International Journal of Biology and Life Sciences
ISSN: 2957-9511 | Vol. 13, No. 3, 2026

A Study on the Frequency Correlation of Repetitive Transcranial Magnetic Stimulation on the Functional Impact in Patients with Chronic Lower Back Pain

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Abstract: The aim of this study is to investigate the differential effects of different frequencies of repetitive transcranial magnetic stimulation (rTMS) on pain and functional improvement in patients with chronic low back pain (CLBP). We selected 80 CLBP patients admitted to the Department of Rehabilitation Medicine/Pain Department of Zigong Fourth People's Hospital from July 2023 to September 2024, and randomly divided them into a control group (n=20), a 1Hz rTMS group (n=20), a 5Hz rTMS group (n=20), and a 10Hz rTMS group (n=20). Pain visual analogue scale (VAS) scores and Roland-Morris Disability Questionnaire (RMDQ) scores were assessed before treatment, after treatment, and 1 month after the end of treatment, and adverse reactions during treatment and follow-up were recorded. The results showed that VAS and RMDQ scores at post-treatment and 1-month follow-up were significantly lower than those before treatment in all four groups (all $P<0.05$). After treatment, pairwise comparisons of VAS scores between groups showed statistically significant differences (all $P<0.05$); for RMDQ scores, significant differences were only found between the control group and the 5Hz group, and between the 5Hz group and the 10Hz group (all $P<0.05$). At the 1-month follow-up, VAS scores showed significant differences between each rTMS group and the control group (all $P<0.05$), and also between the 1Hz group and the 10Hz group ($P<0.05$); RMDQ scores showed significant differences between the control group and the 5Hz group, between the 5Hz group and the 10Hz group, and between the 1Hz group and the 10Hz group (all $P<0.05$), while no statistically significant differences were found in other pairwise comparisons. No significant adverse reactions were reported in any group during treatment and follow-up. The conclusion indicates that rTMS can safely and effectively alleviate pain and improve function in CLBP patients. High-frequency stimulation (10Hz, 5Hz) showed superior effects in pain reduction and functional recovery compared to low-frequency stimulation (1Hz) and the control group, and the degree of pain improvement showed a frequency-dependent trend (10Hz > 5Hz > 1Hz > control group).

Keywords: Chronic Low Back Pain; Transcranial Magnetic Stimulation; Pain; Functional Impairment; Randomized Controlled Trial.

1. Introduction

Chronic Low Back Pain (CLBP) is one of the most disabling musculoskeletal disorders worldwide, with a lifetime prevalence as high as 58-84%. It not only affects patients' quality of life but also imposes a significant socioeconomic burden [1-3]. CLBP is a complex and chronic pain syndrome characterized by pathological physiological changes such as central sensitization and motor control abnormalities. These changes pose clinical challenges to traditional treatment modalities, including pharmacological analgesia and physical therapy, due to limited efficacy and high recurrence rates [4-6]. Repetitive Transcranial Magnetic Stimulation (rTMS), with its non-invasive nature and ability to precisely modulate cortical excitability, has demonstrated unique advantages in the field of pain medicine [7-8]. Studies suggest that low-frequency (1Hz) rTMS may alleviate pain by inhibiting cortical excitability, while high-frequency (≥5Hz) rTMS may promote analgesic effects by enhancing cortical activity [9-10]. However, there is a lack of systematic comparative research on the efficacy differences of rTMS at various frequencies for CLBP, creating an important research gap for future clinical applications and personalized treatment. To address this, this study will employ a randomized controlled trial design to compare the clinical effectiveness of different frequency rTMS in treating CLBP, aiming to provide evidence-based support for personalized treatment.

2. Materials and Methods

2.1. Subject of Study

80 patients with chronic low back pain who visited the Department of Rehabilitation Medicine/Department of Pain Management of Zigong Fourth People's Hospital between July 2023 and September 2024 were enrolled in the study.

Inclusion criteria: 1) Met the diagnostic criteria for chronic low back pain [11], defined as pain lasting more than 3 months, radiating from the costal margin to the gluteal fold, possibly appearing in the thigh above the knee, and localized to the musculoskeletal system, excluding low back pain caused by fractures, metabolic diseases, infections, tumors, and inflammatory arthritis; 2) Possessed good compliance and normal mental status.

Exclusion criteria: 1) Patients with contraindications to rTMS, such as malignancies, hepatic or renal failure, epilepsy, patients with uncontrolled hypertension, patients with head and neck metal implants or cardiac pacemakers, and pregnant or lactating women [12]; 2) Patients with severe pain (pain score >6); 3) Patients unwilling to receive repetitive transcranial magnetic stimulation treatment. Patients were randomly divided into a control group (n=20), 1Hz rTMS group (n=20), 5Hz rTMS group (n=20), and 10Hz rTMS group (n=20) using a random number table method.

This study was approved by the Medical Ethics Committee

of Zigong Fourth People's Hospital. All enrolled patients provided informed consent and voluntarily signed written informed consent forms.

2.2. Treatment Methods

All basic treatments employed conventional rehabilitation therapies, including rehabilitation education, rehabilitation nursing, local intermediate-frequency pulse electrotherapy for pain, and acupuncture therapy.

For the rTMS group, intervention was administered using a Magneuro100 magnetic stimulator produced by Nanjing Weisi Medical Technology Co.,Ltd. The target area was determined using a combination of functional reaction zone localization and cap-based localization. Initially, the position of the left primary motor cortex (M1) was identified by recording motor evoked potentials (MEPs) in the target muscle group (right abductor pollicis brevis). Subsequently, the position of the left M1 was aligned with the C3 electrode site on a cap designed according to the 10-20 EEG electrode system. Finally, the F3 position (i.e.,the left dorsolateral prefrontal cortex, LDLPFC) was designated as the stimulation target. The resting motor threshold (RMT) was determined as the minimum stimulation intensity required to elicit MEPs exceeding 50 μV in at least 5 out of 10 consecutive stimuli, recorded using the motor evoked potential detection module. Stimulation was conducted at 80% of the lowest RMT, with each sequence consisting of 20 pulses, inter-sequence intervals of 5 seconds, and a total of 100 sequences (2000 pulses). Treatment was administered once daily, six times per week, for a continuous period of two weeks. The 1Hz rTMS group received magnetic stimulation at a frequency of 1Hz; the 5Hz rTMS group at 5Hz; and the 10Hz rTMS group at 10Hz. The control group did not measure RMT, instead using a 1Hz stimulation frequency with the stimulus intensity adjusted to the minimum level. The stimulation coil was positioned vertically over the LDLPFC region, ensuring that patients could hear the sound but no magnetic field penetration through the scalp occurred.

2.3. Observation Indicators

Pain Intensity: The pain intensity of four groups of patients was statistically analyzed before treatment, after treatment, and one month after treatment termination using the Visual Analogue Scale (VAS). This scale employs a 10cm visual rating ruler, where '0' indicates no pain and '10' represents the maximum imaginable pain. Participants mark a point on the ruler corresponding to their perceived pain intensity; the measured length is converted to a pain score, with higher scores indicating more severe pain [13].

Degree of Functional Impairment: The Roland-Morris Disability Questionnaire (RMDQ) was used to assess the severity of functional impairment in four groups of patients before treatment, after treatment, and one month after treatment termination. The questionnaire comprises 24 items, each scored 0-1. The degree of functional impairment is positively correlated with the total score.

Adverse Reactions: All patients were monitored for adverse reaction occurrences during treatment and during the one-month follow-up period after treatment.

2.4. Statistical Methods

SPSS 22.0 statistical software was used for data statistics and analysis. For normally distributed metric data, results are presented as mean ± standard deviation ($\bar{x}\pm s$), and group comparisons are performed using analysis of variance. For non-normally distributed metric data, results are expressed as median (interquartile range), and group comparisons are conducted using non-parametric tests. Count data are described as number of cases and percentage [n(%)]. Statistical significance was set at $P < 0.05$.

3. Results

3.1. Comparative Analysis of Baseline Data of Patients in Four Groups

Comparative analysis of baseline data such as age and gender of patients in four groups showed that there were no statistically significant differences among the groups (all $P>0.05$), as shown in Table 1.

Table 1. Baseline characteristics among four groups

Project	Control group	1Hz group	5Hz group	10Hz group	X^2/F-value	P-value
	n=20	n=20	n=20	n=20		
Women	12(60%)	12（60%)	12(60%)	11(55%)	0.155	0.985
Age	42.300±8.461	44.950±10.252	47.450±7.857	44.950±9.865	1.054	0.374

3.2. Comparative Analysis of VAS Scores Among the Four Groups of Patients

Intra-group comparative analysis showed that the differences in VAS scores among the four groups before treatment, after treatment, and at 1 month after treatment completion were all significant (all $P < 0.05$). Pairwise comparisons revealed that VAS scores after treatment and at 1 month after treatment completion were significantly lower than those before treatment (all $P < 0.05$), and the differences between each time point were statistically significant. In the control group, there was no significant change in VAS scores between after treatment and at 1 month after treatment completion ($P > 0.05$); whereas in the three rTMS groups, the differences in scores at the two aforementioned time points were all significant (all $P < 0.05$). Specific data are shown in Table 2 and Table 3.

Inter-group comparative analysis showed that at both after treatment and at 1 month after treatment completion, the VAS scores of the three rTMS groups were significantly lower than those of the control group at the same time points, and the inter-group differences at each time point were statistically significant (all $P < 0.05$). Further pairwise comparisons revealed that all pairwise differences in VAS scores among the four groups after treatment were significant (all $P < 0.05$); at 1 month after treatment completion, the score differences between the three rTMS groups and the control group were also all significant (all $P < 0.05$). Additionally, at 1 month after treatment completion, comparisons among the different frequency rTMS groups showed: the difference in VAS scores between the 1Hz group and the 10Hz group was significant ($P < 0.05$), whereas the differences between the 1Hz group and the 5Hz group, and between the 5Hz group and the 10Hz group, were not statistically significant (all $P > 0.05$). Specific

data are shown in Table 2 and Table 3.

Table 2. Comparison of VAS scores among four groups before and after treatment

Project		Control group n=20	1Hz group n=20	5Hz group n=20	10Hz group n=20	F-value	P-value
VAS	Before treatment	5.525±0.294	5.565±0.285	5.520±0.259	5.500±0.294	0.185	0.906
	After treatment	2.575±0.331	2.140±0.320	1.995±0.436	1.665±0.418	19.753	0.000
	1 month after treatment completion	2.805±0.302	2.425±0.302	2.200±0.463	1.935±0.325	21.591	0.000
F-value		563.729	787.149	498.032	749.244		
P-value		0.000	0.000	0.000	0.000		

Table 3. Multiple comparisons of VAS scores within and between four groups before and after treatment

	Group/Period	Between Groups(I)	Between Groups(J)	Mean Difference(I-J)	P-value
Pairwise Comparisons Within Groups Across Different Periods	Control group	Before treatment	After treatment	2.950	0.000
		Before treatment	1 month after treatment completion	2.720	0.000
		After treatment	1 month after treatment completion	-0.230	0.066
	1Hz group	Before treatment	After treatment	3.425	0.000
		Before treatment	1 month after treatment completion	3.140	0.000
		After treatment	1 month after treatment completion	-0.285	0.013
	5Hz group	Before treatment	After treatment	3.525	0.000
		Before treatment	1 month after treatment completion	3.320	0.000
		After treatment	1 month after treatment completion	-0.290	0.003
	10Hz group	Before treatment	After treatment	3.835	0.000
		Before treatment	1 month after treatment completion	3.565	0.000
		After treatment	1 month after treatment completion	-0.295	0.000
Pairwise Comparisons Between Groups Across Different Periods	After treatment	Control group	1Hz group	0.435	0.003
		Control group	5Hz group	0.580	0.000
		Control group	10Hz group	0.910	0.000
		1Hz group	5Hz group	0.345	0.031
		1Hz group	10Hz group	0.475	0.001
		5Hz group	10Hz group	0.330	0.045
	1 month after treatment completion	Control group	1Hz group	0.380	0.007
		Control group	5Hz group	0.605	0.000
		Control group	10Hz group	0.870	0.000
		1Hz group	5Hz group	0.225	0.290
		1Hz group	10Hz group	0.490	0.000
		5Hz group	10Hz group	0.265	0.124

3.3. Comparative Analysis of RMDQ Scores Among the Four Groups of Patients

Intra-group analysis showed that the differences in RMDQ scores among the four groups before treatment, after treatment, and at 1 month after treatment completion were statistically significant (all P<0.05). Pairwise comparisons within groups revealed that the scores after treatment and at 1 month after treatment completion were significantly lower than those before treatment (all P<0.05), but no significant difference was observed between the scores after treatment and at 1 month after treatment completion (all P>0.05). Specific data are presented in Tables 4 and Tables 5.

Inter-group comparisons found that at both after treatment and 1 month after treatment completion, the RMDQ scores of the three rTMS groups were significantly lower than those of the control group at the same time points (all P<0.05). Pairwise comparisons showed significant differences in scores between the control group and the 5Hz group, and between the 5Hz group and the 10Hz group after treatment (all P<0.05), while no statistically significant differences were observed in the remaining inter-group comparisons. At 1 month after treatment completion, significant differences in scores were found between the control group and the 5Hz group, between the 5Hz group and the 10Hz group, and between the 1Hz group and the 10Hz group (all P<0.05), with no significant differences observed in other inter-group comparisons (all P>0.05). Specific data are presented in Table 4 and Table 5.

Table 4. Comparison of RMDQ scores among four groups before and after treatment

Project		Control group n=20	1Hz group n=20	5Hz group n=20	10Hz group n=20	F-value	P-value
RMDQ	Before treatment	15.100±2.447	15.050±2.645	15.150±2.540	15.100±2.634	0.005	1.000
	After treatment	6.050±2.013	5.050±1.849	4.250±1.682	3.950±1.504	5.622	0.002
	1 month after treatment completion	7.100±2.024	6.500±2.236	5.050±1.638	4.500±1.906	7.670	0.000
F-value		104.007	113.653	185.159	184.727		
P-value		0.000	0.000	0.000	0.000		

Table 5. Multiple comparisons of RMDQ scores within and between four groups before and after treatment

	Group/Period	Between Groups(I)	Between Groups(J)	Mean Difference(I-J)	P-value
Pairwise Comparisons Within Groups Across Different Periods	Control group	Before treatment	After treatment	9.050	0.000
		Before treatment	1 month after treatment completion	8.000	0.000
		After treatment	1 month after treatment completion	-1.050	0.395
	1Hz group	Before treatment	After treatment	10.000	0.000
		Before treatment	1 month after treatment completion	8.550	0.000
		After treatment	1 month after treatment completion	-1.450	0.143
	5Hz group	Before treatment	After treatment	10.900	0.000
		Before treatment	1 month after treatment completion	10.100	0.000
		After treatment	1 month after treatment completion	-0.800	0.631
	10Hz group	Before treatment	After treatment	11.150	0.000
		Before treatment	1 month after treatment completion	10.600	0.000
		After treatment	1 month after treatment completion	-0.550	1.000
Pairwise Comparisons Between Groups Across Different Periods	After treatment	Control group	1Hz group	1.000	0.470
		Control group	5Hz group	1.800	0.012
		Control group	10Hz group	2.100	0.002
		1Hz group	5Hz group	0.800	0.945
		1Hz group	10Hz group	1.100	0.320
		5Hz group	10Hz group	0.300	1.000
	1 month after treatment completion	Control group	1Hz group	0.600	1.000
		Control group	5Hz group	2.050	0.009
		Control group	10Hz group	2.600	0.000
		1Hz group	5Hz group	1.450	0.133
		1Hz group	10Hz group	2.000	0.011
		5Hz group	10Hz group	0.550	1.000

3.4. Adverse Reactions

No serious adverse reactions occurred during treatment and follow-up in any of the four groups. In the 5Hz group, one patient experienced dizziness and fatigue after the second treatment in the second week. Immediate blood sugar testing indicated hypoglycemia, and symptoms were relieved after timely sugar supplementation, without affecting subsequent treatment and follow-up. In the 10Hz group, one patient experienced brief syncope due to emotional tension during the first treatment. Symptoms were relieved after psychological counseling and rest, and the patient continued to complete the treatment.

4. Discussion

Chronic low back pain (CLBP) is a prevalent global health issue affecting the quality of life of millions of people; it not only causes significant pain and functional impairment for patients but also imposes a substantial economic burden, increasing healthcare costs and societal work losses[1,3]. Currently, treatment methods for chronic low back pain mainly include drug therapy, physical therapy, and surgical treatment, among others. However, these approaches have certain limitations in terms of efficacy and are associated with side effects[14-15]. Therefore, finding new treatment modalities is of significant clinical importance to improve patients' quality of life and alleviate the economic burden. Existing studies have shown that rTMS can effectively reduce pain and improve patients' functional status, with its mechanism of action closely related to the modulation of the central nervous system[16-17]. Different frequencies of repetitive transcranial magnetic stimulation (rTMS) may have varying effects on the pain intensity and functional impairment in patients with chronic low back pain[18-20]. Based on this, this study explores the application and efficacy of transcranial magnetic stimulation (rTMS) in patients with chronic low back pain and aims to evaluate the impact of different rTMS frequencies on pain intensity and functional impairment.

The left dorsolateral prefrontal cortex (LDLPFC) is significantly involved in pain modulation. Studies by Seminowicz et al.[21] and Ehsani et al.[22] have confirmed that the LDLPFC participates in the experience and regulation of pain, which may be related to pain reduction, cognitive burden, and patients' fear of movement and disability. Research by De Martino et al.[23] and Miyashiro et al.[24] has demonstrated that muscle pain can modulate the excitability of the sensorimotor cortex, and stimulation of the LDLPFC has analgesic effects while also reducing oxyhemoglobin levels. Therefore, this study selected the LDLPFC region as the rTMS target to observe the correlation between pain scores (VAS) and the Roland Morris Disability Questionnaire (RMDQ) with rTMS frequency in CLBP patients. Garg et al.[25], through analysis of various pain assessment tools for low back pain, found that the Roland Morris Disability Questionnaire (RMDQ) and the Oswestry Disability Index (ODI) have good construct validity and reliability, as well as responsiveness over short intervals.

This study provides an in-depth exploration of the therapeutic effects of different rTMS frequencies on CLBP patients, thereby partially addressing the gap in existing literature regarding the impact of rTMS stimulation frequency. Although previous studies have revealed the potential efficacy of rTMS in alleviating chronic pain, there is still a lack of in-depth investigation into the specific effects of different stimulation frequencies (e.g., 1Hz, 5Hz, and 10Hz) on pain reduction[26]. The findings of this study indicate that the high-frequency group (10Hz) demonstrates more significant effects in pain relief and exhibits longer-lasting

efficacy; this is consistent with the results of Hodaj et al.[27], which showed that repetitive transcranial magnetic stimulation (rTMS) can provide long-term analgesic effects lasting over one month when treating complex regional pain syndrome.

In clinical practice, the results of this study hold significant application value. Research indicates that rTMS, as a non-invasive treatment modality, can effectively improve pain intensity and functional impairment in patients with chronic low back pain. Particularly under high-frequency stimulation, it can more significantly enhance patients' functional impairment and maintain the durability of therapeutic effects. These findings suggest that clinicians may consider rTMS as an effective intervention when developing treatment plans for chronic pain, especially for patients who respond poorly to traditional therapies. Additionally, the low incidence of side effects associated with rTMS provides a safety guarantee for its clinical application, potentially making it a new option for managing refractory pain.

However, this study also has certain limitations. First, the relatively small sample size (20 cases per group) may affect the generalizability of the results. Second, the study was conducted at a single center, lacking validation from multicenter data. Furthermore, only a one-month follow-up was conducted, failing to assess longer-term efficacy and safety. Future research could consider expanding the sample size and follow-up duration and incorporating validation mechanisms such as neuroimaging or biomarkers to further confirm the effects of different rTMS frequencies and their underlying mechanisms.

In summary, this study demonstrates that rTMS treatment at different frequencies has significant effects in alleviating pain and improving functional impairment in CLBP patients, with particularly outstanding performance in the high-frequency group, where higher frequencies appear to correlate with stronger durability of efficacy. These results provide a scientific basis for the clinical application of rTMS and indicate potential directions for future research in chronic pain management. Future studies should continue to explore the optimal frequency of rTMS, treatment protocol optimization, and the combined effects with other treatment methods, aiming to provide more effective treatment options for patients with chronic low back pain.

Acknowledgments

This work was supported by Zigong Science and Technology Program, Project Number: 2023YLWS23.

References

[1] Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017[J]. LANCET. 2018; 392 LANCET. doi: 10.1016/S0140-6736(18)32279-7.

[2] Foster NE, Anema JR, Cherkin D, et al. Prevention and treatment of low back pain: evidence, challenges, and promising directions[J]. LANCET. 2018; 391 LANCET. doi: 10.1016/S0140-6736(18)30489-6.

[3] Hartvigsen J, Hancock MJ, Kongsted A, et al. What low back pain is and why we need to pay attention[J]. LANCET. 2018; 391 LANCET. doi: 10.1016/S0140-6736(18)30480-X.

[4] Markman JD, Baron R, Gewandter JS. Why are there no drugs indicated for sciatica, the most common chronic neuropathic syndrome of all?[J]. DRUG DISCOV TODAY. 2018; 23 DRUG DISCOV TODAY. doi: 10.1016/j.drudis.2018.06.004.

[5] Tan W, Wang W, Yang Y, et al. Spinal Manipulative Therapy Alters Brain Activity in Patients With Chronic Low Back Pain: A Longitudinal Brain fMRI Study[J]. Front Integr Neurosci. 2020; 14 Front Integr Neurosci. doi: 10.3389/fnint. 2020. 534595.

[6] Egan M, Seeger D, Schöps P. Physiotherapy and physical therapy in pain management[J]. SCHMERZ. 2015; 29 SCHMERZ. doi: 10.1007/s00482-015-0043-z.

[7] Lefaucheur JP, Aleman A, Baeken C, et al. Evidence-based guidelines on the therapeutic use of repetitive transcranial magnetic stimulation (rTMS): An update (2014-2018)[J]. CLIN NEUROPHYSIOL. 2020; 131 CLIN NEUROPHYSIOL. doi: 10.1016/j.clinph.2019.11.002.

[8] Zhang H, Zhao Y, Qu Y, et al. Transcutaneous Cervical Vagus Nerve Magnetic Stimulation in Patients With Traumatic Brain Injury: A Feasibility Study[J]. NEUROMODULATION. 2023; 27 NEUROMODULATION. doi: 10.1016/j. neurom. 2023. 09. 004.

[9] Fierro B, De Tommaso M, Giglia F, et al. Repetitive transcranial magnetic stimulation (rTMS) of the dorsolateral prefrontal cortex (DLPFC) during capsaicin-induced pain: modulatory effects on motor cortex excitability[J]. EXP BRAIN RES. 2010; 203 EXP BRAIN RES. doi: 10.1007/ s00 221-010-2206-6.

[10] Chowdhury NS, Millard SK, de Martino E, et al. Posterior-superior insula repetitive transcranial magnetic stimulation reduces experimental tonic pain and pain-related cortical inhibition in humans[J]. PAIN. 2023; PAIN. doi: 10. 1097/j.pain.0000000000003488.

[11] Shi Y, Guo W, Yu L. Non-specific low back pain: interpretation of North American Spine Society (NASS) guidelines for evidence-based medicine[J]. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi. 2021;35(10):1336-1340. doi:10.7507/1002-1892.202103131.

[12] Wang Lei,Shi Xueying,Yuan Liangjin,et al. Clinical study of high frequency repetitive transcranial magnetic stimulation in chronic tension-type headache[J].Zhonghua Shen Jing Yi Xue Za Zhi.2022:21(06):600-605.DOI:10.3760/cma.j.cn115354-20220404-00203.

[13] LIU An-zhong, LIU Shi-wei, SHU Zhen.Clinical observation of extracorporeal shock wave in the treatment of plantar fasciitis with calcaneus spur[J]. BME & Clin Med, May 2021, Vol. 25,No.3. DOI:10. 13339/j. cnki.sglc. 2021 0422.002.

[14] Maharty DC, Hines SC, Brown RB. Chronic Low Back Pain in Adults: Evaluation and Management[J]. Am Fam Physician. 2024;109(3):233-244.

[15] Yasunaga Y, Koizumi R, Toyoda T, et al. Biofeedback Physical Therapy With the Hybrid Assistive Limb (HAL) Lumbar Type for Chronic Low Back Pain: A Pilot Study. Cureus[J]. 2022;14(3): e23475. Published 2022 Mar. doi:10. 7759/ cureus.23475.

[16] Bai YW, Yang QH, Chen PJ, Wang XQ. Repetitive transcranial magnetic stimulation regulates neuroinflammation in neuropathic pain[J]. Front Immunol. 14:1172293. Published 2023 None. doi:10.3389/fimmu.2023.1172293.

[17] Nguyen JP, Dixneuf V, Esnaut J, et al. The Value of High-Frequency Repetitive Transcranial Magnetic Stimulation of the Motor Cortex to Treat Central Pain Sensitization Associated With Knee Osteoarthritis[J]. Front Neurosci. 13:388. Published 2019 None. doi:10.3389/fnins.2019.00388.

[18] Tsai YY, Wu WT, Han DS, et al. Application of Repetitive Transcranial Magnetic Stimulation in Neuropathic Pain: A

Narrative Review[J]. Life (Basel). 2023; 13 Life (Basel). doi: 10.3390/life13020258.

[19] Patricio P, Roy JS, Macedo L, et al. Repetitive transcranial magnetic stimulation alone and in combination with motor control exercise for the treatment of individuals with chronic non-specific low back pain (ExTraStim trial): study protocol for a randomised controlled trial[J]. BMJ Open. 2021; 11 BMJ Open. doi: 10.1136/bmjopen-2020-045504

[20] Li C, Hu J, He C. Analgesic efficacy of transcranial combined peripheral magnetic stimulation in chronic nonspecific low back pain: a fNIRS study[J]. EUR J PHYS REHAB MED. 2023; 61 EUR J PHYS REHAB MED. doi: 10.23736/S1973-9087.24.08594-0

[21] Seminowicz DA, de Martino E, Schabrun SM, et al. Left dorsolateral prefrontal cortex repetitive transcranial magnetic stimulation reduces the development of long-term muscle pain[J]. PAIN. 2018; 159 PAIN. doi: 10.1097/j. pain. 0000 000000001350

[22] Ehsani F, Hafez Yousefi MS, Jafarzadeh A, et al. Does Multisession Cathodal Transcranial Direct Current Stimulation of the Left Dorsolateral Prefrontal Cortex Prime the Effects of Cognitive Behavioral Therapy on Fear of Pain, Fear of Movement, and Disability in Patients with Nonspecific Low Back Pain? A Randomized Clinical Trial Study[J]. Brain Sci. 2023; 13 Brain Sci. doi: 10.3390/brainsci13101381

[23] De Martino E, Seminowicz DA, Schabrun SM, et al. High frequency repetitive transcranial magnetic stimulation to the left dorsolateral prefrontal cortex modulates sensorimotor cortex function in the transition to sustained muscle pain[J]. NEUROIMAGE. 2019; 186 NEUROIMAGE. doi: 10. 1016/ j.neuroimage.2018.10.076

[24] Miyashiro S, Yamada Y, Nagaoka M, et al. Pain relief associated with decreased oxyhemoglobin level in left dorsolateral prefrontal cortex[J]. PLoS One. 2021; 16 PLoS One. doi: 10.1371/journal.pone.0256626

[25] Garg A, Pathak H, Churyukanov MV, et al. Low back pain: critical assessment of various scales[J]. EUR SPINE J. 2020; 29 EUR SPINE J. doi: 10.1007/s00586-019-06279-5

[26] Olechowski C, Gener M, Aiyer R, et al. Transcranial magnetic stimulation for the treatment of chronic low back pain: a narrative review[J]. Front Pain Res (Lausanne). 2023; 4 Front Pain Res (Lausanne). doi: 10.3389/fpain.2023.1092158

[27] Hodaj H, Payen JF, Hodaj E, et al. Long-term analgesic effect of trans-spinal direct current stimulation compared to non-invasive motor cortex stimulation in complex regional pain syndrome[J]. Brain Commun. 2023; 5 Brain Commun. doi: 10.1093/braincomms/fcad191.