ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-515-x, Impact Factor: 9.23

American Academic publishers, volume 6, issue 01,2026

Journal: https://www.academicpublishers.org/journals/index.php/ijai

BIOPHYSICAL MECHANISMS OF TRANSCRANIAL MAGNETIC STIMULATION IN MIGRAINE

Abdukadirova D. T.,

Darmankulova D. F.

Andijan State Medical Institute Department of Neurology

Abstract

This research work presents an analysis of the biophysical mechanisms underlying the therapeutic effects of the Transcranial Magnetic Stimulation in patients with chronic migraine. The study focuses on the influence of TMS on cortical excitability, neuronal membrane polarization and modulation of synaptic transmission.

Key words

non-pharmacological methods, chronic migraine, magnetic stimulation.

One of the non-pharmacological methods for influencing the central nervous system is transcranial magnetic stimulation (TMS) — a technique that allows non-invasive stimulation of the cerebral cortex. This method is based on the ability of magnetic fields to penetrate bone and soft tissues. The induced magnetic field depolarizes neuronal membranes, generating action potentials that propagate along neural pathways. This review analyzes the biophysical effects of TMS, as well as its neuronal, immune, neurotransmitter, and systemic (macro-level) effects. The main contraindications and side effects of TMS are also discussed.

Non-pharmacological treatment of tension-type headache (TTH) and migraine is a promising approach, since the prevalence of these primary headache disorders reaches 40–65% and 11–22%, respectively.

In recent years, the number of randomized, placebo-controlled trials evaluating the effectiveness of TMS in migraine treatment has been increasing. Numerous studies have demonstrated positive effects of TMS in TTH and migraine; however, in many trials the number of participants is still insufficient to achieve the highest level of evidence.

Animal experiments, together with functional neuroimaging techniques, have significantly contributed to understanding the mechanisms of action of TMS. Active involvement of physiologists, neurophysiologists, and biophysicists in such studies will improve the evaluation of TMS as a non-pharmacological treatment for pain syndromes, thereby enhancing work capacity and quality of life in patients with migraine and TTH.

Physical and Physiological Aspects of Transcranial Magnetic Stimulation

Despite the wide range of pharmacological agents available for the treatment of primary headache disorders such as tension-type headache and migraine, the development of non-drug therapies remains highly relevant. One such method is transcranial magnetic stimulation (TMS), which enables non-invasive stimulation of the cerebral cortex. TMS was first introduced by A. T. Barker in 1985 and is now widely used worldwide. The method is based on Michael Faraday's principle of electromagnetic induction. In 1896, Jacques-Arsène d'Arsonval was the

ISSN: 2692-515-x, Impact Factor: 9.23
American Academic publishers, volume 6, issue 01,2026
Journal: https://www.academicpublishers.org/journals/index.php/ijai

first to apply magnetic fields to humans and demonstrated the induction of phosphenes — visual sensations occurring in the absence of light stimulation of the eyes.

At present, the phosphene threshold is not only studied as a response to TMS but is also considered one of the criteria for the differential diagnosis of migraine with aura.

The characteristics of the electromagnetic field during TMS depend on the shape, size, and design of the stimulation coil, as well as on its orientation relative to the patient's head and on the stimulation parameters. A wide variety of coils are used in magnetic stimulation, differing in outer and inner diameters, number of turns, and magnetic and electric field strengths. Small-diameter coils generate a high magnetic field intensity at the skin surface, making them effective for the stimulation of superficial nerves. In contrast, large-diameter coils allow efficient magnetic stimulation of deep brain structures. Focal stimulation can be achieved using figure-of-eight (double) coils.

TMS is also used for electrical stimulation of peripheral nerves. In this case, the ability of magnetic fields to penetrate superficial anatomical structures and activate tissues covered by skin, muscle, and bone is essential.

The induced magnetic field depolarizes neuronal membranes, and the resulting action potential propagates along neural pathways. Application of TMS to the brain and peripheral nerves enables clinical assessment of motor cortical areas and allows quantitative evaluation of corticospinal tract involvement.

Two main forms of TMS are distinguished: single-pulse TMS and repetitive TMS (rTMS). The effect of a single stimulus is short-lived, whereas repetitive stimulation produces longer-lasting effects and is therefore considered a non-pharmacological treatment option for tension-type headache and migraine.

TMS induces a series of changes in the central nervous system, which can be classified into several levels: biophysical, neuronal, immune, neurotransmitter, and macro-level effects.

At the biophysical level, TMS alters the electrical activity of neurons and their membranes.

At the neuronal level, it leads to reorganization of interactions between different cortical regions.

At the immune level, it modifies the activity of immune cells and the levels of pro-inflammatory cytokines.

At the neurotransmitter level, it changes the concentrations of neurotransmitters, including serotonin and dopamine.

At the macro level, these effects manifest clinically as a reduction in the intensity and frequency of headaches and an improvement in overall well-being.

The main contraindications for TMS include:

Epilepsy, implanted cardiac pacemakers, metallic implants in the head, and acute psychiatric disorders.

ORIGINAL ARTICLE
INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE
ISSN: 2692-515-x, Impact Factor: 9.23
American Academic publishers, volume 6, issue 01,2026
Journal: https://www.academicpublishers.org/journals/index.php/ijai

The side effects of TMS may include:

Mild headache, discomfort at the stimulation site, and, rarely, transient loss of consciousness.

Overall, however, TMS is considered a safe method when proper procedures and contraindications are respected. Effectiveness of TMS in Tension-Type Headache (TTH)

Tension-type headache (TTH) is the most common form of primary headache. According to various studies, its prevalence ranges from 40% to 65% of the population.

Although its pain intensity is usually lower than that of migraine, TTH significantly affects work performance, quality of life, and emotional well-being.

The use of TMS in TTH leads to:

– reduced frequency of headache episodes,

– decreased pain intensity,

– improved general condition,

– reduced levels of anxiety and depression associated with TTH.

Randomized, placebo-controlled studies have shown that repetitive TMS applied over 10–15 sessions results in a significant reduction in headache severity.

The most effective targets for stimulation were the dorsolateral prefrontal cortex (DLPFC) and the motor areas of the cerebral cortex. Studies also indicate that the beneficial effects of TMS persist for several weeks and even months after completion of the treatment course.

Thus, TMS can be regarded as a promising non-pharmacological treatment for tension-type headache (TTH), especially in patients who show insufficient efficacy or intolerance to conventional pharmacological therapies.

Effectiveness of Transcranial Magnetic Stimulation in Migraine

Migraine is one of the most disabling disorders of the nervous system. According to the World Health Organization, migraine ranks among the leading causes of temporary disability in people aged 15–49 years. The prevalence of migraine in the population ranges from 11% to 22%. A considerable proportion of patients experience insufficient efficacy of standard medications or have contraindications to their use, making the search for alternative therapeutic approaches highly relevant.

TMS is used in both migraine with aura and migraine without aura.

The mechanisms underlying the beneficial effects of TMS in migraine are associated with:

– suppression of cortical spreading depression,

– normalization of neural network activity,

ORIGINAL ARTICLE
INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE
ISSN: 2692-515-x, Impact Factor: 9.23
American Academic publishers, volume 6, issue 01,2026
Journal: https://www.academicpublishers.org/journals/index.php/ijai

– reduction of cortical hyperexcitability,

– modulation of serotonin and dopamine levels,

– influence on trigeminal pain pathways.

Clinical studies have shown that repetitive TMS leads to:

– a reduction in the frequency of migraine attacks,

– a decrease in their intensity and duration,

– a reduced need for analgesics and triptans,

– an improvement in patients' quality of life.

Particular attention has been given to stimulation of the dorsolateral prefrontal cortex and the occipital cortex, which play a key role in the pathogenesis of migraine.

Several studies have demonstrated that after only 5–10 TMS sessions, patients experience a reduction in headache severity and a decrease in anxiety and depression levels.

Comparative Effectiveness of TMS in Tension-Type Headache and Migraine

Despite differences in the pathogenesis of tension-type headache (TTH) and migraine, TMS shows efficacy in both forms of primary headache.

TTH, TMS significantly reduces the frequency and intensity of pain and improves the emotional state of patients.

In migraine, the effectiveness of TMS is manifested not only by a reduction in attack frequency, but also by a shortening of attack duration and a decrease in the need for pharmacological treatment.

A number of studies indicate that the beneficial effect of TMS may be more pronounced in migraine than in TTH, which is related to its direct influence on cortical mechanisms involved in the initiation and propagation of pain.

Comparative studies show that:

– in TTH, TMS mainly affects emotional regulation and reduction of muscle tension,

– in migraine, it primarily acts through suppression of cortical spreading depression and normalization of cortical excitability.

Thus, TMS can be considered a universal non-pharmacological treatment for different forms of primary headache, although its mechanisms of action differ depending on the type of headache.

Neurobiological Mechanisms of Action of Transcranial Magnetic Stimulation

The effects of TMS are mediated through complex neurobiological mechanisms involving changes at multiple levels:

ISSN: 2692-515-x, Impact Factor: 9.23
American Academic publishers, volume 6, issue 01,2026
Journal: https://www.academicpublishers.org/journals/index.php/ijai

1. Neuronal level

TMS induces neuronal depolarization, leading to the generation of action potentials.

Repeated stimulation promotes long-lasting changes in the excitability of neural networks, similar to the processes of long-term potentiation and long-term depression.

2. Synaptic level

There is modulation of glutamatergic and GABAergic receptor activity.

An increase in synaptic plasticity is observed, which is essential for the adaptive reorganization of neural networks.

3. Neurotransmitter level

TMS alters the release and balance of key neurotransmitters, including serotonin, dopamine, and noradrenaline, which are critically involved in pain modulation and emotional regulation.

– TMS alters the levels of key neurotransmitters, including serotonin, dopamine, and noradrenaline.

– These changes contribute to reduced pain sensitivity and normalization of emotional state.

4. Immune level

– Studies have demonstrated a reduction in pro-inflammatory cytokine concentrations after a course of TMS.

– This finding supports the involvement of immune mechanisms in the analgesic effects of TMS.

5. Macro level

– Patients report a decrease in the intensity and frequency of pain attacks.

– Cognitive function and psycho-emotional state improve.

Thus, the therapeutic effects of TMS are explained by its multilevel influence on neural networks, synaptic transmission, neurotransmitter systems, and immune processes.

Limitations and Future Perspectives of Transcranial Magnetic Stimulation

Despite numerous positive results, the use of TMS in headache treatment has several limitations:

– A relatively small number of patients included in clinical trials.

– Insufficient duration of follow-up after treatment courses.

– The need for standardization of stimulation parameters (frequency, intensity, and target location).

ISSN: 2692-515-x, Impact Factor: 9.23
American Academic publishers, volume 6, issue 01,2026
Journal: https://www.academicpublishers.org/journals/index.php/ijai

– Limited access to equipment and the high cost of the procedure.

Promising directions for future development include:

– Conducting large-scale, multicenter, randomized controlled trials.

– Developing individualized TMS protocols based on patient-specific characteristics.

– Combining TMS with other treatment modalities (pharmacotherapy, psychotherapy, physiotherapy).

– Using functional neuroimaging techniques to optimize stimulation targeting.

– Investigating the long-term effects of TMS and its preventive potential in chronic headache.

Thus, TMS represents a promising and relatively safe non-pharmacological treatment for tension-type headache and migraine, but it requires further research and methodological refinement.

References:

1. Eldaief M., Pascual-Leone A. Transcranial magnetic stimulation in neurology // Clinical practice. 2013. Vol. 12. P. 519-525.
2. Deblieck C., Thompson B., Iacoboni M., et al. Correlation between motor and phosphene thresholds: a transcranial magnetic stimulation study // Hum. Brain Mapping. 2008. Vol. 6. P. 662-670.
3. Dodick D.W, Schembri C.T, Helmuth M., et al. Transcranial magnetic stimulation for migraine: a safety review // Headache. 2010. Vol. 50, №7. P. 1153-1163. doi:10.1111/j.1526-4610.2010.01697.x
4. Сорочинский А.А. Транскраниальная магнитная стимуляция // Известия Южного федерального университета. 2010. Т. 110**,** №9. С. 207**-210.**
5. Сорокина Н.Д., Селицкий Г.В., Смирнов В.М. Изменение биоэлектрической активности мозга под влиянием опосредованного кратковременного переменного магнитного поля у здоровых и больных эпилепсией // Российский медицинский журнал. 2012. №6. С. 11**-14.**
6. Войтенков В.Б., Mally J., Скрипченко Н.В., и др. Транскраниальная магнитная стимуляция как диагностическая и терапевтическая методика // Неврологический журнал. 2015. Т. 20**,** №5. С. 4**-13**
7. Червяков А.В., Пирадов М.А., Савицкая Н.Г., и др. Новый шаг к персонифицированной медицине. Навигационная система транскраниальной магнитной стимуляции (NBS eXimia Nexstim) // Анналы неврологии. 2012. Т. 6**,** №3. С. 37**-46.**
8. Червяков А.В., Пирадов М.А., Назарова М.А., и др. Картирование моторного представительства **m.** abductorpollicisbrevis у здоровых добровольцев с

ISSN: 2692-515-x, Impact Factor: 9.23
American Academic publishers, volume 6, issue 01,2026
Journal: https://www.academicpublishers.org/journals/index.php/ijai

применением навигационной транскраниальной магнитной стимуляции NBS eXimia NEXSTIM // Анналы клинической и экспериментальной неврологии. 2012. Т. 6**,** №3. С. 14**-16.**

9. Rossi S., Hallett M., Rossini P., et al. Safety of TMS Consensus Group. Clinical safety, ethical considerations, and application guidelines for the use of transcranial magnetic stimulation in clinical practice and research // Clin Neurophysiol. 2009. Vol. 120, №12. P. 2008-2039. doi:10.1016/j. clinph.2009.08.016

10. Бинги В.Н., Савин А.В. Физические проблемы действия слабых магнитных полей на биологические системы // Успехи физических наук. **2003. Т. 173,** №3. С. 265**-300.**