 REVIEW ARTICLE

The use of noninvasive neuromodulation in the treatment of chronic pain in individuals with temporomandibular dysfunction

O uso da neuromodulação não invasiva no tratamento da dor crônica em indivíduos com disfunção temporomandibular

Tatyanne dos Santos Falcão Silva[1], Melyssa Kelyanne Cavalcanti Galdino[1]

DOI 10.5935/1806-0013.20170128

ABSTRACT

BACKGROUND AND OBJECTIVES: Faced with mechanisms of maladaptive neuroplasticity that can generate a memorization of pain sensation in individuals with temporomandibular dysfunction, the transcranial direct current stimulation emerges as a possible treatment strategy for chronic pain. However, further studies are needed to demonstrate the efficacy of this therapeutic modality and its long-term effect. Thus, the present study aims to discuss the use of transcranial direct current stimulation in the treatment of temporomandibular dysfunction in individuals with chronic pain.
CONTENTS: The present review encompasses 40 articles, published between the years 2000 and 2016. The temporomandibular dysfunction is a disease characterized by a set of signs and symptoms that may include joint noise, pain in the muscles of mastication, limitation of mandibular movements, facial pain, joint pain and/or dental wear. Pain appears as a very present and striking symptom, with a tendency to chronicity, a condition that is difficult to treat and often associated with psychological factors such as anxiety and depression. Studies using transcranial direct current stimulation in patients with chronic pain symptomatology have been showing good results through neuromodulation of neuronal excitability. It is worth noting that it corresponds to a non-invasive technique, low cost, easy and quick to apply, besides having minimal adverse effects.
CONCLUSION: The transcranial direct current stimulation has shown promising results in the treatment of temporomandibular dysfunction pain, with the possibility of becoming a complementary technique to the existing treatments, and thus, providing a professional assistance of better quality and resolution to the patient with this disorder.

Keywords: Analgesia, Facial pain, Rehabilitation, Temporomandibular joint disorders, Transcranial direct current stimulation.

1. Universidade Federal da Paraíba, Departamento de Psicologia, João Pessoa, PB, Brasil.

Submitted in June 05, 2017.
Accepted for publication in October 27, 2017.
Conflict of interests: none – Sponsoring sources: none.

Correspondence to:
Universidade Federal da Paraíba, Departamento de Psicologia - Castelo Branco
58033-455 João Pessoa, PB, Brasil.
E-mail: tatyannefalcao@yahoo.com.br

RESUMO

JUSTIFICATIVA E OBJETIVOS: Diante de mecanismos de neuroplasticidade mal adaptativa, que podem levar a uma memorização da sensação dolorosa em indivíduos com disfunção temporomandibular, a estimulação transcraniana por corrente contínua surge como uma possível estratégia de tratamento para a condição álgica crônica. No entanto, é necessário o desenvolvimento de estudos subsequentes que comprovem a eficácia dessa modalidade terapêutica e de seu efeito em longo prazo. Dessa forma, o presente estudo teve como objetivo discorrer sobre o uso da estimulação transcraniana por corrente contínua no tratamento da disfunção temporomandibular em indivíduos com dor crônica.
CONTEÚDO: O presente estudo engloba 40 artigos, publicados entre 2000 e 2016. A disfunção temporomandibular é uma doença caracterizada por um conjunto de sinais e sintomas que pode incluir ruídos articulares, dor nos músculos da mastigação, limitação dos movimentos mandibulares, dor na articulação e/ou desgaste dental. A dor aparece como um sintoma bastante presente e marcante, com tendência à cronicidade, sendo essa uma condição de difícil tratamento, muitas vezes associada a fatores psicológicos de ansiedade e depressão. Estudos utilizando a estimulação transcraniana por corrente contínua, em pacientes com sintoma doloroso crônico, vêm demonstrando bons resultados por meio da neuromodulação da excitabilidade neuronal. Trata-se de uma técnica não invasiva, de baixo custo, de fácil e rápida aplicação, além de possuir efeitos adversos mínimos.
CONCLUSÃO: A estimulação transcraniana por corrente contínua vem apresentando resultados promissores no tratamento da dor na disfunção temporomandibular, havendo a possibilidade de se tornar uma técnica complementar aos tratamentos já existentes, e desse modo, proporcionar uma assistência profissional de melhor qualidade e resolutividade ao paciente portador dessa desordem.

Descritores: Analgesia, Dor orofacial, Estimulação transcraniana por corrente contínua, Reabilitação, Transtornos da articulação temporomandibular.

INTRODUCTION

Temporomandibular disorder (TMD) is a pathological condition that encompasses clinical problems related to masticatory musculature, temporomandibular joint (TMJ), or both structures[1]. In many cases, individuals with this disease present pain as the most striking symptom, which may be acute or chronic, the latter having a dysfunctional character, with a tendency to persist even after removing the initial cause[2].

Through scientific investigations, it was observed that neuronal circuits responsible for the pain and emotion processing are associated, one overlapping the other, suggesting a mutual influence relationship[3,4]. These results corroborate the frequent association of chronic pain with psychological dysfunctions, such as anxiety and depression[5-8]. Based on these data, it was found that pain sensation does not only depend on the stimulus nature and intensity, it is a multidimensional experience composed of emotional, sensory and cognitive aspects[3,4,9].

Considering that chronic pain is a complex and multidimensional phenomenon[1], it requires a multidisciplinary treatment, addressing different therapies[5-7]. However, some patients have a temporary and/or unsatisfactory response, leading to a suspicion that the emotional components of pain often underlie treatment refractiveness. It is also worth mentioning the development of a memory for pain[1,5,10], due to reversible structural and physiological changes in the cerebral cortex[11].

Considering that neuroplastic changes play an important role in the maintenance of chronic pain in TMD, transcranial direct current stimulation (TDCS) emerges as another treatment option, seeking to modify the cortical activity pattern and restore normal activation of the pain processing centers[12,13].

The application of stimulation protocols has shown promise in some studies, with satisfactory results regarding the reduction of painful symptoms in patients with chronic pain[13-17]. The analgesic effect provided by TDCS has been reported through anodic stimulation, mainly in the primary motor cortex (M1)[15,17,18]. However, there is another option of stimulation protocol, with the anode in the dorsolateral of prefrontal cortex (DLPFC), which has also demonstrated therapeutic effect on pain[15,19]. However, these results are still inconclusive, which indicates the need for further investigation[16,20-22].

In this context, it is pertinent to investigate alternative methods for the treatment of chronic TMD in order to increase the range of possibilities and, therefore, to promote pain relief, functional recovery and, consequently, better quality of life for a greater number of patients[1,6,11].

This study aimed to discuss the therapeutic use of TDCS in individuals with chronic pain due to muscular TMD.

CONTENTS

This is a bibliographic survey carried out between January and September of 2016 in Pubmed and Virtual Health Library (BIREME), chosen due the fact of aggregating different databases, both international and national. Some books and several articles were selected, published between the years 2000 and 2016, which approached the theme of the present study. Descriptors such as “Analgesia”, “Orofacial pain”, “Transcranial direct current stimulation”, “Rehabilitation”, “Temporomandibular joint disorders” were used. 40 articles were selected to compose the literature review, since they fit the objective of this study.

TMD is a subgroup of craniofacial pain, constituting the main cause of orofacial pain of non-dental origin that may involve masticatory muscles, TMJ and/or associated structures[23]. It has been defined as a pathological condition characterized by a set of signs and symptoms that may include joint noises, pain in the mastication muscles, limitation of mandibular movements, facial pain, headache, joint and/or dental wear[1,23,24]. It is observed that the symptoms manifest themselves in a varied form, being related to the anatomical components that collapse by the disorder, depending on the physiological tolerance of each structure of the stomatognathic system[1].

It is estimated that approximately 40 to 60% of the population presents some detectable clinical signs of TMD, being more frequent in people between 20 and 40 years old[1,25]. A very prevalent disease whose etiology is considered complex and multifactorial, being the result of an interrelationship between some main etiological factors: occlusal condition, trauma, psychological alterations, sources of deep pain stimulus and parafunctional activities[1,6,24]. Studies in the behavioral area observed that TMD was often related to psychopathologies, which may present as a initiating, precipitating and even perpetuating factor[5,6,8,26].

TEMPOROMANDIBULAR AND EMOTIONAL DISORDERS

Pain appears in a very marked and present way in the TMD and may affect the development of daily activities, physical and psychosocial functioning, as well as the quality of life (IASP-International Association for the Study of Pain). Especially when chronic, pain is related to emotional factors, such as anxiety and depression, possibly due to a sharing and proximity of neural pathways of processing[3,4,27-29]. Studies performed with patients with chronic TMD corroborate this relationship when they observe a positive correlation between the severity of this disease and the levels of anxiety and depression presented by the patients[5-8]. In addition, women showed a greater propensity to present emotional stress and concomitant psychiatric disorders[26].

PAINFUL SYMPTOMS

According to IASP, pain is defined as an unpleasant sensory and emotional experience, being associated with or related to actual or potential tissue damage. Approximately 10% of the world population presents facial pain due TDM (IASP), and this painful symptom may be characterized as acute or chronic[1,2].

Acute pain has a physiological and protective character, is self-limiting and responds to conventional therapies. It usually ceases after treatment of the causative factor. Chronic pain, however, does not have a biological character and persists after removing the cause, with a tendency not to respond to conventional therapies, requiring a multidisciplinary treatment to control pain[2,30].

Even eliminating the nociceptive stimulus, pain will not subside, because learning-related neuroplasticity mechanisms can lead to a memorization of the pain sensation[11], making it chronic, especially if it is a constant pain condition, without periods of complete remission[1]. This memory for pain is due to functional and structural changes in the synapses underlying the painful experience, due to a repetitive pain stimulus that reinforces this circuit, and culminates in the establishment of brain memory traces that maintain the sensation of pain[1,31,32].

The painful experience is a complex phenomenon, which can be physiologically initiated by a somatic factor, but its permanence results from important structural and functional cortical modifications such as cortical atrophy and neuronal hyperactivity in different regions of the central nervous system (CNS)[11,27]. It involves brain areas responsible for emotion, perception, motor planning, behavior and memory, such as the anterior insula, anterior cingulate cortex, somatosensory, motor area, limbic system and thalamus[31-33].

Studies observed that neuronal circuits responsible for the pain and emotion processing are associated, one overlapping the other, suggesting a mutual influence relationship[3,4,28,29]. Based on these data, the principle that painful sensation does not depend only on the nature and intensity of the stimulus is reinforced. It is a multidimensional experience composed of emotional, sensory, and cognitive aspects[3,4,9]. Thus, the chronic pain understanding should address the concept of learning, emotional and motivational state, as well as memory mechanism[1,31].

In view of the complexity and multidimensionality of painful experience, the diagnosis of TMD should be judicious, including the patient's history, clinical examination and complementary tests, and the information collected mainly during anamnesis[1]. It requires a research for psychological, physical and social factors, and a multidisciplinary team is usually required[6,10,30,34].

THERAPEUTIC ALTERNATIVES

In view of the above, when it comes to chronic pain, the mechanistic model of treatment is insufficient, and the dental surgeon must understand the man as a biopsychosocial being in order to implement and/or refer the patient to the most indicated alternative therapy. Some aim to treat the musculature, others act on dental occlusion or joint structures and there are those whose main focus is the psychoemotional factor[6,10,30,34].

In dental area, there are several treatment modalities for TMD, since this disease has a variety of symptoms. These include patient education in relation to self-care, behavior modification (including relaxation techniques), drugs, physical therapy, acupuncture, stabilizing occlusal plates, occlusal therapy (orthodontics, oral rehabilitation) and surgery. The need to give preference to reversible and non-invasive procedures is emphasized. Thus, invasive procedures such as surgical, orthodontic and occlusal adjustment are not first-choice treatments and their efficacy is still questionable[1,35,36]. Among the therapies promoted by professionals from other areas are biofeedback, iontophoresis, ultrasound, transcutaneous electrical nerve stimulation (TENS), cognitive-behavioral therapy and meditation[1,35,36].

Despite the wide variety of strategies used to treat patients with TMD, some patients have a temporary and/or unsatisfactory relief response, generating hypotheses that emotional components often underlie treatment refractiveness and development of a memory for pain[1,5,10,12,31]. Given that chronic pain generates structural and physiological changes in the cerebral cortex, and these, in turn, are not irreversible[11].

Thus, it is evident the need for a therapy that acts directly on the CNS. This action can occur through drugs, however, many individuals are refractory or present adverse effects, such as dependence and/or tolerance[1,35,36]. Therefore, the importance of new treatments involving neuromodulation and neuroplasticity mechanisms is detached, such as TDCS, which can be a complementary alternative to the different types of treatment already in use[12,13].

Transcranial direct current stimulation

Neuroplastic changes play an important role in pain maintenance, thus, cerebral stimulation emerges as a possible therapeutic strategy, differentiating itself from existing treatment alternatives due to its direct action at the level of the CNS[12].

Neuromodulation techniques include TDCS, which is based on the use of a continuous electric current with the objective of modifying the neuronal membrane potential and consequently changing the pattern of cortical activity, besides restoring the normal activation of the centers processing the pain[13,15,16,26].

TDCS apparatus has two electrodes: an anode (positive pole) and a cathode (negative pole) that generate a low intensity DC current. Depending on the assembly, the flow will be either anodic, cathodic or both, where anodic stimulation results in increased neuronal excitability, while cathodic stimulation results in the opposite effect[12,13]. In addition to interfering with the neuronal activity of areas located just below the electrodes, this technique also affects the interconnected cortical and subcortical regions[16,17].

TDCS effects can be divided essentially into neuromodulatory and neuroplastic. The first corresponds to the change generated in the resting potential of the membrane, without significant effects on the synaptic plasticity. On the other hand, secondary effects occur due to modifications of the synaptic force after the stimulation period, being dependent on the modulation of GABAergic and glutamatergic synapses. Thus, TDCS efficacy is influenced by the current density applied, which involves the stimulation duration, current amplitude, location and electrode size. In general, the stimulation parameters used are: duration between 5 to 30 minutes, intensity of 0.5 to 2.0 mA, size of the electrodes between 20 and 35cm^2 [37].

It is a simple, low-cost, safe, non-invasive, well-tolerated, and painless technique that can modulate brain activity locally, presenting therapeutic effects[13,15,17,38]. These favorable characteristics stimulated the development of several clinical studies involving neurological and psychiatric disorders such as major depressive disorder, acute and chronic pain, motor rehabilitation, drug dependence, among other diseases[38].

The application of active stimulation protocols has shown promise in some studies, with good results regarding the reduction of painful symptoms in patients with chronic pain, when compared to placebo stimulation[13-18.22]. TDCS studies obtained a significant analgesic effect through anodic stimulation in the primary motor cortex (M1)[15,17,18], possibly due to the secondary activation of the ipsilateral thalamus and other regions related to the pain processing and modulation, such as the cingulate cortex, prefrontal cortex and estriatum[12,39]. Evidence also indicates that M1 cortex stimulation inhibits the activity of the ipsilateral primary somatosensory cortex (S1)[40]. For this purpose, the anode is positioned on the contralateral M1 cortex in the affected side in case of unilateral pain or on the M1 of the dominant hemisphere in case of bilateral pain, and the cathode on the supraorbital region contralateral to the anode[13,15-18,41].

This therapeutic effect on pain after stimulation of the M1 region was reproduced in different groups of patients with chronic pain resulting from diseases such as trigeminal neuralgia, TMD, post-stroke pain and fibromyalgia[13,17,18]. However, there is another option of assembly, applying the anode in the dorsolateral region of the left prefrontal cortex (DLPFC), which has also been demonstrating therapeutic effect[15,16,19,41], since this region shows to be hypoactive in individuals with chronic pain[27-33].

Although less explored, stimulation in DLPFC region may be a useful strategy to modulate affective-emotional cognitive networks associated with pain processing in patients with chronic pain, changing their perception through cortico-subcortical and cortico-cortical pathways, since this area seems to play an important role in the cortical processing of the pain emotional aspects[19,41,42]. Thus, it could be a good alternative in cases of chronic pain, in which the emotional components are often underlying the treatment refractiveness, possibly due to an anatomical relationship of quite proximity between the circuits of pain and emotions[1,3,4,28].

Although TDCS seems to be an easy-to-use instrument, there is a minimal risk of serious adverse effects[14]. Through a systematic review, the most common side effects of active TDCS were pruritus (39.3%), tingling (22.2%), headache (14.8%), discomfort (10.4%), and burning sensation (8.7%)[43]. Thus, researches should follow protocols for TDCS' application, which include parameters such as duration, intensity, standardization of adverse effects assessment and reports, among others[14].

Although the aforementioned technique has potential for pain management, the limited number of available randomized clinical trials and their heterogeneous results evidences the need for further scientific investigations regarding the technique efficacy, in order to identify the optimal stimulation parameters (intensity, repetition rate, time, electrode positions and stimulation polarity) since the stimulation protocols optimization in relation to specific populations of patients is an important aspect in the efficacy of said therapeutic technique, as well as to monitor its analgesic effects and probable psychological repercussion in the short, medium and long term[16,19-22].

CONCLUSION

TDCS has shown promising results in the treatment of chronic TMD pain, whose technique's differential involves a direct action in the CNS, through the neuromodulation of the painful stimulus' processing centers. Thus, it presents itself as a possible therapeutic strategy, aiming to complementing the range of existing treatment alternatives.

REFERENCES

1. Okeson JP. Tratamento das desordens temporomandibulares e oclusão. Rio de Janeiro: Elsevier; 2013.
2. Sessle BJ. Acute and chronic craniofacial pain: brainstem mechanisms of nociceptive transmission and neuroplasticity, and their clinical correlates. Crit Rev Oral Biol Med. 2000;11(1):57-91.
3. Flaten MA, Al'Absi M. The Neuroscience of Pain, Stress, and Emotion: Psychological and Clinical Implications. 1ª ed. Rio de Janeiro: Elsevier; 2016.
4. Rhudy JL, Meagher MW. The role of emotion in pain modulation. Curr Opin Psychiatr. 2001;14(3):241-5.
5. Piccin CF, Pozzebon D, Chiodelli L, Boufleus J, Pasinato F, Correa EC. Aspectos clínicos e psicossociais avaliados por critérios de diagnóstico para disfunção temporomandibular. Rev CEFAC. 2016;18(1):113-9.
6. Chisnoiu AM, Picos AM, Popa S, Chisnoiu PD, Lascu L, Picos A, et al. Factors involved in the etiology of temporomandibular disorders - a literature review. Clujul Med. 2015;88(4):473-8.
7. Sipilä K, Mäki P, Laajala A, Taanila A, Joukamaa M, Veijola J. Association of depressiveness with chronic facial pain: a longitudinal study. Acta Odontol Scand. 2013;71(3-4):644-9.
8. Auerbach SM, Laskin DM, Frantsve LM, Orr T. Depression, pain, exposure to stressful life events, and long-term outcomes in temporomandibular disorder patients. J Oral Maxillofac Surg. 2001;59(6):628-34.
9. Ogino Y, Nemoto H, Inui K, Saito S, Kakigi R, Goto F. Inner experience of pain: imagination of pain while viewing images showing painful events forms subjective pain representation in human brain. Cereb Cortex. 2007;17(5):1139-46.
10. Jakrzewska JM. Multi-dimensionality of chronic pain of the oral cavity and face. J Headache Pain. 2013;14:37.
11. Rodriguez-Raecke R, Niemeier A, Ihle K, Ruether W, May A. Brain gray matter decrease in chronic pain is the consequence and not the cause of pain. J Neurosci. 2004;29(44):13746-50.
12. Fregni F, Boggio PS, Brunoni AR. Neuromodulação terapêutica: princípios e avanços da estimulação cerebral não invasiva em neurologia, reabilitação, psiquiatria e neuropsicologia. 1ª ed. São Paulo: Sarvier; 2012.
13. Nitsche MA, Paulus W. Excitability changes induced in the human motor cortex by weak transcranial direct current stimulation. J Physiol. 2000;527(Pt3):633-9.
14. Fregni F, Nitsche MA, Loo CK, Brunoni AR, Marangolo P, Leite J, et al. Regulatory considerations for the clinical and research use of transcranial direct current stimulation (tDCS): review and recommendations from an expert panel. Clin Res Regul Aff. 2015;32(1):22-35.
15. Choi YH, Jung SJ, Lee CH, Lee SU. Additional effects of transcranial direct-current stimulation and trigger-point injection for treatment of myofascial pain syndrome: a pilot study with randomized, single-blinded trial. J Altern Complement Med. 2014;20(9):698-704.
16. Knotkova H, Nitsche MA, Cruciani RA. Putative physiological mechanisms underlying tDCS analgesic effects. Front Hum Neurosci. 2013;7:628.
17. Antal A, Terney D, Kühnl S, Paulus W. Anodal transcranial direct current stimulation of the motor cortex ameliorates chronic pain and reduces short intracortical inhibition. J Pain Symptom Manage. 2010;39(5):890-903.
18. Donnell A, Nascimento T, Lawrence M, Gupta V, Zieba T, Truong DQ, et al. High--definition and non-invasive brain modulation of pain and motor dysfunction in chronic TMD. Brain Stimul. 2015;8(6):1085-92.
19. Boggio PS, Zaghi S, Fregni F. Modulation of emotions associated with images of human pain using anodal transcranial direct current stimulation (tDCS). Neuropsychologia. 2009;47(1):212-7.
20. Shiozawa P, Fregni F, Benseñor IM, Lotufo PA, Berlim MT, Daskalakis JZ, et. al. Transcranial direct current stimulation for major depression: an updated systematic review and meta-analysis. Int J Neuropsychopharmacol. 2014;17(9):1443-52.
21. O'Connell NE, Wand BM, Marston L, Spencer S, Desouza LH. Non-invasive brain stimulation techniques for chronic pain. Cochrane Database Syst Rev. 2014;(4):CD008208.
22. Vaseghi B, Zoghi M, Jaberzadeh S. Does anodal transcranial direct current stimulation modulate sensory perception and pain? A meta-analysis study. Clin Neurophysiol. 2014;125(9):1847-58.
23. Scrivani SJ, Keith DA, Kaban LB. Temporomandibular disorders. N Engl J Med. 2008;359(25):2693-705.

24. Ohrbach R, Fillingim RB, Mulkey F, Gonzalez Y, Gordon S, Gremillion H, et al. Clinical findings and pain symptoms as potential risk factors for chronic TMD: descriptive data and empirically identified domains from the OPPERA case-control study. J Pain. 2011;12(11 Suppl):T27-45.
25. Mello VV, Barbosa AC, Morais MP, Gomes SG, Vasconcelos MM, Caldas Júnior Ade F. Temporomandibular disorders in a sample population of the Brazilian northeast. Braz Dent J. 2014;25(5):442-6.
26. Yoon HJ, Lee SH, Hur JY, Kim HS, Seok JH, Kim HG, et al. Relationship between stress levels and treatment in patients with temporomandibular disorders. J Korean Assoc Oral Maxillofac Surg. 2012;38:326-31.
27. Wiech K, Tracey I. The influence of negative emotions on pain: behavioral effects and neural mechanisms. Neuroimage. 2009;47(3):987-94.
28. Duquette M, Roy M, Leporé F, Peretz I, Rainville P. [Cerebral mechanisms involved in the interaction between pain and emotion]. Rev Neurol. 2007;163(2):169-79. French.
29. Price DD. Psychological and neural mechanisms of the affective dimension of pain. Science. 2000;288(5472):1769-72.
30. Turk DC, Okifuji A. Psychological factors in chronic pain: evolution and revolution. J Consult Clin Psychol. 2002;70(3):678-90.
31. Mansour AR, Farmer MA, Baliki MN, Apkarian AV. Chronic pain: the role of learning and brain plasticity. Restor Neurol Neurosci. 2014;32(1):129-39.
32. May A. Chronic pain may change the structure of the brain. Pain. 2008;137(1):7-15.
33. Tracey I, Mantyh PW. The cerebral signature for pain perception and its modulation. Neuron. 2007;55(3):377-91.
34. Gremillion HA. Multidisciplinary diagnosis and management of orofacial pain. Gen Dent. 2002;50(2):178-89.
35. Wieckiewicz M, Boening K, Wiland P, Shiau YY, Paradowska-Stolarz A. Reported concepts for the treatment modalities and pain management of temporomandibular disorders. J Headache Pain. 2015;16:106.
36. List T, Axelsson S. Management of TMD: evidence from systematic reviews and meta-analyses. J Oral Rehabil. 2010;37(6):430-51.
37. Stagg CJ, Nitsche MA. Physiological basis of transcranial direct current stimulation. The Neuroscientist. 2011;17(1):37-53.
38. George MS, Aston-Jones G. Noninvasive techniques for probing neurocircuitry and treating illness: vagus nerve stimulation (VNS), transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS). Neuropsychopharmacology. 2010;35(1):301-16.
39. Polanía R, Paulus W, Nitsche MA. Modulating cortico-striatal and thalamo-cortical functional connectivity with transcranial direct current stimulation. Human Brain Mapp. 2012;33(10):2499-508.
40. Chiou RJ, Lee HY, Chang CW, Lin KH, Kuo CC. Epidural motor cortex stimulation suppresses somatosensory evoked potentials in the primary somatosensory cortex of the rat. Brain Res. 2012;1463:42-50.
41. DaSilva AF, Volz MS, Bikson M, Fregni F. Electrode positioning and montage in transcranial direct current stimulation. J Vis Exp. 2011;23(51). pii 2744.
42. Lorenz J, Minoshima S, Casey KL. Keeping pain out of mind: the role of the dorsolateral prefrontal cortex in pain modulation. Brain. 2003;126(5):1079-91.
43. Brunoni AR, Nitsche MA, Bolognini N, Bikson M, Wagner T, Merabet L, et al. Clinical research with transcranial direct current stimulation (tDCS): challenges and future directions. Brain Stimul. 2012;5(3):175-95.