Case Report

Application of add-on anodal cerebellar direct current stimulation for balance rehabilitation in cerebellar ataxia: a case report

Aplicação simultânea de estimulação transcraniana por corrente contínua cerebelar anódica para reabilitação do equilíbrio na ataxia cerebelar: relato de caso

Mariana Sacchi Mendonça[1]
Juliana Barbosa Goulardins[2]
Carolina de Oliveira Souza[3]
Katia Monte-Silva[4]
Clarice Tanaka[5]

[1,3,5]Universidade de São Paulo (São Paulo). São Paulo, Brazil. mariana.sacchi@hc.fm.usp.br, souzaco@ig.com.br, cltanaka@usp.br
[2]Corresponding author. Universidade de São Paulo (São Paulo); Universidade Cruzeiro do Sul (São Paulo). São Paulo, Brazil. juligoulardins@gmail.com
[4]Universidade Federal de Pernambuco (Recife). Pernambuco, Brazil. monte.silvakk@gmail.com

ABSTRACT | INTRODUCTION: Cerebellar ataxias are an extensive group of diseases, which cause many disorders in gait and balance that seriously impair quality of life, and without effective treatment options. Kinesiotherapy is the basis of multifaceted programs that incorporate more than one focus, such as coordination and balance training. Recently, transcranial direct current stimulation (tDCS) over the cerebellum has emerged as an intervention to improve balance disorders. **OBJECTIVE:** To describe a daily multiple session's simultaneous application of anodal cerebellar tDCS to kinesiotherapy for rehabilitation in cerebellar ataxia. **MATERIALS AND METHODS:** This case report included a 34-year-old male patient with a 10-year history of spinocerebellar ataxia. His main goals were to improve his walking ability and balance. He presented with axial and appendicular ataxia, impaired gait, and balance. The protocol used to stimulate the cerebellum consisted of twenty-minute tDCS, 2mA, daily applied, over two weeks, with anode positioned over the inion and cathode over the right deltoid muscle. Simultaneous kinesiotherapy included progressive functional exercises with the main objective of balance training. **RESULTS:** Clinical improvement was particularly evidenced by a 4-point reduction in the Scale for the Assessment and Rating of Ataxia after ten sessions, while literature recommends efficacy of a new therapy that would retard ataxia progression by 1 point per year. **CONCLUSION:** Our results suggest that the association between tDCS and kinesiotherapy was effective in this patient; tDCS sessions were safe and well-tolerated and may have played a role in improving functional tests. Further controlled studies involving a larger number of patients are needed to analyze the benefits of these combined techniques to maximize motor rehabilitation in this population.

KEYWORDS: Spinocerebellar Ataxias; Transcranial Direct Current Stimulation; Rehabilitation; Case reports.

RESUMO | INTRODUÇÃO: As ataxias cerebelares são um extenso grupo de doenças que causam diversos distúrbios na marcha e no equilíbrio, e que comprometem seriamente a qualidade de vida, sem opções de tratamento eficazes. A cinesioterapia é a base de programas multifacetados que incorporam mais de um enfoque, como o treinamento de coordenação e equilíbrio. Recentemente, a estimulação transcraniana por corrente contínua (tDCS) sobre o cerebelo surgiu como uma intervenção para melhorar os distúrbios do equilíbrio. **OBJETIVO:** Descrever a aplicação simultânea de tDCS anódica cerebelar e cinesioterapia, em sessões múltiplas diárias para reabilitação da ataxia cerebelar. **MATERIAIS E MÉTODOS:** Este relato de caso incluiu um paciente do sexo masculino, de 34 anos, com história de ataxia espinocerebelar há 10 anos. Seus principais objetivos eram melhorar a marcha e o equilíbrio. Ele apresentava ataxia axial e apendicular, dificuldades na marcha e no equilíbrio. O protocolo de estimulação do cerebelo consistiu na aplicação de tDCS por 20 minutos, 2mA, diariamente, durante duas semanas, com ânodo posicionado sobre o ínion e cátodo sobre o músculo deltóide direito. A cinesioterapia simultânea incluiu exercícios funcionais progressivos com objetivo principal de treinamento de equilíbrio. **RESULTADOS:** A melhora clínica foi particularmente evidenciada por uma redução de 4 pontos na Escala para Avaliação e Graduação da Ataxia após 10 sessões, enquanto a literatura recomenda a eficácia de uma nova terapia que retardaria a progressão da ataxia em 1 ponto por ano. **CONCLUSÃO:** Nossos resultados sugerem que a associação entre tDCS e cinesioterapia foi eficaz neste paciente; as sessões de tDCS foram seguras e bem toleradas e podem ter desempenhado um papel na melhora nos testes funcionais. Novos estudos controlados envolvendo um número maior de pacientes são necessários para analisar os benefícios destas técnicas combinadas para maximizar a reabilitação motora nesta população.

PALAVRAS-CHAVE: Ataxias espinocerebelares. Estimulação Transcraniana por Corrente Contínua. Reabilitação. Relatos de caso.

Submitted 02/07/2021, Accepted 04/29/2021, Published 05/11/2021
J. Physiother. Res., Salvador, 2021 May;11(2):427-434
http://dx.doi.org/10.17267/2238-2704rpf.v11i2.3636 | ISSN: 2238-2704
Designated editors: Abrahão Baptista, Katia Sá

How to cite this article: Mendonça MS, Goulardins JB, Souza CO, Monte-Silva K, Tanaka C. Application of add-on anodal cerebellar direct current stimulation for balance rehabilitation in cerebellar ataxia: a case report. J Physiother Res. 2021;11(2):427-434. http://dx.doi.org/10.17267/2238-2704rpf.v11i2.3636

Introduction

Cerebellar ataxias are an extensive group of diseases, which cause many disorders in gait and balance that seriously impair quality of life, usually related to cerebellar involvement. There are several forms of cerebellar ataxias, including acute causes (e.g., cerebellar stroke) or neurodegenerative disorders (e.g., hereditary ataxias).[1,2] The cerebellum plays a fundamental role in motor performance as an intermediary and modulator of cortical and peripheral information in motor learning, automatic tasks, and postural control, generating anticipatory or compensatory responses to unexpected stimuli.[3]

To date, there is no effective treatment for hereditary ataxias, and management remains supportive and symptomatic.[4] However, rehabilitation is mandatory to improve function, mobility, ataxia, and balance.[5] Kinesiotherapy is the basis of multifaceted programs that incorporate more than one focus, such as coordination and balance training.[6,7] The treatments cannot modify the condition itself but address the signs and symptoms installed in patients while maintaining maximum independence possible within the residual functions intact.[8] Therapeutic exercises show significant improvement in symptoms but need to be applied longitudinally to maintain functionality and independence.[9]

In recent years, transcranial direct current stimulation (tDCS), a modality of non-invasive brain stimulation, has emerged as a potential intervention for patients with balance disorders because it can influence cerebellum excitability[10,11], and is a safe and well-tolerated procedure.[12] Previous studies have shown promising results from cerebellar tDCS to improve long-term neurophysiological effects and clinical scores of posture, gait, and kinetic functions in patients with different types of ataxia.[13,14]

In addition, tDCS is believed to potentiate the results achieved during the motor rehabilitation process and represent a powerful method for priming cortical excitability for a subsequent motor task, demand, or stimulation. Thus, their mutual use can optimize the plastic changes induced by motor practice, leading to more remarkable and outlasting clinical gains in rehabilitation.[15] However, to our knowledge, this is the first case report addressing the effects of tDCS combined with individualized kinesiotherapy on balance in an adult with cerebellar ataxia.

Materials and Methods

Case description

This case report refers to a 34-year-old male patient, single, white ethnicity, who worked as a coffee machine replenisher, diagnosed with spinocerebellar ataxia type III (Machado Joseph's Disease), according to the medical record, diagnosed by a neurologist. The patient reports the absence of previous family history and no genetic mapping, as these data were not found in electronic medical records. Magnetic resonance imaging shows cerebellar atrophy. The patient has signed an informed consent form, and this study was approved by the local ethical committee (CAAE: 93840318.6.0000.5208).

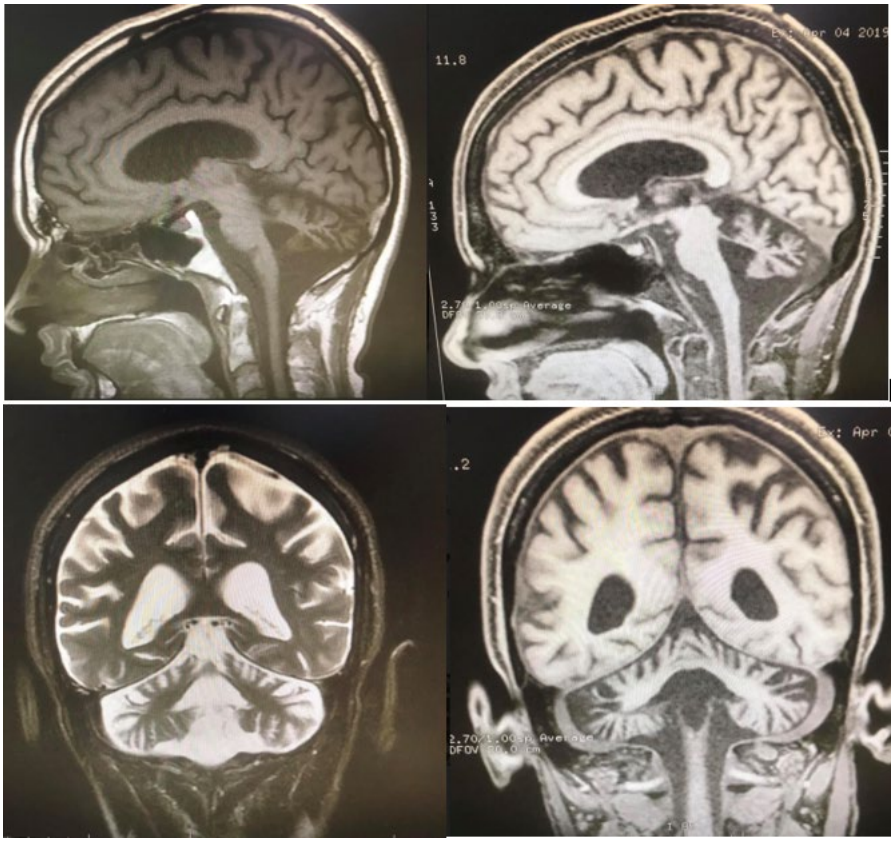
The symptoms began ten years ago when he started to experience difficulties and instabilities when running and playing soccer. The disease evolved gradually, with the patient realizing the difficulty in gait and articulating words. Three years later, he began to show vertigo symptoms when he was diagnosed with the disease. Four years later, he attended a rehabilitation program, which included four months of physical therapy intervention and six months of physical conditioning, which reestablished his self-confidence to leave his house. After this period, he was able to walk independently, without any gait device. Two years later, he was again referred to the physiotherapy service due to increased walking instability with a risk of falls. He underwent individualized kinesiotherapy for three months, with a slight improvement in complaints when referred to the Neuromodulation Clinic. All information about the clinical course and previous interventions were collected from the patient's report, as it was not possible to access the records of previous health services.

Examination

Clinical examination revealed axial and appendicular ataxia, rotatory nystagmus with slow saccadic eye movements, scanning speech with dysarthria, truncal ataxia, and a wide-based gait, being able to walk independently without using an auxiliary device, showing some instability. The patient reported an imbalance in walking. Muscular strength in general (grade 5), tonus, and sensitivity, either superficial and deep, were normal. The index-index test demonstrated dysmetria and dysdiadochokinesia.

The Romberg test was positive as well. When consulting the patient's electronic medical record, no electroneuromyography or other exams were found to identify involvement of peripheral nerve involvement. In addition, during the physical examination, no sensory deficits were found. Brain magnetic resonance imaging (MRI) showed cerebellar atrophy and no other lesions or abnormalities (Figure 1).

Figure 1. Patient's Brain Magnetic resonance imaging (MRI)



Baseline assessments of cortical neurophysiology using transcranial magnetic stimulation (TMS) and clinical scales were performed, such as (1) Scale for the Assessment and Rating of Ataxia (SARA), ranging from 0 (no ataxia) to 40 (most severe ataxia); (2) Barthel Index (functional and mobility scale), ranging from 0 to 100; and (3) Berg Balance Scale (BBS, predictor of fall risk), ranging from 0 to 56, all of them ranged from the worst-best condition.

SARA is a scale subdivided into eight items: gait (score 0 to 8), standing balance (score 0 to 6), sitting balance (score 0 to 4), disorders of speech (score from 0 to 6), finger chase test (score from 0 to 4), index-nose test (score from 0 to 4), dysdiadochokinesia (score from 0 to 4) and heel-knee test (score from 0 to 4). The sum of the score of each item is performed, and then the total score is observed, which can vary from 0 (without ataxia) to 40 (more severe ataxia). In this way, SARA can assess the patient in three domains of the international classification on functionality, disability, and health: structure, function, and activity.[16]

Balance was assessed using the Berg Balance Scale, where the patient's balance is assessed based on 14 activities of daily living that will be assessed from 0 (worst performance) to 4 (best performance) points.[17]

The Barthel Index is a worldwide used instrument to assess functional independence and mobility. A review study on the elderly functional study assessment instruments from 2004 identified this index as one of the most used instruments to assess daily life activities.[18] The Barthel Index belongs to the daily life activity (DLAs) assessment field and measures the functional independence at personal care, mobility, locomotion, and excretion. In the original version, each item is scored according to the patient's ability to perform activities independently, with some help, or completely depending on help. A general scoring is composed by attributing points to each category, depending on the time and assistance needed by each patient. Points vary from 0 to 100, in 5 points intervals, and the higher the scoring, the more patients are independent.[19]

The hemispherical motor threshold, defined as the minimum TMS intensity necessary to produce a visually detectable twitch on 50% of pulses[20] was assessed with Magstim Rapid2 (Magstim, Wales, UK), using a figure-8 coil in the primary motor cortex. All assessments were repeated to verify acute treatment effects, two weeks after baseline, after completing the protocol.

Intervention

The protocol used to stimulate the cerebellum consisted of twenty-minute tDCS, 2mA, daily applied, except on the weekends, during two weeks, with anode positioned over the inion and cathode over the right deltoid muscle. A TCT tDCS stimulator (TCT Research Limited, Hong Kong) by saline-soaked sponge electrodes was used. Although in many studies, the stimulating electrode, measuring 5 cm × 5 cm (area 25 cm2), can be placed 1–2 cm below the ion for stimulation of a cerebellar hemisphere, in this study we chose to use a larger stimulating electrode, measuring 7 cm × 5 cm (area 35 cm2), for stimulation of the whole cerebellum.[21]

Kinesiotherapy included progressive functional exercises with the main objective of balance training. Exercises program included: sitting and standing up; shin gait training, reverse stabilization trunk exercises, stairs training, postural adjustments on stable surface progressing to unstable surface, and aerobic training with ergometer bike. In the first sessions, we started with exercises on a stable surface, with repetitions and stabilization training (Figure 2). The exercises were performed in progress with the evolution of the patient. After the timing of action with tDCS, we continued the exercises until the end of the session. In the subsequent sessions, we used unstable surfaces for training (Figure 3). The therapy was based on exercises that emphasized activation of deep muscles of the trunk in different postures, followed by coordination exercises with upper and lower limbs, always focusing on functional exercises, based on a task in the following sessions it was trained gait with tasks that simulated functional and trivial activities, for example crossing the street.[5,22] The total kinesiotherapy time was about 40 minutes per day, with tDCS being applied simultaneously during the first 20 minutes.

Figure 2. Gait training on stable surface during anodal cerebellar tDCS altering velocities

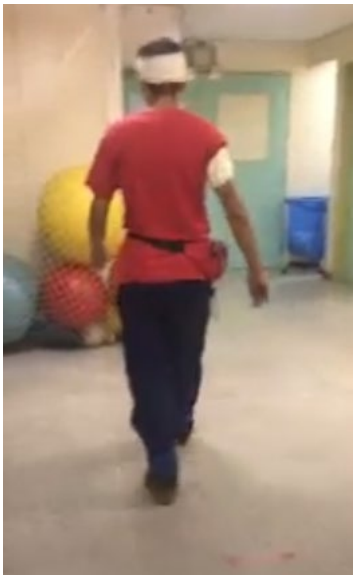


Figure 3. Balance training on an unstable surface during anodal cerebellar tDCS

http://dx.doi.org/10.17267/2238-2704rpf.v11i2.3636 | ISSN: 2238-2704

Results

The patient showed improvements in all scales, and changes in hemispherical motor threshold, as shown in Table 1. There were no reports of adverse effects, except excessive sleepiness during the first week of application. A questioning about adverse effects was carried out daily before and after the sessions.

Table 1. Outcome measures

Assessment	Baseline	Immediately post treatment
Scale for the assessment and rating of Ataxia	12	8
Barthel Index	90	100
Berg Balance Scale	48	37
Hemispherical Motor Threshold (Left/Right)	92/84	84/78

Discussion

Our results suggest that the association between tDCS and kinesiotherapy was effective in this patient with spinocerebellar ataxia; tDCS sessions were safe and well-tolerated and may have played a role in the significant improvement on functional tests. At the end of the sessions, the patient had reported a self-perception of well-being and a decrease in imbalance and particularly demonstrated by participation in a popular festival of great circulation of people, about three months after completing the protocol (as he mentioned in a spontaneous telephone contact). This demonstrates that the treatment reached the functional level of the structures and functions of the body and activities and social participation.

It has been suggested that cerebellar anodal stimulation produces an increase in cerebellar inhibition and clinically could result in faster locomotor adaptations.[23] The cerebellum plays an important role in the control of motor activity through the cerebello-thalamocortical connections.[24] Purkinje cells exert a physiological inhibitory tone over the primary motor cortex, referred to as cerebellar brain inhibition[25], through the inhibition of the dentate nucleus, which has an excitatory effect on the ventrolateral motor thalamus and eventually, on the motor cortex.[25,26] A decrease in the motor threshold was observed after tDCS combined with kinesiotherapy in this patient, representing an increase in motor cortex excitability. It is suggested that cerebellar stimulation may have a facilitatory influence on the motor cortex through low-frequency tonic excitatory inputs connected to the motor cortex from the contralateral cerebellum, which can be explained by the dentototalamocortical route.[27]

Anodal cerebellar tDCS has been applied as a complementary therapy in the management of ataxias. It is shown that in healthy patients, these techniques can accelerate motor learning by acting in the motor cortex inhibition mechanism during the early stages of learning. In the same way, in ataxias, where derangement occurs in the inhibition of the cerebellar nuclei mediated by Purkinje cells, non-invasive cerebellar stimulation associated with a motor task would be able to modulate the cerebellar impulses, restoring the synergy of effector organs in maintaining posture and uncoordinated tasks, in addition to enhancing learning.[8,28]

Usually, the rehabilitation treatment for this patient's profile is considerably long, and the association of tDCS and kinesiotherapy has obtained an acute improvement of balance in two weeks. It may be due to the effect of tDCS as a tool to potentialize rehabilitation processes in a relatively short period, which was not achieved with previous interventions in adults (only kinesiotherapy). Studies show that tDCS can modulate motor learning[29], and it is thought to modify cerebellum activity and alter the output from cerebellar nuclei.[12] It may explain the fast improvements by adding the stimuli in association with the motor training. Clinical improvement was particularly evidenced by a 4-point reduction in SARA after ten sessions, while literature recommends the efficacy of a new therapy that would retard ataxia progression by 1 point per year.[30] In addition, we highlight a possible role of the combination of tDCS and kinesiotherapy, since a previous study found differences before and after intervention in SARA of 2.8 points reduction, using anodal cerebellar tDCS protocol (5 days/week for two weeks) in twenty patients with ataxia.[14]

Another possibility is that cerebellar anodal tDCS is capable of enhancing cortical excitability, minimizing dysfunctional neurological patterns, and facilitating the learning process regarding postural reactions and balance, as seen in the study with children with motor ataxia who performed anodal tDCS and treadmill training.[29]

This case report has many limitations, but many of them are intrinsic to the case reports. Possible placebo effect or confounding effect from unblinded rater should be considered for the interpretation of this case. The clinical improvement could be attributable either to tDCS, kinesiotherapy, or both. Controlled clinical studies need to be done to examine each intervention strategies' effectiveness separately and combined.

Research also should examine the effect of these interventions on patients with cerebellar ataxia with varying degrees of walking and balance impairment and chronicity of the disease. The impact of these treatments on other factors such as disability and the ability to perform activities of daily living should also be examined. Further controlled studies involving a larger number of patients are allowed for the benefits of this combined technique to maximize motor rehabilitation in this population.

Acknowledgments

This study received support from National Council for Scientific and Technological Development (CNPQ - process no. 424076 / 2018-7).

Author contributions

Monte-Silva K and Tanaka C conceived and planned the experiments. Mendonça MS, Souza CO and Goulardins JB planned and carried out the simulations. Goulardins JB, Monte-Silva K, and Tanaka C contributed to sample preparation and interpreting the results. Mendonça MS and Goulardins JB took the lead in writing the manuscript. All authors provided critical feedback and helped shape the research, analysis, and manuscript.

Competing interests

No financial, legal, or political competing interests with third parties (government, commercial, private foundation, etc.) were disclosed for any aspect of the submitted work (including but not limited to grants, data monitoring board, study design, manuscript preparation, statistical analysis, etc.).

Referências

1. Marsden J, Harris C. Cerebellar ataxia: pathophysiology and rehabilitation. Clin Rehabil. 2011;25(3):195–216. https://doi.org/10.1177/0269215510382495

2. Bultmann U, Pierscianek D, Gizewski ER, Schoch B, Fritsche N, Timmann D, et al. Functional recovery and rehabilitation of postural impairment and gait ataxia in patients with acute cerebellar stroke. Gait Posture. 2014;39(1):563-9. https://doi.org/10.1016/j.gaitpost.2013.09.011

3. Bodranghien F, Bastian A, Casali C, Hallett M, Louis ED, Manto M, et al. Consensus Paper: Revisiting the Symptoms and Signs of Cerebellar Syndrome. Cerebellum. 2016;15(3):369-91. https://doi.org/10.1007/s12311-015-0687-3

4. Fonteyn EM, Keus SH, Verstappen CC, Schöls L, de Groot IJ, van de Warrenburg BP. The effectiveness of allied health care in patients with ataxia: a systematic review. J Neurol. 2014;261(2):251-8. https://doi.org/10.1007/s00415-013-6910-6

5. Artigas NR, Ayres JS, Noll J, Peralles SRN, Borges MK, Brito CIB. Atendimento Fisioterapêutico para Indivíduos com Ataxia Espinocerebelar: Uma Revisão da Literatura. Rev Neurocienc. 2013;21(1):126–35. https://doi.org/10.34024/rnc.2013.v21.8212

6. Milne SC, Corben LA, Georgiou-Karistianis N, Delatycki MB, Yiu EM. Rehabilitation for Individuals With Genetic Degenerative Ataxia: A Systematic Review. Neurorehabil Neural Repair. 2017;31(7):609-22. https://doi.org/10.1177/1545968317712469

7. Fonteyn EM, Keus SH, Verstappen CC, van de Warrenburg BP. Physiotherapy in degenerative cerebellar ataxias: utilisation, patient satisfaction, and professional expertise. Cerebellum. 2013;12(6):841-7. https://doi.org/10.1007/s12311-013-0495-6

8. Mitoma H, Manto M. The Era of Cerebellar Therapy. Curr Neuropharmacol. 2019;17(1):3-6. https://doi.org/10.2174/1570159x1701181129111212

9. Kelly G, Shanley J. Rehabilitation of ataxic gait following cerebellar lesions: Applying theory to practice. Physiother Theory Pract. 2016;32(6):430-7. https://doi.org/10.1080/09593985.2016.1202364

10. van Dun K, Manto M. Non-invasive Cerebellar Stimulation: Moving Towards Clinical Applications for Cerebellar and Extra-Cerebellar Disorders. Cerebellum. 2018;17(3):259-63. https://doi.org/10.1007/s12311-017-0908-z

11. Ferrucci R, Priori A. Noninvasive stimulation. Handb Clin Neurol. 2018;155:393–405. https://doi.org/10.1016/b978-0-444-64189-2.00026-3

12. França C, Andrade DC, Teixeira MJ, Galhardoni R, Silva V, Barbosa ER, et al. Effects of cerebellar neuromodulation in movement disorders: A systematic review. Brain Stimul. 2018;11(2):249-60. https://doi.org/10.1016/j.brs.2017.11.015

13. van Dun K, Bodranghien F, Manto M, Mariën P. Targeting the Cerebellum by Noninvasive Neurostimulation: a Review. Cerebellum. 2017;16(3):695-741. https://doi.org/10.1007/s12311-016-0840-7

14. Benussi A, Dell'Era V, Cotelli MS, Turla M, Casali C, Padovani A, et al. Long term clinical and neurophysiological effects of cerebellar transcranial direct current stimulation in patients with neurodegenerative ataxia. Brain Stimul. 2017;10(2):242-50. https://doi.org/10.1016/j.brs.2016.11.001

15. Bolognini N, Pascual-Leone A, Fregni F. Using non-invasive brain stimulation to augment motor training-induced plasticity. J Neuroeng Rehabil. 2009;6:8. https://doi.org/10.1186/1743-0003-6-8

16. Schmitz-Hübsch T, Montcel ST, Baliko L, Berciano J, Boesch S, Depondt C, et al. Scale for the assessment and rating of ataxia: development of a new clinical scale. Neurology. 2006;66(11):1717-20. https://doi.org/10.1212/01.wnl.0000219042.60538.92

17. Scalzo PL, Nova IC, Perracini MR, Sacramento DRC, Cardoso F, Ferraz HB, et al. Validation of the Brazilian version of the Berg balance scale for patients with Parkinson's disease. Arq Neuropsiquiatr 2009;67(3b):831–5. https://doi.org/10.1590/S0004-282X2009000500010

18. Paixão Júnior CM, Reichenheim ME. Uma revisão sobre instrumentos de avaliação do estado funcional do idoso. Cad Saúde Pública. 2005;21(1):7–19. https://doi.org/10.1590/S0102-311X2005000100002

19. Alves-Guerreiro J. Measuring Health: A Guide to Rating Scales and Questionnaires. Physl Ther Rev. 2000;5(3):183. https://doi.org/10.1179/ptr.2000.5.3.183

20. Sandrini M, Umiltà C, Rusconi E. The use of transcranial magnetic stimulation in cognitive neuroscience: a new synthesis of methodological issues. Neurosci Biobehav Rev. 2011;35(3):516-36. https://doi.org/10.1016/j.neubiorev.2010.06.005

21. Ferrucci R, Cortese F, Priori A. Cerebellar tDCS: how to do it. Cerebellum. 2015;14(1):27-30. https://doi.org/10.1007/s12311-014-0599-7

22. Ilg W, Synofzik M, Brötz D, Burkard S, Giese MA, Schöls L. Intensive coordinative training improves motor performance in degenerative cerebellar disease. Neurology. 2009;73(22):1823-30. https://doi.org/10.1212/wnl.0b013e3181c33adf

23. Jayaram G, Tang B, Pallegadda R, Vasudevan EV, Celnik P, Bastian A. Modulating locomotor adaptation with cerebellar stimulation. J Neurophysiol. 2012;107(11):2950-7. https://doi.org/10.1152/jn.00645.2011

24. Holdefer RN, Miller LE, Chen LL, Houk JC. Functional connectivity between cerebellum and primary motor cortex in the awake monkey. J Neurophysiol. 2000;84(1):585-90. https://doi.org/10.1152/jn.2000.84.1.585

25. Galea JM, Jayaram G, Ajagbe L, Celnik P. Modulation of cerebellar excitability by polarity-specific noninvasive direct current stimulation. J Neurosci. 2009;29(28):9115-22. https://doi.org/10.1523/jneurosci.2184-09.2009

26. Daskalakis ZJ, Paradiso GO, Christensen BK, Fitzgerald PB, Gunraj C, Chen R. Exploring the connectivity between the cerebellum and motor cortex in humans. J Physiol. 2004;557(Pt 2):689-700. https://dx.doi.org/10.1113%2Fjphysiol.2003.059808

27. Ugawa Y. Cerebellar Stimulation in Normal Subjects and Ataxic Patients [Internet]. In: Hallet M, Chokroverty S. Magnetic Stimulation in Clinical Neurophysiology. 2a ed. Oxford: Butterworth-Heinemann; 2005. p. 197–210. Disponível em: https://www.sciencedirect.com/book/9780750673730/magnetic-stimulation-in-clinical-neurophysiology

28. Benussi A, Koch G, Cotelli M, Padovani A, Borroni B. Cerebellar tDCS in patients with ataxic disorders: A double-blind, randomized, crossover, sham-controlled study. Clin Neurophysiol. 2016;127(3):e23–e24. https://doi.org/10.1016/j.clinph.2015.11.066

29. Grecco LA, Oliveira CS, Duarte NA, Lima VL, Zanon N, Fregni F. Cerebellar transcranial direct current stimulation in children with ataxic cerebral palsy: A sham-controlled, crossover, pilot study. Dev Neurorehabil. 2017;20(3):142-8. https://doi.org/10.3109/17518423.2016.1139639

30. Lee YC, Liao YC, Wang PS, Lee IH, Lin KP, Soong BW. Comparison of cerebellar ataxias: A three-year prospective longitudinal assessment. Mov Disord. 2011;26(11):2081-7. https://doi.org/10.1002/mds.23809