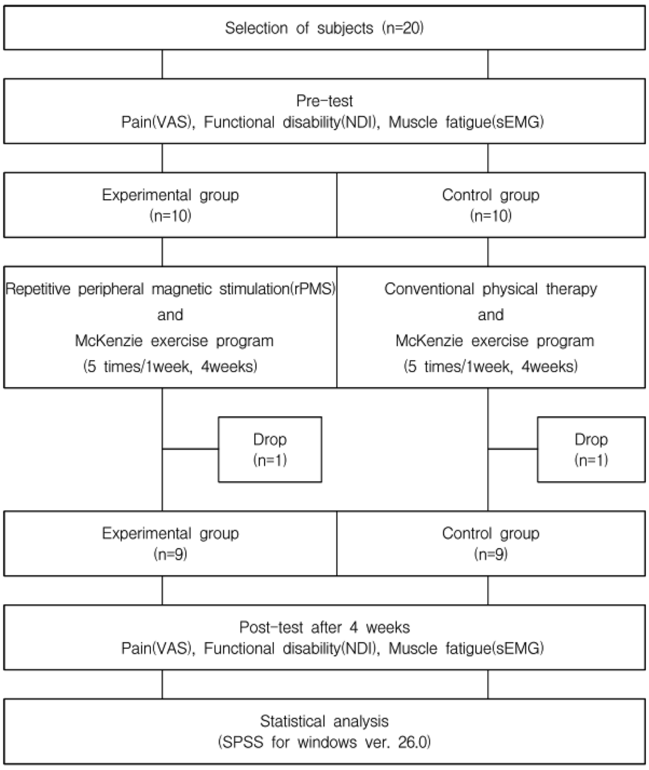


Fig. 1. CONSORT Flow diagram of participant progress through the study.

not performed.

2.3. Intervention

The experimental group underwent repetitive peripheral magnetic stimulation (rPMS) for 10 minutes per session, five sessions per week for four consecutive weeks. The intervention utilized a Neuro MSL magnetic stimulator (MR Inc., Korea) (Fig. 2). A circular coil recognized for its ability to stimulate deeper muscle structures was employed. Stimulation sites were selected based on each patient's most sensitive trigger points. The coil was positioned parallel to the skin surface, primarily over the upper trapezius and sternocleidomastoid muscles, in prone and side-lying postures to ensure optimal penetration of magnetic fields into the target muscles [12, 13]. Each session lasted 10 minutes and entailed an intermittent stimulation protocol consisting of 5 seconds of stimulation at a frequency of 20 Hz followed by 2 seconds of resting. The total number of stimuli over 10 minutes amounted to 1,400 times. Intensity levels were individually adjusted to ensure comfort and were gradually increased within the subject's tolerance (Fig. 3). The control group received conventional physical therapy consisting of thermotherapy and electrical stimulation for 10 minutes per session, at the same weekly frequency and total duration as the experimental group. Interferential Current Therapy (ICT) was applied as conventional physical therapy. Following each intervention, both groups participated in a standardized McKenzie exercise program. Although the original McKenzie method comprises seven movements, it was simplified to four essential exercises in this study to enhance adherence and prevent fatigue [14]. These exercises were designed to improve postural alignment and restore cervical range of motion. The program included cervical retraction, extension, rotation, and lateral flexion. Each movement was performed for three sets of 10 repetitions, maintaining maximal contraction for 7 seconds with a 10-second rest interval (Fig. 4). Additionally, both the experimental and control groups received heat therapy for 10 minutes before each treatment to relax the muscles. Each session lasted approximately 10 minutes, and all exercises were supervised by an experienced physical therapist with over

Fig. 2. (Color online) Application of repetitive peripheral magnetic stimulation.

Fig. 3. (Color online) Electrode montage for rPMS application to the upper trapezius muscle.

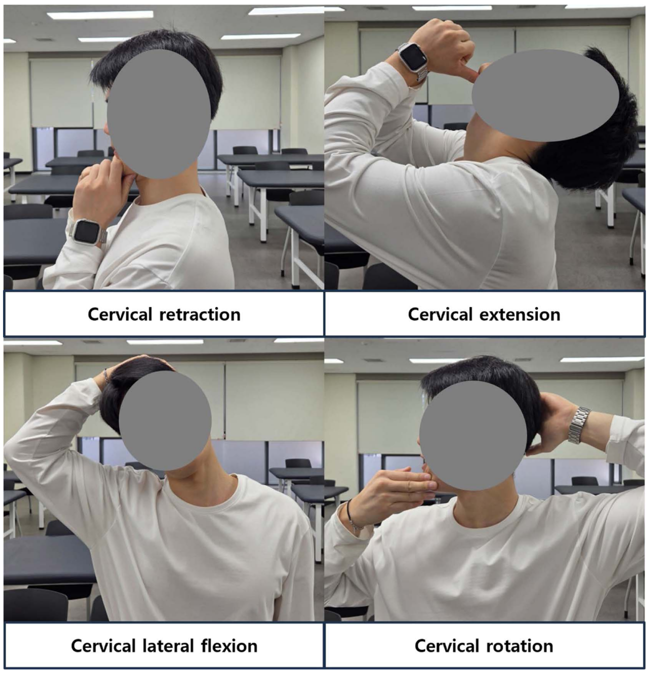


Fig. 4. (Color online) McKenzie exercise protocol (4 of the Standard 7 Movements).

5 years of experience to ensure proper execution and safety.

2.4. Outcome measure

2.4.1. Visual Analogue Scale

Pain intensity was quantified using the Visual Analogue Scale (VAS), consisting of a 10-centimeter horizontal line, where "0" represented the absence of pain and "10" denoted the worst imaginable pain. This simple yet reliable instrument is widely adopted in clinical research to evaluate subjective pain perception and assess therapeutic outcomes [15].

2.4.2. Neck Disability Index

Functional disability was evaluated using the Neck Disability Index (NDI), a validated self-report questionnaire developed to measure the impact of neck pain on daily activities. The NDI includes 10 items covering various functional domains such as pain intensity, lifting, concentration, reading, personal care, driving, work, sleep, and recreational activities. Each item is scored from 0 to 5, with higher total scores indicating greater functional impairment [16].

2.4.3. Electromyography

Muscle fatigue of the cervical region was assessed using a two-channel surface electromyography (sEMG) system. The study focused on two primary muscles associated with posture and movement—the upper trapezius (UT) and sternocleidomastoid (SCM). Disposable surface electrodes were positioned parallel to the muscle fibers. For the UT, electrodes were placed at the midpoint between the C7 spinous process and the acromion, while for the SCM, they were positioned between the mastoid process and the sternum's jugular notch (Fig. 5) [17]. Prior to electrode placement, the skin was shaved and cleaned with an alcohol swab to minimize impedance.

Participants performed a 30-second sustained cervical flexion in a supine position for SCM measurement and a 30-second sustained cervical extension in a prone position for UT measurement. The EMG signals were sampled at 1000 Hz, filtered with a 30–450 Hz band-pass filter, and processed using a 60 Hz notch filter to remove electrical noise. Muscle fatigue was quantified through the median frequency (MDF) obtained via Fast Fourier Transform and power spectrum analysis. MDF is a sensitive indicator of peripheral muscle fatigue. When fatigue develops, ionic imbalance and metabolite accumulation (e.g., lactate, H^+) reduce muscle fiber conduction velocity, causing a spectral shift toward lower frequencies. Consequently, an increase in MDF represents a shift toward higher frequencies, indicating preserved conduction velocity and reduced fatigue in the muscle [18]. Each movement was measured three times, and the mean value was used for analysis, with a 2-minute rest between trials. All measurements were performed exclusively on the dominant side.

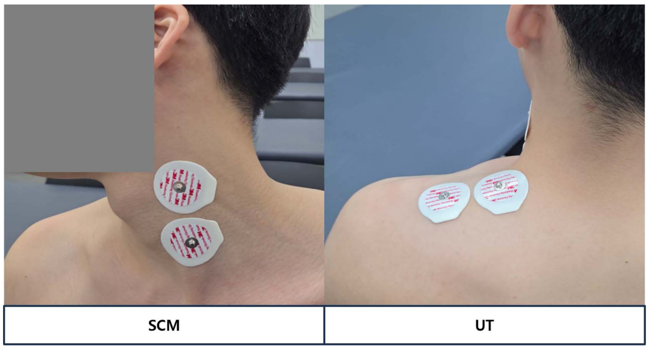


Fig. 5. (Color online) EMG Electrode Placement for the SCM and UT Muscles.

2.4. Statistical analysis

A Shapiro-Wilk test was conducted to determine the normal distribution of each measurement item, and all items were normally distributed. All collected data were expressed as mean ± standard deviation (SD). The normality of the data distribution was confirmed using the Shapiro–Wilk test. An independent samples t-test was used to compare baseline characteristics between groups. Within-group differences (pre- vs. post-treatment) were analyzed using paired t-tests, while between-group differences were determined using independent t-tests. All statistical analyses were performed using SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA), and statistical significance was set at $p < 0.05$.

3. Results and Discussion

Table 1 presents the demographic and clinical characteristics of the participants. No statistically significant

Table 1. General characteristics of subjects.

	EG	CG
Sex(male/female)	2/7	3/6
Age(years)	52.33±6[a]	50.66±7.76
Height(cm)	163.33±7.24	166.22±9.17
Weight(kg)	63.77±11.16	65.01±13.21
On set(month)	12.77±8.31	14.33±9.64

[a] Mean ± SD, EG: Repetitive Peripheral Magnetic Stimulation Group, CG: General Physical Therapy Group

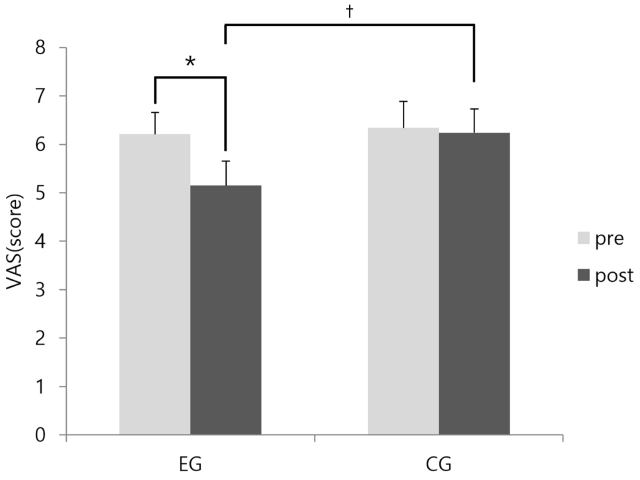
Table 2. Comparison of change in variables in each group.

Variables	Group	Pre	Post	t	*p*
VAS (score)	EG	6.21±0.45[a]	5.15±0.5	7.407	.000*
	CG	6.34±0.55	6.24±0.57	1.014	.340
	t	-.558	-4.269		
	p	.585	.001*		
NDI (score)	EG	12.74±2.68	9.97±1.85	5.488	.001*
	CG	13.38±1.28	12.91±1.77	.740	.480
	t	-.649	-3.428		
	p	.525	.003*		
UT (Hz)	EG	57.16±3.91	63.38±3.4	-5.248	.001*
	CG	56.16±4.01	62.11±2.93	-3.496	.008*
	t	.536	.850		
	p	.599	.408		
SCM (Hz)	EG	67.01±7.43	73.63±6.84	-7.155	.000*
	CG	65.56±7.71	68.58±7.78	-4.807	.001*
	t	.406	1.460		
	p	.690	.164		

[a]Mean ± SD, *p<.05, EG: Repetitive Peripheral Magnetic Stimulation Group, CG: General Physical Therapy Group, VAS: Visual Analogue Scale, NDI: Neck Disability Index, UT: Upper Trapezius, SCM: sternocleidomastoid

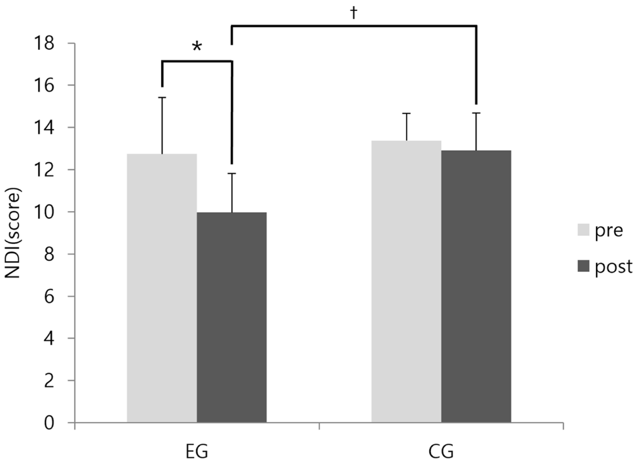
differences were found between the experimental and control groups in baseline variables, confirming homogeneity prior to the intervention.

After four weeks of treatment, the experimental group demonstrated a significant reduction in pain intensity as indicated by the Visual Analogue Scale (VAS) ($p < .05$), whereas the control group showed no significant change ($p > .05$). Between-group comparisons revealed a statistically significant improvement in VAS scores favoring the experimental group ($p < .05$) (Table 2). The results are shown in Fig. 6. Similarly, the Neck Disability Index (NDI) exhibited significant improvement in the experimental group following treatment ($p < .05$), while no significant differences were observed in the control group ($p > .05$). Comparative analysis between groups confirmed that reductions in NDI scores were significantly greater in the experimental group ($p < .05$) (Table 2). The results are shown in Fig. 7. Both groups showed significant post-treatment improvement in muscle fatigue indices, as reflected by increased median



* significant difference between the pre and post value
† significant difference between the EG and CG

Fig. 6. Comparison of pre-value and post-value VAS between the groups.



* significant difference between the pre and post value
† significant difference between the EG and CG

Fig. 7. Comparison of pre-value and post-value NDI between the groups.

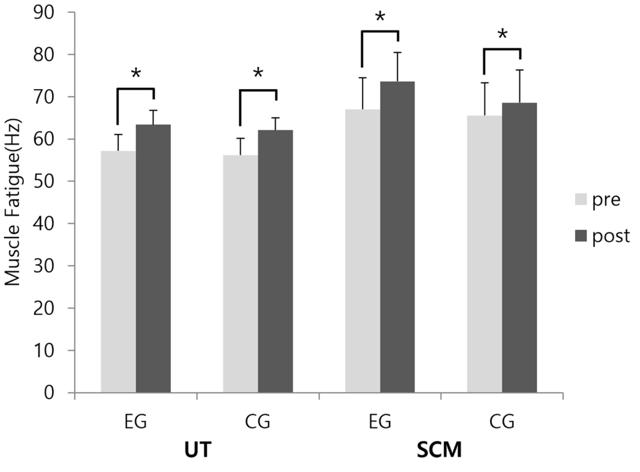


Fig. 8. Comparison of pre-value and post-value muscle fatigue between the groups.

frequency (MDF) values of the upper trapezius and sternocleidomastoid muscles ($p < .05$). However, intergroup differences were not statistically significant ($p > .05$) (Table 2). The results are shown in Fig. 8.

The purpose of this study was to evaluate whether the combined application of repetitive peripheral magnetic stimulation (rPMS) and exercise therapy could reduce muscle fatigue in the upper trapezius and sternocleidomastoid muscles and improve pain and functional disability among individuals with chronic neck pain. The findings confirmed that both groups exhibited decreased muscle fatigue, but only the experimental group demonstrated significant improvements in VAS and NDI outcomes. These results suggest that the integration of rPMS with therapeutic exercise provides superior clinical benefits for pain relief and functional enhancement compared with exercise therapy combined with conventional physical modalities. Previous research has shown that rPMS can noninvasively stimulate peripheral nerves and muscles through rapidly alternating magnetic fields, inducing depolarization of motor neurons and influencing pain signaling pathways [19]. The induced electric field is thought to activate large-diameter myelinated Aβ afferent fibers, which suppress nociceptive input carried by smaller Aδ and C fibers, thereby interrupting pain transmission to the central nervous system [20]. This mechanism differs from traditional electrotherapy, such as interferential current treatment, which primarily enhances local blood circulation and provides only short-term analgesic effects. Consequently, rPMS are considered a promising method for achieving more durable pain reduction in chronic musculoskeletal disorders. The present results align with earlier findings showing that exercise interventions alone can effectively alleviate pain and improve functional outcomes in chronic neck pain populations [21]. However, the greater improvement observed in the rPMS group indicates that magnetic stimulation may potentiate the effects of exercise therapy by promoting neuromuscular relaxation and optimizing motor unit recruitment.

The NDI served as an indicator of functional disability, and significant post-treatment improvement was observed exclusively in the experimental group. This improvement is likely associated with the marked reduction in pain severity. Previous studies have demonstrated a strong correlation between pain intensity and NDI scores [22]. It is therefore reasonable to infer that the analgesic effects of rPMS contributed directly to the observed functional recovery. Chronic neck pain is typically characterized by a complex interplay of symptoms-pain, restricted cervical motion, impaired postural control, and diminished muscle coordination. The synergistic effects of rPMS and exercise therapy may address these multidimensional deficits: rPMS enhance neuromuscular efficiency and reduces excessive muscle tension, while exercise promotes postural correction, joint mobility, and muscle strength [23]. The combined approach, therefore, appears to yield more pronounced improvements in cervical function compared with conventional therapy. In contrast, participants in the control group, who received only standard physical therapy, may have experienced transient analgesia or improved blood flow but failed to achieve substantial functional restoration. This finding supports the notion that rPMS contribute to deeper physiological modulation beyond superficial thermal or sensory effects, reinforcing its role as a valuable adjunct in the rehabilitation of chronic neck pain.

The minimal clinically important difference (MCID) for the Visual Analog Scale (VAS) in chronic neck pain has been reported to range from 1.5 to 2.0 points on a 10-point scale, while the MCID for the Neck Disability Index (NDI) is approximately 5 to 7 points (10–14%) of the total score, depending on baseline severity [24, 25]. Although the EG demonstrated significant reductions in both VAS (1.06 points) and NDI (2.77 points), these values were lower than the commonly cited MCID thresholds for chronic neck pain. While these results showed statistically significant improvements, the short four-week intervention period made it difficult to achieve clinically meaningful changes. Future research is needed to determine whether long-term interventions can lead to clinically meaningful changes.

Electromyographic analysis revealed notable changes in the median frequency (MDF) of the upper trapezius and sternocleidomastoid muscles following intervention. Prior literature suggests that individuals with chronic neck pain display excessive activation of these muscles compared with asymptomatic subjects, primarily due to habitual forward head posture and sustained muscle tension [26]. Such overactivation accelerates metabolic fatigue, reduces muscle fiber conduction velocity, and increases low-frequency spectral components [27]. This pattern is reflected in decreased MDF values, signifying greater muscle fatigue. The present results demonstrated an increase in MDF following treatment, indicating reduced fatigue and improved neuromuscular performance. The upper trapezius is a critical muscle implicated in the pain–spasm–pain cycle, and its chronic overuse exacerbates both fatigue and discomfort. Likewise, the sternocleidomastoid plays a key role in maintaining head posture and tends to fatigue rapidly under sustained load [28]. Both muscles showed significant recovery of median frequency after the four-week intervention, regardless of group allocation, suggesting that the exercise program substantially contributed to fatigue reduction. The stretching and strengthening components of the exercise regimen likely enhanced circulation, facilitated metabolic waste removal, and improved conduction velocity in muscle fibers [29]. These adaptations correspond to an upward shift in MDF and a consequent decrease in perceived fatigue. Similar findings have been reported in studies demonstrating that McKenzie exercises effectively improve neck function, alleviate pain, and reduce muscle fatigue in individuals with chronic cervical pain [30]. The simplified McKenzie protocol used in this study maintained repetitive and controlled movement patterns, encouraging correct postural alignment and reducing mechanical stress on the cervical spine. Moreover, these exercises may have contributed to beneficial physiological adaptations such as normalized muscle fiber length and decreased excessive muscle activation.

Although both groups exhibited recovery of median frequency following the exercise program, it is important to note that only the rPMS group received neuromuscular facilitation stimulation. Therefore, the improvement observed in the rPMS group may reflect additive effects beyond exercise alone. rPMS deliver repetitive magnetic pulses that penetrate deep tissues and induce painless muscle contractions, enhancing neuromuscular activation and local circulation. These physiological changes can facilitate metabolic waste clearance and increase muscle fiber conduction velocity, mechanisms known to shift the EMG power spectrum toward higher frequencies [31].

Consequently, the greater enhancement of MDF in the rPMS group may be attributed to these rPMS-specific mechanisms, suggesting that rPMS contributed independently to reducing peripheral muscle fatigue.

Despite the positive outcomes, several limitations must be acknowledged. The relatively small sample size limits the generalizability of the results. Additionally, only the median frequency was used as an indicator of muscle fatigue; other surface EMG parameters, such as root mean square (RMS) amplitude, were not analyzed. Finally, the absence of a long-term follow-up prevented evaluation of the durability of treatment effects. Future research should incorporate larger sample sizes. And, adopt a randomized controlled trial design that includes multiple intervention arms (e.g., rPMS only, exercise only, combined therapy, and sham stimulation) to clarify the independent and interactive effects of each component. Incorporating long-term follow-up assessments at several time points, along with additional EMG metrics such as RMS amplitude or muscle activation patterns, would provide a more comprehensive understanding of the mechanisms underlying treatment efficacy and its long-term sustainability.

4. Conclusion

In summary, the present study demonstrated that the combination of repetitive peripheral magnetic stimulation (rPMS) and exercise therapy produced significant improvements in pain reduction, functional recovery, and muscle fatigue among individuals with chronic neck pain. These outcomes suggest that integrating rPMS with therapeutic exercise provides synergistic benefits by simultaneously targeting neuromuscular activation and postural correction mechanisms. rPMS likely facilitate immediate pain modulation and muscle relaxation through peripheral nerve stimulation, while exercise therapy reinforces long-term stability and function through strength and flexibility improvements. Consequently, this combined intervention may serve as a valuable non-invasive, nonpharmacological alternative for managing chronic neck pain and preventing recurrence.

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