Original Article

Short-Term Efficacy of Peripheral Magnetic Stimulation in Reducing Pain in Knee Osteoarthritis: A Randomized Controlled Trial

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ABSTRACT

Objectives: To investigate the short-term efficacy of repetitive peripheral magnetic stimulation (rPMS) on pain reduction in knee osteoarthritis.

Study design: Randomized controlled trial.

Setting: Ramathibodi Hospital, Mahidol University, Bangkok, Thailand.

Subjects: Knee osteoarthritis patients with Kellgren-Lawrence classification (KL) 2-4 and Visual analog scale (VAS) > 4.

Methods: Participants were allocated into two groups. The rPMS group received 6,000 pulses of magnetic stimulation of the knee joint at a frequency of 20 Hertz for one session, and the sham group received a sham stimulation for one session. All the participants received conventional treatment. The result was measured by VAS and the Thai version of the modified Western Ontario and McMaster Universities Arthritis Index (WOMAC) score.

Results: The KL 2, 3, and 4 grades of the 30 participants, average age 62.83 years (SD 6.38), were 16, 11, and 3, respectively. The median (Q1, Q3) decrement of VAS between baseline and immediately after treatment and between baseline and one week after treatment of the rPMS group were 47 (38, 59) and 21 (9, 46). The median (Q1, Q3) decrement of VAS between baseline and immediately after treatment and between baseline and one week after treatment of the sham group were 41 (29, 50) and 17 (3, 30). The median (Q1, Q3) decrement of modified WOMAC between baseline and one week after treatment of rPMS and sham group were 25 (7, 53) and 2 (1, 15). The study found improvement of VAS and modified WOMAC in both groups, but the change in VAS was not statistically significant while modified WOMAC in the rPMS group showed statistically significant.

Conclusions: rPMS provides no significant additional therapeutic effect in a short-term improvement of pain in primary knee osteoarthritis patients compared with sham treatment.

Keywords: repetitive peripheral magnetic stimulation, knee osteoarthritis, pain

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Introduction

Knee osteoarthritis is one of the most common joint problems in Bangkok, Thailand. The prevalence of knee osteoarthritis is 0.34-0.45.[1] In due course, the causes of knee osteoarthritis are older age, greater weight, female sex, family history of osteoarthritis, strenuous work, and knee trauma. The main symptoms of knee osteoarthritis are pain and swelling in the knee, limited range of motion, and crepitation.[2] These symptoms affect activities of daily living and decrease quality of life.[3]

There are several treatments for knee osteoarthritis, such as non-medication, medication, and surgery. Non-medication treatments include lifestyle modification, exercise, and physical modalities.[2] Subsequently, pulsed electromagnetic field therapy is one of the physical modalities that can decrease pain in knee osteoarthritis[4] and able to slow the increase of osteoarthritis in animals.[5]

A recent study reported on the use of rPMS to reduce pain, a method which produces a more powerful magnetic field than traditional pulsed electromagnetic field therapies.[6] A magnetic field around a coil passes the magnetic field's pulses to the body. It also induces a voltage difference between two points which inducing an ion flow. Axonal depolarization and action potential can stimulate the brain and change the nervous system's connections.[6] However, there is no evidence regarding mechanism by which rPMS can decrease pain.[6,7] It has been hypothesized that the magnetic field stimulates A-beta afferent fibers and inhibits A-delta and C fibers which are pain conductor to the brain, thus decreasing pain. Another possible mechanism is that rPMS may simulate the descending inhibitory pathway.[8]

A review of the literature found that many studies mentioned rPMS and musculoskeletal pains,[8-16] however, no studies of rPMS and knee osteoarthritis were identified. The present study aimed to investigate the short-term effects of repetitive peripheral magnetic stimulation on pain reduction in knee osteoarthritis.

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Methods

Study design

This randomized control trial was approved by the Faculty of Medicine Ethics Committee, Ramathibodi Hospital, Mahidol University, on Aug 9, 2019 (approval number MURA2019/707). The ClinicalTrials.gov number is NCT05484752.

Participants

Study participants were knee osteoarthritis patients at the outpatient clinic, Department of Rehabilitation Medicine at Ramathibodi Hospital, Mahidol University, Bangkok, Thailand, from August 2019 through March 2020. The inclusion criteria were patients with primary knee osteoarthritis who had had knee pain for at least six months, were age 50 years or older, had morning stiffness lasting not more than 30 minutes, and had crepitation, KL classification 2-4, and a VAS pain score of 4 or higher. The exclusion criteria were patients with other musculoskeletal problems associated with the knee joint; a history of physical therapy in the past month; patients with a pacemaker, cochlear implant, or cerebral shunt; patients with a history of knee surgery; patients with a neurological or other severe disease and patients who had previously had a seizure.

The sample size was calculated using the standard deviation (SD) of the pain score of 1.657. The minimal clinically significant difference (MCSD) in VAS pain score was set at 2, the statistical significance level was set at $p < 0.05$, and the power was 80%. The sample size was calculated based on a loss follow-up of 20% and sample size was 15 participants per group.

Randomization

Participants were randomly assigned to either the rPMS or the sham group using a computer-generated block of 6 randomizations. All participants were blinded to whether they received real or sham rPMS.

Materials

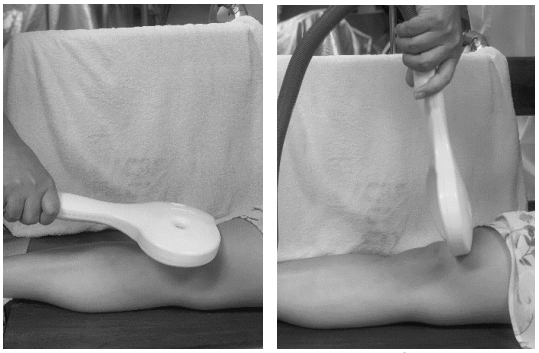
1. Neuro-MS magnetic stimulator form Neurosoft® Ivanovo, Russia
2. 100-mm horizontal Visual Analog Scales (VAS)[17]
3. The Thai version of modified Western Ontario and McMaster University Osteoarthritis Index (WOMAC)[18]
4. Lifestyle modification and self-exercise leaflet produced by the Thai Rheumatism Association Guideline for the Treatment of Osteoarthritis[19]

Intervention

After randomization, participants answered a questionnaire about baseline characteristics, VAS pain score at baseline, and completed the modified WOMAC questionnaire. In the rPMS group, the participants received peripheral magnetic stimulation at the medial and lateral knee joint of 6,000 pulses at a frequency 20 Hertz for one 20-minute session. The stimulation was delivered through a figure-of-eight coil using a Neurosoft® stimulator. The initial intensity was 20% of maximum output which was then increased by increments of 5% until the participants had non-pain sensation at the knee joint. On-time was 10 seconds, and the off-time was 30 seconds. The sham group received a sham magnetic stimulation at the knee joint for one session. The sham magnetic stimulation was performed using the same coil as rPMS, but at a position perpendicular to the knee joint at the medial and lateral sides, using an intensity of 5% of the maximum output. Although there was a sound of stimulation, the participants did not receive actual stimulation. All participants were educated on lifestyle modification and were taught to do strengthening exercises, including isometric quadriceps exercises, isometric knee exercises, and semi-squats. Each patient did each of the exercises with 10 repetitions per set, 2 sets per day. Figure 1 shows the application of rPMS in the rPMS and sham groups.

Outcome measurements

The primary outcome, level of pain, was as measured using VAS with a pain scale of 0-100 where a higher score indicates greater pain. VAS measurements were made at baseline, immediately after treatment, and one week after treatment. The secondary outcome was the modified WOMAC which contains 22 items and covering three dimensions: pain, stiffness, and function. A higher score means poorer health performance. The modified WOMAC was measured at baseline and one week after treatment. Outcomes were also assessed by the same blinded assessor prior to and after the intervention. The flow chart of the study is shown in Figure 2.



a b

Figure 1. Application of the rPMS; a. Intervention group, b. Sham group

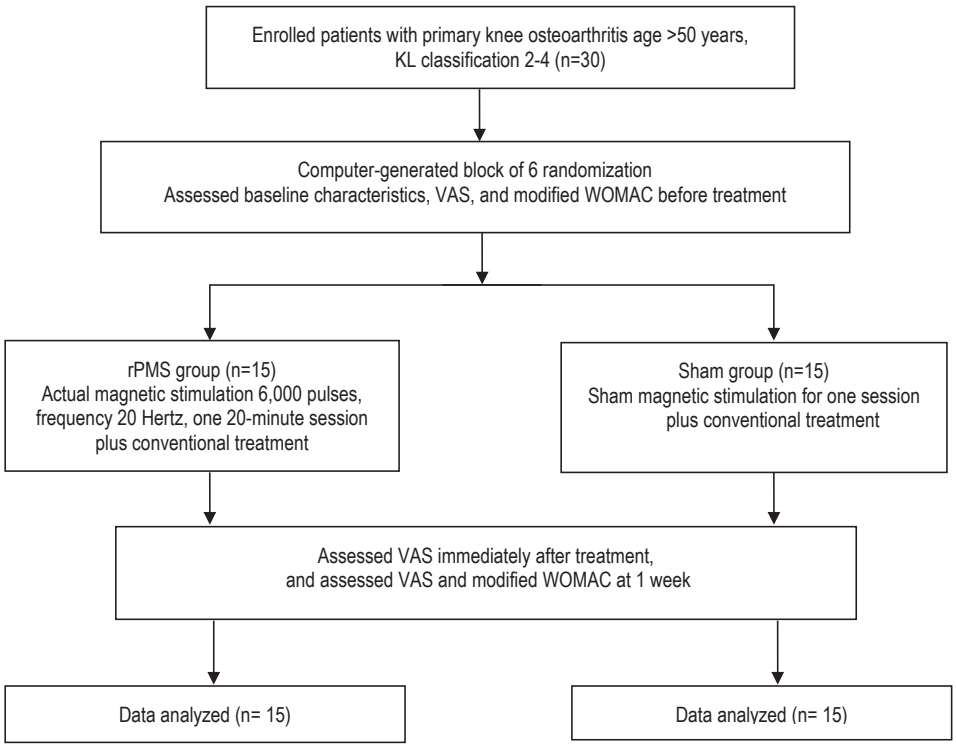


Figure 2. Flow chart of the study

Statistical methods

STATA version 16 was used for all statistical analyses. This study used descriptive statistics to analyze the baseline characteristics of the patients, including age, sex, BMI plus duration and severity of the disease. VAS and modified WOMAC scores were assessed using the Mann-Whitney U test. $P < 0.05$ were considered statistically significant.

Results

The mean (SD) age of the thirty participants was 62.83 (6.38) years, 81% were female, mean (SD) BMI was 26.24 (4.25) kg/cm^2, and the median (Q1, Q3) duration of knee pain was 3 (1,5) years. Most of the participants' severity was in KL 2 and 3. In the rPMS group, there were 8 participants in KL 3 (53.33%), more than the KL 3 in the sham group (20%). Baseline VAS and modified WOMAC were not statistically significantly different between the groups. Baseline demographics and clinical characteristics of patients are shown in Table 1.

The median (Q1, Q3) difference in VAS before and immediately after treatment had decreased in both groups. In the rPMS group, VAS decreased by 47 (38,59) points compared to 41 (29, 50) points in the sham group. The difference in VAS before and one week after treatment also decreased in

Table 1. Baseline demographics and clinical characteristics of patients with knee osteoarthritis

Characteristics	rPMS (n=15)	Sham (n=15)	*p*-value
Age[1], year	63.80 (5.93)	61.86 (6.86)	0.41
BMI[1], kg/m^2	26.57 (4.69)	25.90 (3.89)	0.65
Sex, No. (%)			1.00
Female	13 (86.67)	14 (93.33)	
Duration[2], month (Q1, Q3)	36 (12, 60)	24 (12, 60)	0.41
Severity (KL grading), No (%)			0.19
2	6 (40.00)	10 (66.67)	
3	8 (53.33)	3 (20.00)	
4	1 (6.67)	2 (13.33)	
VAS baseline[2]	60 (48,70)	60 (43,73)	0.88
Modified WOMAC baseline[2]	104 (39,126)	72 (45,102)	0.50
Pain (Q1, Q3)	26 (13, 31)	17 (13, 26)	0.29
Stiffness (Q1, Q3)	6 (0, 12)	7 (4, 13)	0.47
Function (Q1, Q3)	61 (33, 85)	50 (34, 68)	0.53

[1]Mean (SD), [2]Median (Q1, Q3)

rPMS, repetitive peripheral magnetic stimulation; KL, Kellgren-Lawrence classification; VAS, Visual analog scale

Table 2. Effects of repetitive peripheral magnetic stimulation on pain and function in patients with knee osteoarthritis

	rPMS (n=15)	Sham (n=15)	*p*-value
ΔVAS[1]			
- Baseline-immediate after treatment	47 (38,59)	41 (29,50)	0.21[a]
- Baseline-after treatment 1 week	21 (9,46)	17 (3,30)	0.41[a]
ΔModified WOMAC [total][1]	25 (7,53)	2 (1,15)	0.01[a]
ΔModified WOMAC [pain][1]	8 (3,18)	1 (0,3)	0.003[a]
ΔModified WOMAC [stiffness][1]	0 (0,4)	1 (0,2)	0.95[a]
ΔModified WOMAC [function][1]	12 (3,28)	4 (0,9)	0.04[a]

[1]Median (Q1, Q3), [a]Mann-Whitney U test

both groups: 21 (9, 46) points in the rPMS group and 17 (3, 30) in the sham group, although the difference was not statistically significant ($p = 0.21$ and $p = 0.41$, respectively). The effects of rPMS on pain and function in patients with knee osteoarthritis are shown in Table 2. Baseline and follow-up VAS in rPMS and sham groups are shown in Figure 2.

The median (Q1, Q3) decrement in the modified WOMAC scores between baseline and one week after treatment of rPMS and the sham group were 25 (7, 53) and 2 (1, 15), respectively, with a statistically significant difference in both groups ($p = 0.01$). The median (Q1, Q3) difference in modified WOMAC pain subscale at baseline and one week after treatment of rPMS and sham groups were 8 (3,18) and 1 (0, 3) respectively, with a statistical difference in both groups ($p = 0.003$). The median (Q1, Q3) difference in the modified WOMAC stiffness subscale between baseline and one week after treatment of rPMS and the sham group were 0 (0, 4) and 1 (0, 2), respectively, with no statistically significant differences ($p = 0.95$). The median (Q1, Q3) difference in the modified WOMAC function subscale between baseline and one week after treatment of rPMS and the sham group were 12 (3, 28) and 4 (0, 9), respectively, with a statistically significant difference in both groups ($p = 0.04$) as shown in Table 2. All participants reported no side effects or pain after the treatment.

Discussion

In previous studies, Smania[14,15] and Pujol[16] found that repetitive peripheral magnetic stimulation could produce muscle contraction-relaxation and decrease pain. Masse-Alarie[13] also found that 6,000 pulses of rPMS at a frequency of 20 Hz for 20 minutes combined with conservative back exercise could decrease pain scores (VAS) in patients with low back pain. The possible mechanisms might be rPMS, potentially influencing cerebral activation, neuroplasticity,[20] and activation of the descending inhibitory pathway. Consequently, rPMS may trigger massive proprioceptive afferents via two pathways when applied to muscles. The first pathway is the direct activation of sensorimotor nerve fibers and indirect activation of mechanoreceptors in muscle fiber.[20] Moreover, the contraction and relaxation of muscle produced by rPMS might also reduce pain as suggested by the spinal cord gate control theory.[6,7] Many studies[13-15] have reported that multiple sessions of rPMS can decrease pain in patients with chronic diseases such as low back pain or musculoskeletal pain. The current study, however, used only one session of rPMS to examine the short-term efficacy of rPMS in knee osteoarthritis patients. In contrast to other studies, this study found that the VAS score decreased immediately after treatment and at 1-week after treatment in both the rPMS and sham groups, with no statistically significant differences between the groups?

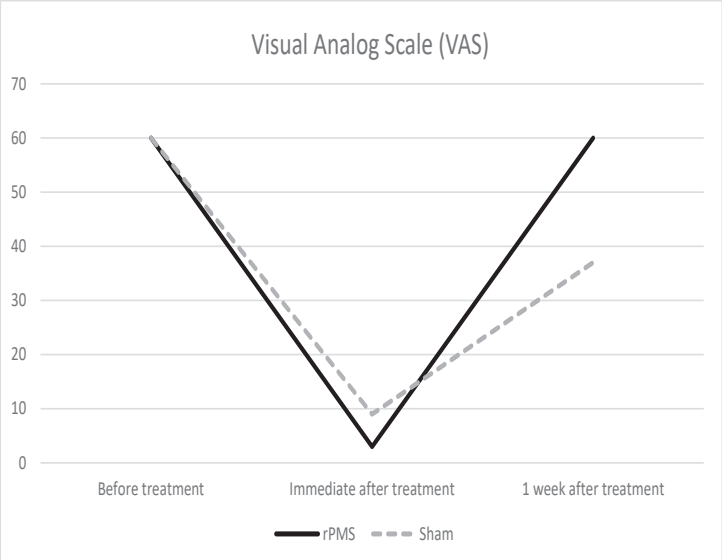


Figure 3. VAS before treatment, immediately after treatment, and 1-week after treatment

One difference between this study and previous studies is that the current study's population was knee osteoarthritis patients, while previous studies evaluated chronic musculoskeletal pain. The primary pathology of pain in knee osteoarthritis is a result of degenerative changes in the knee joint. There have been no definite conclusions regarding the mechanisms by which rPMS could reduce pain in abnormal structural joints. However, the statistically significant decrease in VAS of the rPMS group might result from rPMS producing contraction and relaxation of the muscles around the knee and a decrease in pain as described in the gate control theory.[6,7] Additionally, the patients also received conventional therapies, including strengthening exercises and lifestyle modification, which have shown level 1 evidence of the ability to decrease pain in knee osteoarthritis patients.[19] The VAS of the patients in both groups decreased one week after treatment.

A 2021 study by Lee[21] which used rPMS 20 minutes per day, five times a week for a total of 4 weeks in knee osteoarthritis patients showed a significant decrease in VAS and WOMAC in the rPMS group four weeks post-treatment. That study reported that rPMS might have cumulative effects which were not demonstrated in our study which aimed to study only the effect of single-dose rPMS.

Tubach (2005)[22] found that the change of VAS 19 points was a minimal clinically significant difference. In this study, the decrease in VAS score of rPMS and sham groups immediately occurred after treatment was clinically significant (47 and 41 points, respectively). However, the decrease of VAS one week after treatment was clinically significant only in the rPMS group (21 points). Then the efficacy of rPMS to decrease pain in knee osteoarthritis patients might last longer than the sham group.

This current study found that the decrease in the modified WOMAC before and one week after treatment in the rPMS group was statistically significant when compared to the sham group (25 points vs. 2 points, respectively). This difference was clinically significant. Bellamy (2015)[23] found that a change in modified WOMAC score of ≥ 7 points was the minimal clinically significant difference. A subanalysis in the present study found that the pain and function dimensions of the modified WOMAC in the rPMS group was statistically significantly decreased one week after treatment. When the pain score improved, the function score improved as well which may have also resulted in a reduction of the total modified WOMAC score. A similar result was found with the VAS: there was a clinical significantly decrease in the rPMS group one week after treatment.

The present study found that one session of rPMS can decrease pain in knee osteoarthritis patients for at least one week. Knee osteoarthritis is a chronic disease; however, if the results of treatment last longer, the patient may have a better quality of life.

A limitation of this study is that the results included only short-term effects from one session of rPMS. Future studies should include more than one rPMS session, should investigate an appropriate rPMS protocol including the optimum dose and should observe the long-term effect of rPMS.

Conclusions

Repetitive peripheral magnetic stimulation of 6,000 pulses at a frequency of 20 Hz for 20 minutes for one session provides no significant additional therapeutic effect in short-term improvement of pain in primary knee osteoarthritis patients compared with sham treatment.

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