Original article

DOI: 10.5114/areh.2022.116529
Advances in Rehabilitation, 2022, 36(2), 32–38

A – Research concept and design
B – Collection and/or assembly of data
C – Data analysis and interpretation
D – Writing the article
E – Critical revision of the article
F – Final approval of article

Received: 2022-01-18
Accepted: 2022-05-19
Published: 2022-05-20

The effect of transcranial direct current stimulation on pain, range of motion, and balance in sportspersons with ankle sprain: A randomized controlled trial

Rekha Chaturvedi*[A-F], Rahul Jogi[B-C,F], Shabnam Joshi[E-F], Vandana Yadav[E-F]

Guru Jambheshwar University of Science and Technology, India

***Correspondence:** Rekha Chaturvedi, Guru Jambheshwar University of Science and Technology, India, email: rekhachaturvedi85@gmail.com

Abstract

Introduction: Ankle sprains are the most common sports injury. Injury to ankle joint causes local as well as distant defects in the central nervous system. The interventions that modulate defects centrally, as well as peripherally, can be of great significance in treating the condition. The present study aims to estimate the effects of transcranial direct current stimulation on pain, range of motion, and balance in players with ankle sprain.

Material and methods: The present study was a randomized, controlled participant blinded trial. Twenty players aged between 16 to 30 years with a history of ankle sprain were recruited and were assigned in two groups. Group A received active transcranial direct current stimulation (tDCS) and Group B received sham stimulation of 2mA for 20 min for five consecutive days. The outcome variables were pain (VAS), range of motion at the ankle joint, and balance measured by the Y-balance test measured at the baseline and post-intervention.

Results: There was a significant reduction in pain ($p = 0.039$) and significant improvement in range of motion in dorsiflexion ($p = 0.043$) and plantarflexion ($p = 0.019$) at the ankle joint when between-group comparisons were done. Whereas, no significant improvement in balance ($p = 0.502$) was observed when between-group comparisons were done.

Conclusions: The application of tDCS is effective in decreasing pain and improving range of motion, but ineffective for improving balance in players with ankle sprains. To improve the balance, foot exercises can also be added along with the tDCS to improve the treatment outcomes in players with ankle sprains.

Keywords: pain, range of motion, balance, ankle sprain, transcranial direct current stimulation

Introduction

Of all sports injuries, ankle sprain is the most common, and one that provides billions of dollars annually to the US healthcare system [1]. Of these, the most common type is lateral ankle sprain, affecting around 30% of active people and sportsmen [2]. Sprain at the lateral ligament complex has a very high recurrence rate, which leads to development of long-term symptoms and instability [3,4]. About 40% of patients report chronic ankle instability, characterized by repetitive bouts of the ankle "giving way", recurring sprains or the feeling of an unstable ankle joint following the initial sprain [5,6].

This injury has been associated with reduced excitability of the cortex, which can influence the functional ability of the patient. Individuals with chronic ankle sprain demonstrate lower cortical excitability of the fibularis longus compared to those without ankle injury [7]. In addition, patients with chronic ankle instability have demonstrated decreased spinal reflex excitability in the soleus and fibularis [8], as well as decreased muscle activation and increased antagonistic muscle activity [9]. Younger adults with chronic ankle instability have also displayed lower excitability of the primary motor cortex [8,10]. Thus, it is well established that the cortex plays an important role in chronic ankle instability.

Although the spinal and supraspinal elements play vital roles in the regulation of sensation and balance in patients with ankle sprain [11], the conventional approach to treating ankle sprain often ignore its important sensorimotor component, and focuses primarily on the peripheral neuromuscular function. As the cortical changes observed in chronic ankle sprain derive from the long-term effect of the injury, no study has so far explored the changes taking place in the cortices of patients with acute ankle sprain. The use of transcranial direct current stimulation (tDCS) has gained significant interest among researchers exploring its neuro modulatory effect in various musculoskeletal conditions.

Anodal tDCS treatment has been found offer greater hip range of motion and lowered pain perception compared to dorsolateral prefrontal cortex (DLPFC) in normal healthy subjects [12], while cathodal stimulation over the area has yielded greater increases in range of motion at the ankle joint [13]. A combination of anodal tDCS with eccentric exercises also showed improved cortical excitability, dynamic balance and muscle activation in patients of chronic ankle instability compared to a sham group [14] These findings suggest that in the long term, ankle joint injury not only leads to local defects, but also distant defects in the central nervous system.

Current rehabilitation approaches appear to be inefficient and inadequate for the improvement of ankle sprains. Therefore, new treatment interventions that can modulate pain and improve the range of motion can be of great significance in improving the physical function in sportspersons with ankle sprain. Previous studies have only focused on exploring the effect of tDCS in patients with chronic ankle sprain and instability, and only a few have explored the effect of tDCS in patients with acute ankle sprain. Therefore, the aim of the present study was to estimate the effect of Transcranial Direct Current Stimulation (tDCS) on pain, ROM and balance in sportspersons with acute ankle sprain.

Material and methods

The present study was performed as a randomized, controlled participant blinded trial. The ethical approvals for the study was obtained by the Institutional ethical committee vide letter number PTY/2021/42 dated 05/03/2021, Department of Physiotherapy, Guru Jambheshwar University of Science and Technology, Hisar, Haryana. The study was performed in accordance with the Declaration of Helsinki, 2013. The present study was also registered in Clinical Trial Registry of India vide number CTRI/2021/07/035218. Written informed consent was obtained prior to the participation in the study. The sample size for the present study was estimated based upon the findings of two previous studies [10,14].

Participants

Sporting persons with a history of ankle sprains with duration less than two months were screened for participation in the study using convenience sampling. The inclusion criteria for the study comprised sportspersons with history of ankle sprain in the last two months, no orthopaedic deformity, ability to read and write in Hindi and English, and a willingness to participate. The exclusion criteria for the study comprised ankle sprain of more than two months duration, a history of epilepsy, recent fractures, any arthritic condition or deformity of the lower extremities.

The study group comprised eight athletes, two fencers, four footballers and six wrestlers. The mean age was 21.25 ± 4.73 years; mean height 166.25 ± 8.99 cm; mean weight 61.40 ± 9.41 kg; mean BMI 22.16 ± 2.67 kg/m^2. After allocation to subgroups, the mean duration of injury was 18.40 ± 5.87 days in Group A and 24.00 ± 11.33 days in Group B. The demographic characteristics of the study participants are given in Table 1.

Procedure

The sportspersons at various sports schools in the city of Hisar and its surrounding areas in Haryana state, India were approached. Twenty-eight reported a history of ankle sprain and were screened for participation in the study. Out of these, eight participants were excluded: four participants had history of ankle sprain for a duration more than four months, two participants declined to participate, one participant had a history of epilepsy so was contraindicated for the use of tDCS and one discontinued participation because of positive COVID report. The final group included in the study therefore comprised 20 participants (males = 14, females = 6).

The selected participants were then randomly allocated to two groups, Group A and Group B, by a lottery

Tab. 1. Demographic characteristics of the study participants

Group		N	Mean and SD	t-value	p-value
Age	Group-A	10	19.70 ± 3.06	1.513	0.148
	Group-B	10	22.80 ± 5.71		
Height (cm)	Group-A	10	165.70 ± 9.27	0.267	0.793
	Group-B	10	166.80 ± 9.16		
Weight (Kg)	Group-A	10	60.70 ± 6.90	0.325	0.749
	Group-B	10	62.10 ± 11.76		
BMI	Group-A	10	22.18 ± 2.63	0.041	0.968
	Group-B	10	22.13 ± 2.85		
Injury duration	Group-A	10	18.40 ± 5.87	1.387	0.182
	Group-B	10	24.00 ± 11.33		
Leg length (cm)	Group-A	10	86.80 ± 6.63	0.410	0.686
	Group-B	10	88.00 ± 6.45		

method performed by a person independent from the study. The participants in Group A received active tDCS and the participants in Group B received sham tDCS for five consecutive days. The outcome variables were measured at baseline and on day 5 of stimulation.

Transcranial Direct Current Stimulation (tDCS) was applied through Medicaid equipment (Serial No TD 216209, India).The participants were placed in a seated position. The left dorsolateral pre frontal cortex (DLPFC) and C_z areas were identified as per International 10–20 system EEG, and were marked with a marker. A pair of circular sponge electrodes soaked in normal saline were applied to the identified areas. The anode was placed on the left DLPFC and the cathode on C_z. They were secured with straps and a current intensity of 2mA was given for 20 minutes once daily for five consecutive days [12]. For sham stimulation, the same electrode placement was used, the apparatus was turned on for 10 seconds and then turned off; the procedure was repeated after 24 hours for five consecutive days. The participants were frequently asked for any unpleasant sensation during the treatment sessions. The flow chart of the study is presented in Figure 1.

Outcome variables

The outcome variables for the study were pain, range of motion and balance. Pain at the ankle joint was assessed by the participants from 1 to 10 on a Visual Analogue Scale (VAS)during walking. The range of motion was assessed by an Electrogoniometer. The participants were placed in a lying position with knees flexed to 30 degrees by placing a pillow under the knees. The fulcrum of the goniometer was kept at the lateral malleoli, the fixed arm at the midline of the fibula, and the moving arm was kept along the lateral border of the foot by the therapist. The participants were asked to move the ankle joint in dorsiflexion and plantarflexion, and the passive range of motion was noted. The readings were taken three times by two independent investigators, and the mean readings were noted.

The Dynamic balance was assessed by the Y-Balance test which is based on the “Star Excursion Balance Test”. For the Y-balance test, a large “Y” with easily-distinguishable red cello tape was made on the floor. Each side of the “Y” was 2 m long, the angles on the sides of the “Y” were 135 degrees each, and the middle angle between the arms was 90 degrees. The participant stood on the testing foot, placed at the centre of the “Y”, facing the anterior side of the “Y”, with the other foot flexed. Both hands were placed on the sides of the pelvis, with the thumb projected posteriorly. The participants were then instructed to reach as far as possible along each side of the “Y” with the flexed foot. Three valid measurements in each direction were recorded. The final Y-Balance score was calculated by the formula:

$$\frac{(\text{Anterior} + \text{Posterolateral} + \text{Posterolateral})}{3 \times \text{True leg length}} \times 100$$

Statistical analysis

The data was presented as mean and standard deviation. The data was analysed using SPSS (version 21.0). The data was found to be normally distributed, according to the Shapiro-Wilk test. The unrelated t-test was used to estimate the between-group differences of each outcome variable, and the related t-test to estimate

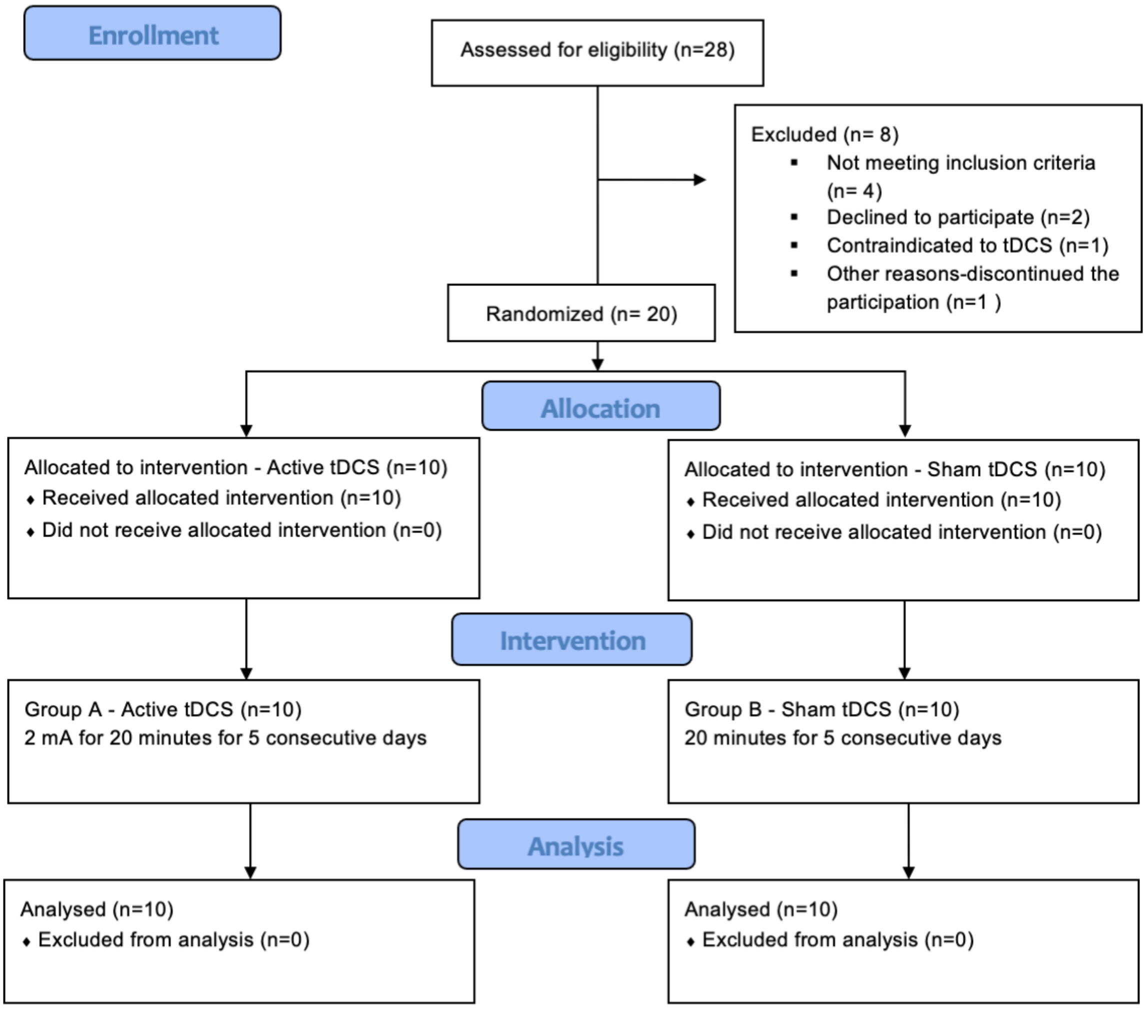

Fig. 1. Flow chart of the study

the within-group differences. To analyse the changes in pain over the course of treatment, the Mann-Whitney U-test was used for between-group comparisons and the Wilcoxon signed rank test for within-group comparisons. The significance level was set at $p < 0.05$.

Results

No significant differences in age, height, weight, injury duration and in leg length were found between the treated and sham groups. The group was characterized by a slight dominance of male participants (n = 14) compared to females (n = 6). Eight participants were athletes, two were fencers, four were footballers and six were wrestlers. More participants had suffered lateral ankle sprain (n = 17) than medial ankle sprain (n = 3).

A significant reduction in pain (p = 0.039) was observed between groups after the application of tDCS for five consecutive sessions. In addition, for both groups, the within-group comparisons for pain identified a statistically significant reduction over the course of treatment. The between-group comparisons of the outcome variable pain are given in Table 2.

A significant improvement in range of motion for dorsiflexion (p = 0.043) and plantar flexion (p = 0.019) was revealed in Group A by the between-group comparisons. However, no significant between-group differences were observed for the balance, assessed by the Y – balance test (p = 0.502). The within-group comparisons revealed a significant improvement over the course of treatment in balance, dorsiflexion range of motion (p = 0.014) and Y-Balance score (p = 0.048) in group A. The between-group comparisons of range of motion and balance are given in Table 3.

The within-group comparison showed a significant improvement in dorsiflexion range of motion in group B; however, no other significant within-group differences were observed for any of the outcome variables in this group.

Tab. 2. Between group comparisons of the Pain (VAS)

	Group-I				Group-II				Mann Whitney U (z)	p-value	Effect size
	N	Median	Quartile-I	Quartile-III	N	Median	Quartile – I	Quartile – III			
VAS (Pre)	10	3.00	2.00	3.00	10	3.00	2.00	3.00	0.119	0.906	0.653
VAS (Post)	10	1.00	1.00	2.00	10	2.00	2.00	3.00	2.064	0.039*	

VAS = visual analog scale, *significant at p < 0.05.

Tab. 3. Between group comparisons of range of motion (ROM) and balance (Y-Balance score)

Group		N	Mean and SD	t-value	p-value	Effect size
Dorsiflexion ROM Pre	Group-A	10	21.10 ± 5.11	0.716	0.483	0.973
	Group-B	10	19.50 ± 4.88			
Dorsiflexion ROM Post	Group-A	10	25.80 ± 4.39	2.175	0.043*	
	Group-B	10	21.70 ± 4.03			
Plantarflexion ROM Pre	Group-A	10	37.40 ± 5.06	1.232	0.234	1.151
	Group-B	10	41.30 ± 8.64			
Plantarflexion ROM Post	Group-A	10	36.50 ± 3.50	2.575	0.019*	
	Group-B	10	43.10 ± 7.31			
Y-balance score Pre	Group-A	10	69.35 ± 6.04	0.637	0.532	0.306
	Group-B	10	71.33 ± 7.76			
Y-balance score Post	Group-A	10	74.50 ± 6.94	0.684	0.502	
	Group-B	10	72.55 ± 5.74			

ROM = range of motion,* significant at p < 0.05.

Discussion

The aim of the study was to estimate the effect of tDCS on pain, range of motion and balance in sportspersons with ankle sprain. Our findings indicate that the application of tDCS was associated with a significant reduction in pain and improvement in range of motion at the ankle joint. However, no significant improvement in balance was observed.

A significant reduction in pain was noted in the experimental group. This may be attributed to the pain-modulating effect of the tDCS, which has also been reported in various musculoskeletal conditions such as chronic low back pain, fibromyalgia and knee osteoarthritis [15−17]. It is possible that in these patients, the mechanism of pain modulation can act through the suppression of the nociceptive inputs from the injured ankle joint by the stimulation of the motor cortex, which inhibits the repetitive firing of neurons and induces a neuroplastic effect in the brain. A similar pain modulating mechanism was also noted in a study on the stimulation of motor cortex that showed suppression of nociceptive neurons and inhibition of burst firing of neurons in the damaged areas of thalamus, with a neuroplastic effect being induced in the thalamus [18]. It has also been suggested that the upregulation of the excitability motor cortex modulates pain perception by acting directly, and indirectly, on pain modulating areas such as thalamic nuclei and cingulated gyrus [19].

The significant improvement observed in pain perception and range of motion can also be attributed to the use of the typical montage, i.e. the anode at DLPFC and cathode at C_z, for five consecutive sessions used in the study, as the effect of tDCS is known to be dependent on the placement of electrodes, areas of stimulation, intensity, frequency and duration of application of stimulation [20]. A similar placement of electrodes previously yielded a significant reduction in pain perception and an improvement in range of motion in healthy normal subjects [12]. Various studies applying tDCS for five consecutive sessions have also shown significant reduction in pain in conditions such as stroke, fibromyalgia and knee osteoarthritis [15-17]. The significant improvement observed in range of motion can be attributed to the decrease in the pain that might have limited it. Indeed, the application of anodal tDCS on DLPFC was previously found to result in increased range of motion and decreased pain perception at the hip joint in normal subjects [12]. Another study also noted significant improvement in ankle range of motion following the application of tDCS in normal healthy subjects [21].

No significant improvement in dynamic balance was observed following tDCS treatment. This may have been due to the study protocol lacking exercises intended to improve balance and proprioception, thus resulting in no apparent improvement in balance in these patients. However, studies using the combined application of tDCS with foot exercises have shown significant improvements in dynamic balance among patients with chronic ankle instability [10]. In addition, the combination of tDCS with eccentric exercises has shown improvement in cortical excitability and functional performance in patients with chronic ankle instability [14]. It has been also suggested that the application of tDCS during the ankle motor learning task resulted in an increase in ankle motor learning skill in healthy subjects [22]. A decrease in motor neuron recruitment and neural drive occurring after ligamentous injury is associated with a decrease in cortical inhibition, which subsequently causes muscle weakness; however, the deficit can be replenished more quickly with the application of eccentric training, [23,24]. Furthermore, as the present study only explores the effect of tDCS, it did not include any exercises for treating ankle sprain; this could be one of the reasons that no improvement in balance performance was observed in sportspersons with ankle sprain.

Although few studies have examined the role of tDCS in acute ankle sprain patients, the existing literature suggests that tDCS can be combined well with foot exercises to improve balance and proprioception in patients with ankle sprain. Therefore, foot exercises and eccentric training can be combined with tDCS to allow proper rehabilitation of ankle sprain.

Our findings also found lateral ankle sprain to predominate among the tested sportspersons, especially on the right ankle. It has been noted that 70% of individuals experiencing lateral ankle sprain or ligament ankle injury demonstrate persistent instability, with the symptoms remaining persistent for long time, increasing the financial cost of treatment [25,26]. Therefore, there is a need for more efficient and cost-effective treatment for managing ankle sprain. tDCS is easy to apply and cost effective, and hence represents potential intervention for reducing pain and improving the range of motion in sportspersons with ankle sprain.

The strength of our study is that this is the first to determine the effect of tDCS on pain, range of motion and balance in sportspersons with acute ankle sprain. Its limitations are that it was conducted on a small sample size and did not control for extraneous factors such as nutrition, hydration, previous activity level, lower body strength. Further studies on larger sample sizes and the combined use of tDCS with foot exercises focusing on improving proprioception and balance are needed to further explore the effectiveness of tDCS in managing ankle sprain.

Conclusion

The application of Transcranial Direct Current Stimulation (tDCS) is an effective approach for decreasing pain and improving range of motion but is not effective for improving balance in sportspersons with ankle sprain. Therefore, exercises that help in improving the balance and proprioception can be incorporated along with tDCS for reducing the symptoms and enhancing the performance of sportspersons suffering from ankle sprain.

Funding
This research received no external funding.

Conflicts of interests
The authors have no conflict of interest to declare.

References

1. Shah S, Thomas AC, Noone JM, Blanchette CM, Wikstrom EA. Incidence and Cost of Ankle Sprains in United States Emergency Departments. Sports Health. 2016; 8(6): 547-52.
2. Tanen L, Docherty CL, Van Der Pol B, Simon J, Schrader J. Prevalence of chronic ankle instability in high school and division I athletes. Foot Ankle Spec. 2014; 7(1): 37-44.
3. Verhagen RA, de Keizer G, van Dijk CN. Long-term follow-up of inversion trauma of the ankle. Arch Orthop Trauma Surg. 1995; 114(2): 92-6.
4. Yeung MS, Chan KM, So CH, Yuan WY. An epidemiological survey on ankle sprain. Br J Sports Med. 1994; 28(2): 112-6.

5. Anandacoomarasamy A, Barnsley L. Long term outcomes of inversion ankle injuries. Br J Sports Med. 2005; 39(3): e14.
6. Gribble PA, Delahunt E, Bleakley C, Caulfield B, Docherty CL, Fourchet F, et al. Selection criteria for patients with chronic ankle instability in controlled research: a position statement of the International Ankle Consortium. J Orthop Sports Phys Ther. 2013; 43(8): 585-91.
7. Pietrosimone BG, Gribble PA. Chronic ankle instability and corticomotor excitability of the fibularis longus muscle. J Athl Train. 2012; 47(6): 621-6.
8. Kim KM, Kim JS, Cruz-Díaz D, Ryu S, Kang M, Taube W. Changes in Spinal and Corticospinal Excitability in Patients with Chronic Ankle Instability: A Systematic Review with Meta-Analysis. J Clin Med. 2019; 8(7): 1037.
9. Needle AR, Lepley AS, Grooms DR. Central Nervous System Adaptation After Ligamentous Injury: a Summary of Theories, Evidence, and Clinical Interpretation. Sports Med. 2017; 47(7): 1271-88.
10. Ma Y, Yin K, Zhuang W, Zhang C, Jiang Y, Huang J, et al. Effects of Combining High-Definition Transcranial Direct Current Stimulation with Short-Foot Exercise on Chronic Ankle Instability: A Pilot Randomized and Double-Blinded Study. Brain Sci. 2020; 10(10): 749.
11. Hung YJ. Neuromuscular control and rehabilitation of the unstable ankle. World J Orthop. 2015; 6(5): 434-8.
12. Henriques IAD, Lattari E, Torres G, Rodrigues GM, Oliveira BRR, Neto GAM, et al. Can transcranial direct current stimulation improve range of motion and modulate pain perception in healthy individuals? Neurosci Lett. 2019; 707: 134311.
13. Mizuno T, Aramaki Y. Cathodal transcranial direct current stimulation over the Cz increases joint flexibility. Neurosci Res. 2017; 114: 55-61.
14. Bruce AS, Howard JS, VAN Werkhoven H, McBride JM, Needle AR. The Effects of Transcranial Direct Current Stimulation on Chronic Ankle Instability. Med Sci Sports Exerc. 2020; 52(2): 335-44.
15. Hazime FA, Baptista AF, de Freitas DG, Monteiro RL, Maretto RL, Hasue RH, et al. Treating low back pain with combined cerebral and peripheral electrical stimulation: A randomized, double-blind, factorial clinical trial. Eur J Pain. 2017; 21(7): 1132-43.
16. Mendonca ME, Simis M, Grecco LC, Battistella LR, Baptista AF, Fregni F. Transcranial Direct Current Stimulation Combined with Aerobic Exercise to Optimize Analgesic Responses in Fibromyalgia: A Randomized Placebo-Controlled Clinical Trial. Front Hum Neurosci. 2016; 10: 68.
17. Chaturvedi R, Joshi S. Effect of transcranial direct current stimulation (tDCS) and transcutaneous electrical nerve stimulation (TENS) in knee osteoarthritis. Physiother Quart. 2021; 29(3): 68-75.
18. Kisler LB, Gurion I, Granovsky Y, Sinai A, Sprecher E, Shamay-Tsoory S, et al. Can a single pulse transcranial magnetic stimulation targeted to the motor cortex interrupt pain processing? PLoS One. 2018; 13(4): e0195739.
19. García-Larrea L, Peyron R, Mertens P, et al. Electrical stimulation of motor cortex for pain control: a combined PET-scan and electrophysiological study. Pain. 1999; 83(2): 259-73.
20. Stagg CJ, Nitsche MA. Physiological basis of transcranial direct current stimulation. Neuroscientist. 2011; 17(1): 37-53.
21. Mizuno T, Aramaki Y. Cathodal transcranial direct current stimulation over the Cz increases joint flexibility. Neurosci Res. 2017; 114: 55-61.
22. Sriraman A, Oishi T, Madhavan S. Timing-dependent priming effects of tDCS on ankle motor skill learning. Brain Res. 2014; 1581: 23-9.
23. Deldar Z, Rustamov N, Bois S, Blanchette I, Piché M. Enhancement of pain inhibition by working memory with anodal transcranial direct current stimulation of the left dorsolateral prefrontal cortex. J Physiol Sci. 2018; 68(6): 825-36.
24. Farina D, Negro F, Dideriksen JL. The effective neural drive to muscles is the common synaptic input to motor neurons. J Physiol. 2014; 592(16): 3427-41.
25. McKeon PO, Wikstrom EA. Sensory-Targeted Ankle Rehabilitation Strategies for Chronic Ankle Instability. Med Sci Sports Exerc. 2016; 48(5): 776-84.
26. Hiller CE, Nightingale EJ, Raymond J, Kilbreath SL, Burns J, Black DA, et al. Prevalence and impact of chronic musculoskeletal ankle disorders in the community. Arch Phys Med Rehabil. 2012; 93(10): 1801-7.