Effectiveness of the Four-Frequency Protocol of Repetitive Peripheral Magnetic Stimulation (rPMS) for Chronic Pain

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ABSTRACT

Objective: Repetitive peripheral magnetic stimulation (rPMS) is a noninvasive method of delivering a magnetic field to the periphery other than the brain. The treatment has shown positive outcomes for chronic pain and provides many advantages. This study investigated the effectiveness of the four-frequency protocol of rPMS in patients with chronic pain.

Materials and Methods: A retrospective review was conducted of patients with chronic pain treated with the four-frequency protocol. Data on patient demographics, pain characteristics, quality of life, and satisfaction were collected and analyzed.

Results: Forty-eight patients (174 sessions) were eligible for analysis. Most patients (81%) were diagnosed with chronic neuropathic pain. Upon completing the 4-week course of treatment, the mean ± SD of percentage of pain reduction was 49.7% ± 34.8%. The pain score also significantly decreased from baseline (mean difference, 3.3; 95% CI, 2.5–4.1; $P < 0.001$). Responses to treatment were observed for most patients (79.2%) and most treatment sessions (87.4%). For immediate effectiveness, the mean ± SD of percentage of pain reduction at the end of each treatment session was 46.2% ± 27.6%. Improvements in mood, function, and sleep were reported by 75.8%, 77.3%, and 79.5% of patients, respectively. Furthermore, most patients (72.5%) expressed satisfaction with the treatment.

Conclusion: The four-frequency protocol of rPMS for patients with chronic pain significantly reduced their pain scores for immediate effect and after the 4-week treatment course. A positive treatment response, an improved quality of life, and satisfaction with the therapy were found for nearly 80% of the patients.

Keywords: Chronic pain; neuromodulation; neuropathic pain; repetitive peripheral magnetic stimulation (Siriraj Med J 2022; 74: 518-529)

INTRODUCTION

Chronic pain has a considerable impact on both an individual's health and public health. It causes physical suffering and emotional distress, contributing to depressed mood, activity impairment, sleep disturbance, and increased healthcare costs worldwide.[1] Many pharmacological approaches have been developed for treating chronic pain. Particularly, chronic neuropathic pain usually required three or more drug combination treatment,[2] which may cause drug-drug interaction or additional side effects. On the other hand, nonpharmacological approach has been widely implemented into the treatment

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Received 25 April 2022 Revised 12 June 2022 Accepted 29 June 2022
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http://dx.doi.org/10.33192/Smj.2022.62

strategies due to high efficacy and less adverse effects. "Magnetic stimulation" is a nonpharmacological technique commonly used in clinical and research settings. The stimulation is divided into 2 noninvasive methods of delivering a high-intensity magnetic field: "transcranial magnetic stimulation" (TMS) and "peripheral magnetic stimulation" (PMS). The field is delivered to the brain by TMS and to the periphery other than the brain by PMS.

When the pulse of the high-intensity magnetic field passes into the body, it generates a voltage difference and creates an electric field, explained by the Maxwell–Faraday equation.[3,4] In turn, ions and electrons are induced to flow, affecting cell bodies in the magnetic field. Each type of cell has a different stimulation threshold. For example, the axons of neurons have a lower stimulation threshold than the cell bodies, so the magnetic stimulation affects the axons rather than neuron cell bodies.[5] The terms "repetitive transcranial magnetic stimulation" (rTMS) and "repetitive peripheral magnetic stimulation" (rPMS) describe the delivery of repetitive magnetic pulses.

In both research and clinical settings, rTMS is a commonly used technique for chronic pain treatment. There are many publications about its applications, efficacy, and safety. In contrast, rPMS has fewer studies and less extensive data on only some types of chronic pain, such as chronic neuropathic pain,[6,7] musculoskeletal injuries,[8] myofascial pain syndrome,[9,10] lumbosacral spondylotic pain,[11] and low back pain.[12,13] The rPMS technique has demonstrated positive outcomes for chronic pain and provides many advantages. It is a therapeutic device that can stimulate through any medium, does not require contact with the skin, can penetrate deep tissue, has no reported serious adverse effects, and is considered a painless method if a proper rPMS intensity is used.[14] The safety considerations relating to heating and magnetization are the same as those for rTMS.[15]

The type of PMS coils, their placement, and their parameter settings affect treatment. The type of coils affects the focus and depth of penetration into the target. Placing the coils flat and tangential to the longitudinal axis of the target structure is more effective for stimulation.[16] In rTMS, the parameter settings are relevant to safety concerns and treatment efficacy. Different parameters create a different preferential activation. The critical factors in determining the effectiveness and safety of rTMS are frequency, the total number of stimuli, duty cycle, and intensity. The term "slow" or "low-frequency" stimulation refers to stimulus rates of 1 Hz or less, which have inhibitory effects, whereas "high-frequency" stimulation refers to stimulus rates of 5 Hz or more, which have excitatory effects in the brain.[15,17] As to rPMS, there is no consensus regarding the standard protocol for parameter settings. The influence of frequency and the total number of rPMS stimuli remains inconclusive.[14] In the duty cycle, a longer "intertrain interval" may reduce the risk of excessive heating of the coils if the rPMS machine does not have a cooling system. As for the intensity parameter, many studies used suprathreshold stimulation, measured by muscle contraction, to produce proprioceptive afferents to induce neuroplasticity.[14] Many other studies used the output power at which patients perceived a significant local sensation or muscle contraction without excessive discomfort as a proper level of intensity.[6,8-10,12,13]

At the Siriraj Pain Clinic, a four-frequency protocol (FFP) of rPMS was implemented for chronic pain treatment in 2019. Patient responses have varied. Limited studies have evaluated the effects of rPMS on chronic pain, and its protocols are still controversial. The present investigation aimed to evaluate the effectiveness of the FFP on pain relief in patients suffering from chronic pain. The efficacy and safety of the FFP for this application has never been reported.

MATERIALS AND METHODS

Study design

Before this retrospective study began, its protocol was approved by the Siriraj Institutional Review Board (Si 1089/2020). Using ICD-11 code numbers, the authors searched medical records for all chronic pain patients at Siriraj Pain Clinic, Siriraj Hospital, Mahidol University, Bangkok, Thailand.

Patients

The inclusion criteria were patients of any age with chronic pain treated with the FFP of rPMS once weekly for 4 weeks. In addition, the patients were required to have had a definitive diagnosis of chronic pain for more than 3 months. The exclusion criteria were any records that lacked essential data (such as a diagnosis or pain score), patients who were treated with other or unknown PMS protocols, or PMS treatment was discontinued within the 4-week course for reasons unrelated to treatment efficacy or side effects.

The authors consecutively recruited patients from June 2019 (when the FFP protocol was introduced) to February 2021 (Fig 1).

Procedures

Patients were placed in the most comfortable and relaxed position (sitting, supine, or prone) for the particular treatment area. The equipment used to produce PMS at

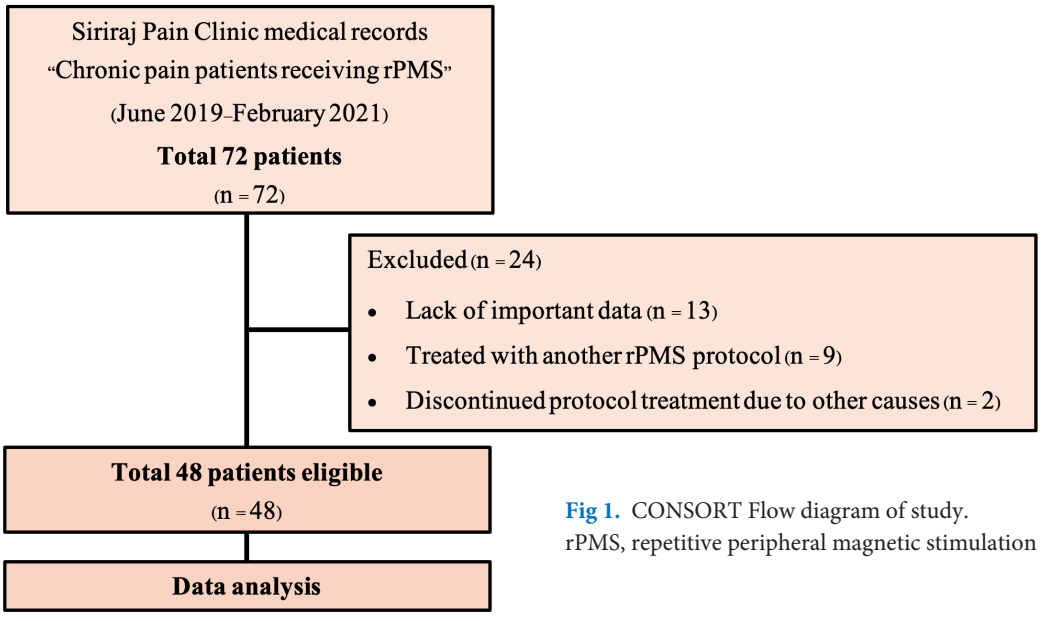

Fig 1. CONSORT Flow diagram of study.
rPMS, repetitive peripheral magnetic stimulation

Siriraj Pain Clinic was a Cool-125, active fluid-cooled, circular coil with a 12.1 cm outer diameter (MagVenture, Farum, Denmark) connected to a MagPro R30 TMS magnetic stimulator (MagVenture).

For the FFP, the machine was set at standard mode with a biphasic waveform, normal current direction, 40 pulses per train, and 40 trains per frequency. The first frequency was set at 10 Hz; each train lasted 4 s during the "On" period, while the intertrain interval (the "Off" period) was 1 s. The second to fourth frequencies were progressively increased to 20, 30, and 40 Hz, with trains lasting 2, 1.3, and 1 s, respectively; the "Off" period was 1 s. The initial treatment course comprised 4 sessions; they were held once weekly over 4 weeks. Each treatment session lasted approximately 10 minutes, with 1600 pulses per frequency and 6400 pulses per session (Fig 2). The stimulation intensity was adjusted at each session for each patient based on the patient's subjectively reported perception of the non-painful stimulation in the stimulated area.

To define the optimal stimulation intensity, pain physicians started the stimulations at 15% of the maximal output power of the machine. The power intensity was progressively in 2% to 3% increments until the patients perceived significant local or regional sensation without excessive discomfort. The authors found that the mean ± SD of stimulation intensity delivered for the initial treatment session was 32.4% ± 6.5%. Moreover, the maximum intensity was 39.3% ± 5.6%.

RPMS was delivered over the pain area depending on the pain diagnosis. For instance, with lumbar radicular pain, pain physicians started at the lumbar spine area and moved distally to cover all pain areas, by area or region. For brachial plexus injuries, treatment started at the area of injury and then moved distally to cover all pain areas, following the cervical dermatome or nerve distribution. With chronic musculoskeletal pain, treatment began at the myofascial trigger point or the most painful area before moving to cover all pain areas progressively (Fig 3).

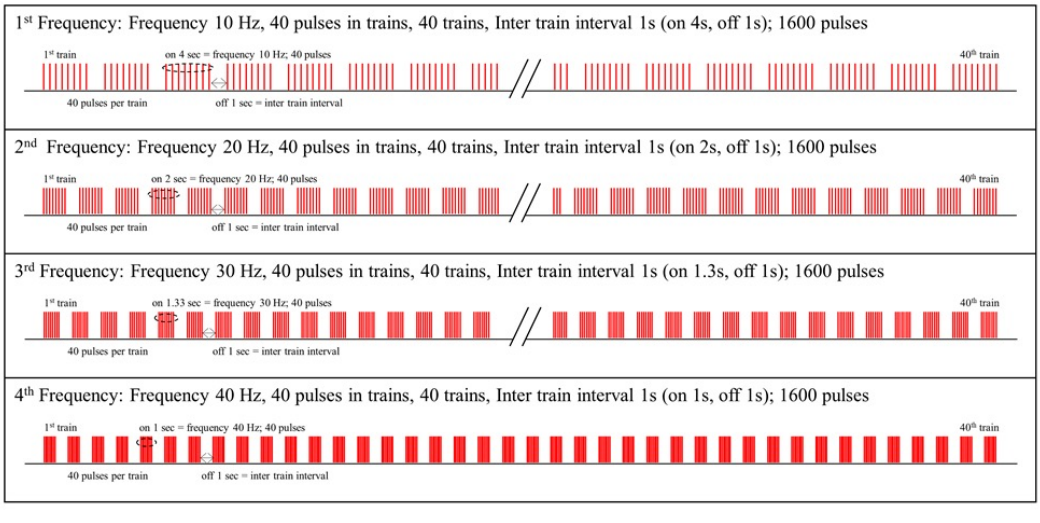

Fig 2. Diagram representing the parameters of the four-frequency protocol of stimulation.

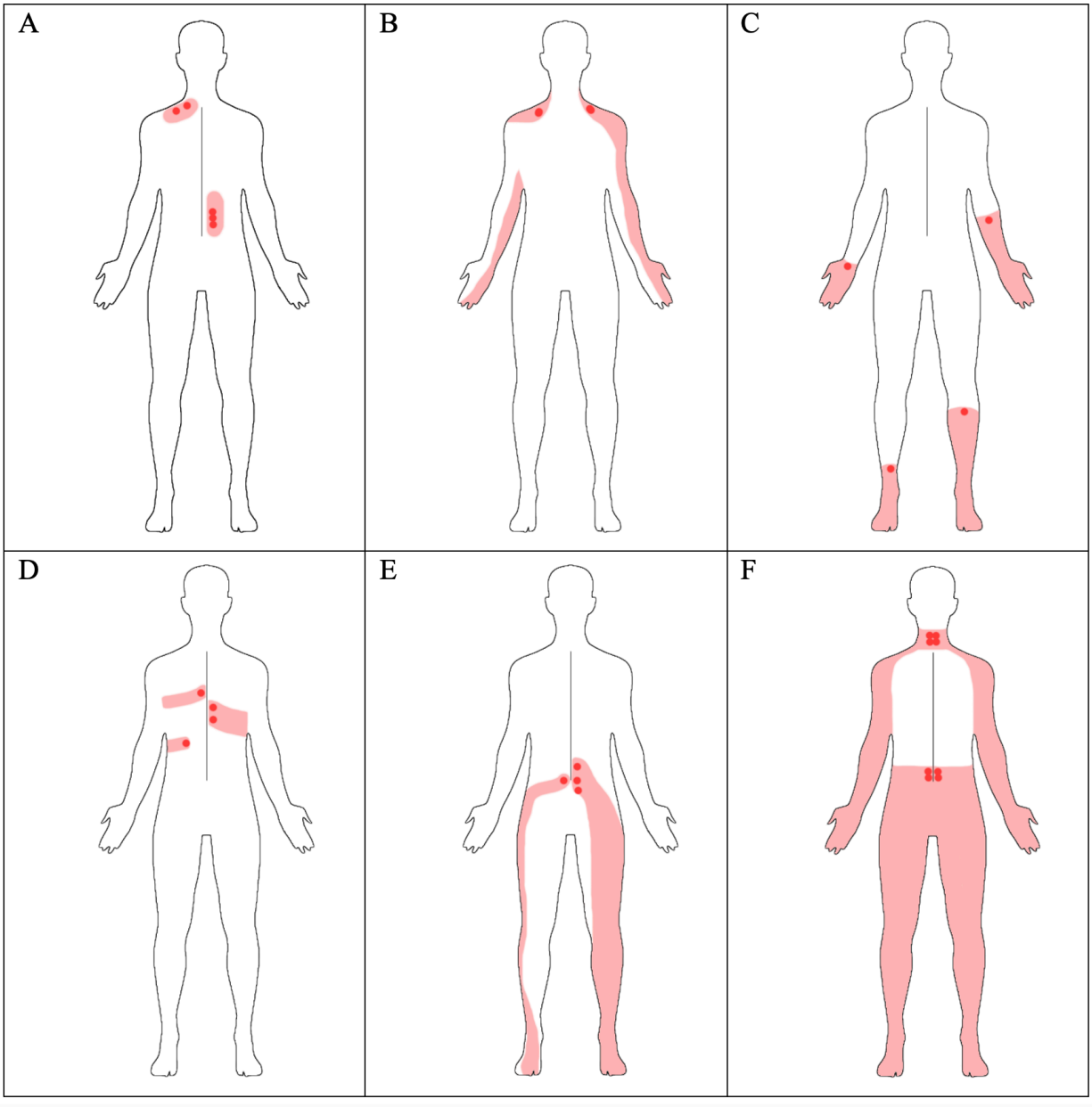

Fig 3. Diagram demonstrating the body area of stimulation. Examples for the areas of stimulation: red = starting area; pink = cover all pain areas; (A) for chronic musculoskeletal pain; (B) for chronic neuropathic pain after peripheral nerve injury; (C) for painful polyneuropathy; (D) for postherpetic neuralgia; (E) for painful radiculopathy; (F) for chronic central neuropathic pain associated with spinal cord injury.

Data collection

Demographic data (age, sex), patient characteristic data (primary diagnosis, pain diagnosis according to ICD-11, type of pain, type of neuropathic pain, area of pain, and associated disease), rPMS protocol settings, and the number of sessions were collected. Pain intensity was assessed by pain score (PS) using a numeric rating scale (0–10: 0 = no pain and 10 = worst possible pain). The PSs at baseline, before and after each treatment session, and at week 4 were recorded.

If the data were available, the authors also collected details relating to changes in quality of life (mood, function, and sleep), patient satisfaction, and adverse events.

Outcome measurements

Outcomes were evaluated at baseline (before treatment), before and after each session, and at week 4. The primary outcomes were:

1. The effectiveness of the FFP. This was measured by calculating the percentage of pain reduction relative to the PSs at baseline and week 4.
2. The number of "responders". This was defined as either:
   - the number of patients with a significant reduction in PS (PS reduction ≥ 2[18] or a percentage of pain reduction ≥ 30%) after the 4-week course of treatment; or

- the number of patients with a satisfactory response to rPMS and desiring to continue the treatment after the 4-week course.

There were 5 secondary outcomes. The first was the "immediate effectiveness" of the FFP. This was measured straight before and after each treatment session by calculating (1) the percentage of pain reduction and (2) the number of "responsive" treatment sessions, measured by the number of sessions that patient reported either significant pain relief (PS reduction ≥ 2 or a percentage of pain reduction ≥ 30%) or no pain or mild pain (PS 0–3) after treatment. The second outcome was the quality-of-life improvement, evaluated by mood, function, and sleep. As the medical records lacked appropriate quality-of-life measures, the authors defined "improvement" as when patients reported having:

- better moods (i.e., not depressed, not irritable, generally good mood, better relationships); or
- better function (i.e., able to stand, sit, walk, run, work, do activities, do activities for more extended periods); or
- better sleep (i.e., being able to sleep, a longer sleep duration, feeling fresh upon awakening).

The third outcome was patient satisfaction. This was defined as patients reporting being "satisfied" or "not satisfied" with their treatment. The fourth outcome was an analysis of factors potentially related to the number of responders and the degree of PS reduction. The factors investigated were sex; pain diagnosis; types of pain; site of stimulation (region or dermatome); and type of neuropathic, peripheral neuropathic and central neuropathic pain. The fifth outcome was adverse events stemming from the FFP.

Statistical analyses

Patient data were recorded and analyzed using PASW Statistics for Windows, version 18.0 (SPSS Inc., Chicago, IL, USA). All results are presented as numbers (*n*) and percentages (%) for categorical variables and means ± standard deviations (SD) for continuous variables. The authors used the Wilson score interval for confidence interval (CI) calculations.[19] The unpaired t-test (normality) or Mann-Whitney U test (nonnormality) was used for continuous variables, and the Chi^2 test or Fisher's exact test for categorical variables. All tests were two-tailed. Results with a probability (*P*) value of < .05 were deemed statistically significant.

RESULTS

Between June 2019 and February 2021, 72 patients with chronic pain received rPMS treatment at the Siriraj Pain Clinic. Of those, 48 patients (174 sessions) were eligible for analysis. Their demographic data and pain characteristics are detailed in Table 1. The mean ± SD of the average initial PS was 6.4 ± 2.2. Chronic neuropathic pain (MG30.5) was found in 81.2% of the patients (39 of 48), while chronic peripheral neuropathic pain (MG30.51) was diagnosed in 70.8% (34 of 48).

Effectiveness of the FFP on primary outcomes

The mean ± SD of percentage of pain reduction was 49.7% ± 34.8%. The average baseline PS was 6.4 (2.2). After 4 weeks, the average PS was 3.2 (2.4). The PS significantly changed from baseline (mean difference, 3.3; 95% CI, 2.5-4.1; *P* < .001; Table 2).

Thirty-eight of 48 patients (79.2%; 95% CI, 65.7%-88.3%) were classed as "responders." No difference was found in the baseline PSs of the responder and non-responder groups (*P* = .703; Table 2).

Effectiveness of the FFP on secondary outcomes

From 174 sessions, the mean ± SD of percentage of pain reduction was 46.2% ± 27.6%. Of those sessions, 152 were classed as "responsive" (87.4%; 95% CI, 81.6%–91.5%; Table 2).

Improvement in quality of life

Some data related to the patients' quality-of-life improvements were missing. Twenty-five of 33 patients (75.8%; 95% CI, 59%–87.2%) reported an improvement in mood; 34 of 44 patients (77.3%; 95% CI, 63%–87.2%) reported an improvement in function; and 31 of 39 patients (79.5%; 95% CI, 64.5%–89.2%) reported an improvement in sleep (Table 2).

Patient satisfaction

Some data related to patient satisfaction were missing. Twenty-nine of 40 patients (72.5%; 95% CI, 57.2%-83.9%) expressed satisfaction with the treatment (Table 2).

Factors related to responder to the FFP

Sex, pain diagnoses, dermatome site of stimulation, type of pain, type of neuropathic pain, and type of peripheral neuropathic pain were not related to the number of responders to the treatment protocol. However, the regional stimulation site demonstrated a significant relation to responsiveness (*P* = .026; Table 3).

Factors related to pain score reduction of the FFP

Significant differences in responsiveness to the treatment protocol were found with only 2 factors: type of pain (*P* = .036) and stimulation site (region;

TABLE 1. Demographic data and pain characteristics of patients.

Characteristics	Values (*n* = 48)
Age (years)	63.4 ± 16.7
Sex	
Male	18 (37.5)
Female	30 (62.5)
Initial pain score	6.4 ± 2.2
Pain diagnoses	
Chronic musculoskeletal pain	9 (18.8)
Chronic neuropathic pain	39 (81.2)
Types of pain	
Nociceptive	6 (12.5)
Neuropathic	39 (81.2)
Mixed	3 (6.3)
Pain areas; sites of stimulation, over the region	
Upper extremity	8 (16.7)
Body	2 (4.1)
Back	12 (25.0)
Lower extremity	26 (54.2)
Sites of stimulation, over the dermatome	
Cervical (C)	13 (27.1)
Thoracic (T)	3 (6.2)
Lumbar-sacral (L)	32 (66.7)
Types of peripheral neuropathic pain (*n* = 34)	
Chronic neuropathic pain after peripheral nerve injury	7 (20.6)
Painful polyneuropathy	1 (2.9)
Postherpetic neuralgia	2 (5.9)
Painful radiculopathy	24 (70.6)
Types of central neuropathic pain (*n* = 4)	
Chronic central neuropathic pain associated with spinal cord injury	3 (75)
Other central neuropathic pain	1 (25)

Data are presented as mean ± SD or number (%). Mixed pain = combination of nociceptive and neuropathic pain.

TABLE 2. Effectiveness of four-frequency protocol of rPMS on primary and secondary outcomes.

		95% CI	*P*-value
Primary outcomes (*n* = 48)			
% Pain reduction (PS at 4th week vs baseline)	49.7 ± 34.8		
PS at baseline	6.4 ± 2.2		
PS at 4th week	3.2 ± 2.4		
Change from baseline	-3.3 ± 2.7	-4.1, -2.5	< .001
Responder	38 (79.2)	65.7, 88.3	
PS reduction ≥ 2	34 (70.8)		
PS reduction ≥ 30%	35 (72.9)		
Prefer to continue further treatment	20 (41.7)		
Non-responder	10 (20.8)	11.7, 34.3	
Baseline PS			.703
Responder group	6.5 ± 2.3		
Non-responder group	6.2 ± 1.6		
Secondary outcomes			
Immediate effectiveness (*n* = 174)			
% Pain reduction (PS at pre vs post treatment)	46.2 ± 27.6		
Responsive	152 (87.4)	81.6, 91.5	
Non-responsive	22 (12.6)	8.5, 18.4	
Improvement of quality of life			
Improvement of mood (*n* = 33)	25 (75.8)	59.0, 87.2	
Improvement of function (*n* = 44)	34 (77.3)	63.0, 87.2	
Improvement of sleep (*n* = 39)	31 (79.5)	64.5, 89.2	
Satisfaction (*n* = 40)	29 (72.5)	57.2, 83.9	
Adverse events (*n* = 174)			
(Pain at ankle became worse, PS 6→10)	1 (0.6)		

Data are presented as mean ± SD or number (%).

P = .009; Table 3). Nevertheless, nearly all other factors demonstrated a good reduction in pain after treatment (Table 3 and Fig 4).

Adverse events

Only 1 adverse event was observed for the whole cohort (1 of 174 sessions; 0.6%; Table 2). A patient in the "non-responder" group received all 4 sessions of rPMS. Although good outcomes with no adverse effects were reported for sessions 1, 2, and 4, an increase in pain was experienced in session 3. Pain in the ankle (the same side as the PMS) worsened, with the PS rising from 6 to 10 after treatment. The pain was subsequently relieved by oral medication (the PS dropped from 10 to 4).

DISCUSSION

Effectiveness of the FFP

The FFP of rPMS effectively decreased the PSs of patients with chronic pain 4 weeks after the initiation of treatment, with an approximately 50% pain reduction. Furthermore, the PS reduction was significantly different from baseline (mean difference, 3.3; 95% CI, 2.5–4.1; $P < 0.001$). Nearly 80% of the patients with chronic pain responded well to the treatment, without any significant difference in the baseline PSs of the responder and non-responder groups. More than 70% of the participants expressed satisfaction with the therapy and reported improvements in mood, function, and sleep.

TABLE 3. Factors related to responsiveness and pain score reduction of four-frequency protocol of rPMS.

	Responder *n*/total *n* (%)	95% CI (%)	*P*-value	Pain score reduction (mean ± SD)	95% CI	*P*-value
Genders			.067			.229
Male	17/18 (94.4)	74.2, 99.0		-3.9 ± 2.4	-5.1, -2.7	< .001
Female	21/30 (70)	52.1, 83.3		-2.9 ± 2.9	-4.0, -1.8	< .001
Pain diagnoses			.661			.107
Chronic musculoskeletal pain	8/9 (88.9)	56.5, 98.0		-5.1 ± 3.7	-7.9, -2.3	.003
Chronic neuropathic pain	30/39 (76.9)	61.7, 87.4		-2.8 ± 2.3	-3.6, -2.1	< .001
Types of pain			.615			***.036***
Nociceptive pain	5/6 (83.3)	43.6, 97.0		-4.3 ± 3.9	-8.4, -0.3	.041
Neuropathic pain	30/39 (76.9)	61.7, 87.4		-2.9 ± 2.3	-3.6, -2.1	< .001
Mixed pain	3/3 (100)	43.9, 100		-6.7 ± 3.2	-14.7, 1.3	.070
Pain areas; Sites of stimulation, over the region			***.026***			***.009***
Upper extremity	8/8 (100)	67.6, 100		-3.6 ± 1.1	-4.5, -2.7	< .001
Body	1/2 (50)	9.5, 90.5		-0.5 ± 0.7	-6.9, 5.8	.500
Back	12/12 (100)	75.8, 100		-5.3 ± 2.9	-7.1, -3.4	< .001
Lower extremity	17/26 (65.4)	46.2, 80.6		-2.5 ± 2.6	-3.5, -1.4	< .001
Sites of stimulation, over the dermatome			.094			.174
Cervical (C)	13/13 (100)	77.2, 100		-4.2 ± 1.9	-5.3, -3.0	< .001
Thoracic (T)	2/3 (66.7)	20.8, 93.9		-1.0 ± 1.0	-3.4, 1.5	.225
Lumbar-sacral (L)	23/32 (71.9)	54.6, 84.4		-3.1 ± 3.0	-4.2, -2.0	< .001
Types of neuropathic pain			.343			.592
Peripheral neuropathic pain	25/34 (73.5)	56.9, 85.4		-2.8 ± 2.4	-3.7, -2.0	< .001
Central neuropathic pain	4/4 (100)	51.0, 100		-3.5 ± 1.9	-6.5, -0.5	.035
Types of peripheral neuropathic pain			.114			.581
Chronic neuropathic pain after peripheral nerve injury	7/7 (100)	64.6, 100		-3.4 ± 1.7	-5.0, -1.8	.002
Painful polyneuropathy	0/1 (0)	0, 79.3		0	N/A	N/A
Postherpetic neuralgia	1/2 (50)	9.5, 90.5		-2.0 ± 2.8	-27.4, 23.4	.5
Painful radiculopathy	17/24 (70.8)	50.8, 85.1		-2.8 ± 2.6	-3.9, -1.7	< .001
Types of central neuropathic pain						
Chronic central neuropathic pain associated with SCI	3/3 (100)	43.9, 100		-4.0 ± 2.0	-9.0, 1.0	.074
Other central neuropathic pain	1/1 (100)	20.7, 100		-2.0	N/A	N/A

Abbreviations: Mixed pain; combination of nociceptive and neuropathic pain, rPMS; repetitive peripheral magnetic stimulation, SCI; spinal cord injury

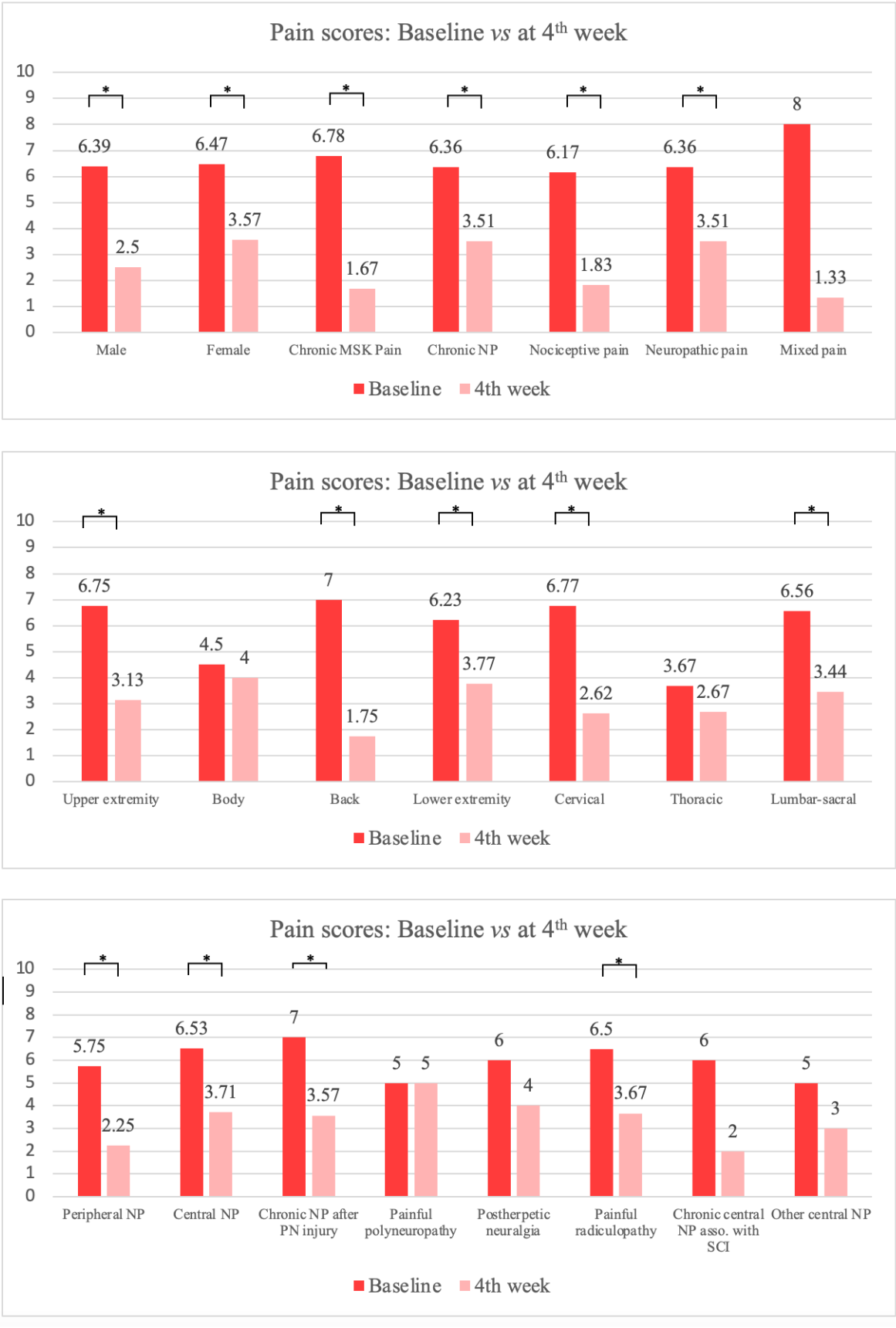

Fig 4. Pain score reduction for each factor after receiving the four-frequency protocol of rPMS.
Data are presented as means; *$P < 0.05$; mixed pain = combination of nociceptive and neuropathic pain; MSK, musculoskeletal; NP, neuropathic pain; PN, peripheral nerve; rPMS, repetitive peripheral magnetic stimulation; SCI, spinal cord injury

As for immediate effectiveness, the mean pain reduction was approximately 46% at the end of each session. Overall, 87.4% of the 174 treatment sessions were responsive to treatment.

Given the above results, the authors conclude that the FFP of rPMS can significantly reduce PSs for immediate effect and after 4 weeks of treatment.

The authors also analyzed factors potentially related to responsiveness to treatment and PS reduction from baseline. The FFP of rPMS may be useful for treating chronic musculoskeletal and neuropathic pain; some types of pain (neuropathic and nociceptive); and pain in the upper extremities, back, lower extremities, and cervical and lumbar dermatomes. As for neuropathic pain, the FFP may be beneficial for chronic peripheral neuropathic pain (chronic neuropathic pain after peripheral nerve injury and painful radiculopathy) and chronic central neuropathic pain.

Only 1 adverse event occurred among the 174 treatment sessions. After 1 session, a patient had worsened pain in the ankle (the same side as the rPMS). At the end of that particular treatment session, the PS rose from 6 to 10. The patient's pain was subsequently relieved by oral medication, resulting in the PS dropping from 10 to 4. This patient had good outcomes without any adverse effects for the other 3 treatment sessions undertaken. The cause of the adverse effects remains unclear. One possible mechanism might be the use of too high an intensity. However, this patient received the same protocol in all 4 sessions. Another possibility is that the coil was placed over the same area for a long time; nevertheless, there was no record. A third possibility is that the high-frequency stimulation increased the excitatory effects in the nervous system; still, there was no evidence of this occurring in any of the patient's 4 treatment sessions.

There is no clear conclusion about the mechanisms of action of rPMS. Some studies have proposed that PMS directly stimulates sensorimotor nerve fibers and indirectly stimulates mechanoreceptors of muscle fibers.[20-22] Another study reported that PMS over spinal roots and muscles decreased spasticity.[23] PMS might have some supraspinal mechanisms. It has been reported that when PMS was applied over an affected peripheral area, there was an increase in regional cerebral blood flow (shown by a PET scan) and increased homeostasis of cortical excitability. Therefore, PMS could potentially influence cerebral activation and neuroplasticity.[24-26]

This study used an rPMS protocol consisting of 4 frequencies (10, 20, 30, and 40 Hz) of magnetic stimulation. This protocol was selected because it can be used for pain diagnosis, many types of pain, and many pain areas. The 4 frequencies would stimulate diverse types of muscle cells and neurons, thereby producing different therapeutic effects. Because the protocol uses a frequency exceeding 1 Hz, the inhibitory effects (weakness and numbness) are not of concern. The treatment protocol may be easy for physicians who use rPMS to treat chronic pain in that it can be applied to almost all patients.

In some pain diseases (such as painful polyneuropathy and postherpetic neuralgia), the studied rPMS protocol did not produce good outcomes. This may be because the sample size was too small. Alternatively, these pain conditions may respond to frequencies below 10 Hz or over 40 Hz. Changing the frequency of the stimulation might provide a better result.

During the authors' 2-year experience of using the FFP, some variations in therapeutic effects were observed: some cases had very satisfactory outcomes, whereas others demonstrated poor results. This retrospective study may guide further practice and research for some types of chronic pain treatment and the selection of cases suited to this protocol. It would need to be modified for the types of pain that did not show good responsiveness.

Comparison with other studies

Many studies have shown that rPMS is advantageous for many medical conditions. Khedr et al, found promising results, with a 90% reduction in chronic neuropathic pain from traumatic brachial plexopathy.[6] An 84% reduction in chronic neuropathic pain from post-trauma (neuroma; nerve entrapment) was reported by Leung et al.[7] Pujol et al, observed that PMS reduced pain severity by 59% in subacute musculoskeletal injuries.[8] In a study on chronic myofascial pain syndrome, Smania et al, showed that PMS provided an improvement that lasted longer than transcutaneous electrical nerve stimulation.[9,10] Lo et al demonstrated a 62.3% reduction in lumbosacral spondylotic pain,[11] while Massé-Alarie et al reported a 46% reduction in chronic low back pain.[12,13] Lim et al, found a 57% reduction in acute low back pain.[27]

In the current investigation, pain levels declined by approximately 50% to 100%, depending on the type of pain diagnosed. The main difference between this study and previous research was the PMS protocol used. A variety of frequencies, number of pulses, and areas where stimulation is applied can be used by PMS. Unlike the present work, most earlier studies only used 1 frequency (0.5, 10, 15, or 20 Hz).[6-13] In addition, different equipment models used to produce PMS and different types of PMS coil may affect therapeutic effects by generating different magnetic fields. Furthermore, the present study evaluated more pain diagnosis types and more kinds of neuropathic pain than other studies.

Limitations

The primary limitation of this research was its retrospective design. This risked the introduction of biases when evaluating effectiveness, such as a selection bias (good candidate selection; no randomization), placebo effects, natural regression, and co-intervention (no control group; no blinding). Some data related to quality-of-life improvements, patient satisfaction, long-term efficacy and duration of pain were also missing in the present work. Moreover, the investigation lacked precise and validated tools for evaluating the quality-of-life and satisfaction outcomes. In addition, there were too few participants to analyze the factors associated with rPMS effectiveness.

Prospective randomized controlled trials should be conducted to investigate the FFP of rPMS for application to specific conditions. The current work can be used as a guide for such studies.

CONCLUSION

The FFP of rPMS for patients with chronic pain significantly reduced pain intensity in terms of immediate effectiveness and after 4 weeks of therapy. Nearly 80% of the patients had a satisfactory treatment response. The FFP effectively reduces chronic musculoskeletal and neuropathic pain (peripheral and central), increases the quality of life, and improves patient satisfaction with minimal adverse effects.

ACKNOWLEDGMENTS

We thank Ms. Julaporn Pooliam for the statistical analysis. We are also indebted to Mr. David Park for English-language editing. This research project was supported by Chalermphrakiat Grant from the Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand.

Conflict-of-interest statement

The authors have no conflicts of interest to declare.

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