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OLGU SUNUMU CASE REPORT

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The Effects of Transcranial Direct Current Stimulation and Robot Assisted Gait Training on Motor Function in Patients with Spinal Cord Injury: A Case Series

Omurilik Yaralanmalı Hastalarda Transkraniyal Doğru Akım Stimülasyonu ve Robot Yardımlı Yürüme Eğitiminin Motor Fonksiyon Üzerine Etkileri: Olgu Serisi

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ABSTRACT In recent years, transcranial direct current stimulation (tDCS) has emerged as a possible therapeutic modality in enhancing functionality following spinal cord injury (SCI). However, the role of tDCS in enhancing locomotion when used alongside other methods of gait training in patients with incomplete SCI remains inadequately addressed in the literature. Here we present the results of an observational case series on the effects of tDCS, robot assisted gait training (RAGT) and physical therapy (PT) on the development of muscle power, locomotor skills, balance and activities of daily living (ADL) in five patients with a history of chronic incomplete SCI. Five patients received two hours of PT, twenty minutes of tDCS and thirty minutes of RAGT five times a week to a total of thirty sessions on an inpatient basis. Patients were evaluated before and following the treatment program using manual muscle testing (MMT), a ten meter walking test (10MWT), Function in Sitting Test (FIST), the Walking Index for SCI (WISCI) and the Spinal Cord Independence Measure III (SCIM III) rating scale. Mean age of the five patients was 28.4±5.13 years. Mean time since SCI was 5.8±1.30 years. Aetiology of SCI was trauma in all cases. Improvements in MMT, 10 MWT, FIST, WISCI, SCIM III were recorded. The findings of this study suggest that this combination of treatment is effective in improving locomotor skills in those with chronic SCI. These findings need to be consolidated using a larger patient sample and compared to sham tDCS, RAGT and PT and PT alone.

Keywords: Gait; physical therapy; robotics; spinal cord injury; transcranial direct current stimulation

ÖZET Son yıllarda transkraniyal doğru akım stimülasyonu [transcranial direct current stimulation (tDAS)], omurilik yaralanması (OY) sonrası fonksiyonelliği geliştirmede kullanılan tedavi seçeneklerinden birisi olmuştur. Literatürde, inkomplet OY hastalarında tDAS'nin diğer yürüyüş eğitimi yöntemleriyle birlikte uygulanmasının lokomosyon üzerine etkisini değerlendiren yetersiz sayıda veri bulunmaktadır. Bu yazıda; inkomplet OY hastalarında tDAS, robot destekli yürüyüş eğitimi ve fizik tedavinin birlikte uygulanmasının kas gücü gelişimi, lokomotor becerileri, denge ve günlük yaşam aktiviteleri üzerine etkilerini 5 hastadan oluşan bir olgu serisi olarak sunduk. Kliniğimizde yatarak tedavi gören 5 hastaya 6 hafta süre ile haftada 5 gün, toplam 30 seans rehabilitasyon programı uygulandı. Her gün 2 saat fizik tedavi, 20 dk tDAS ve 30 dk robot destekli yürüme eğitimi uygulandı. Hastalar tedavi programı öncesi ve sonrası manuel kas testi, on metrelik yürüme testi [ten meter walking test (10MWT)], Oturmada Fonksiyon Testi [Function in Sitting Test (FIST)], Spinal Kord Yaralanması İçin Yürüme İndeksi [Walking Index for SCI (WISCI)] ve Spinal Kord Yaralanması İçin Yürüme İndeksi [Walking Index for SCI (WISCI)] ölçekleri ile değerlendirildi. Beş hastanın yaş ortalaması 28,4±5,13 idi. Olaydan sonra geçen süre ortalama süre 5,8±1,30 yıldı. Hastaların hepsinde travmatik omurilik yaralanması mevcuttu. MMT, 10 MWT, FIST, WISCI ve SCIM III de gelişme kaydedildi. Bu bulgular, daha büyük hasta grubu ile yapılacak çalışmalarla desteklenmelidir. İlerideki çalışmalarda tedavi kombinasyonumuz ile sham tDAS, robot destekli yürüme eğitimi, fizik tedavi kombinasyonu ve sadece fizik tedavi uygulanan hasta grupları arasında karşılaştırmalar yapılmalıdır.

Anahtar Kelimeler: Yürüme; fiziksel tedavi; robotik tedavi; omurilik yaralanması; transkraniyal doğru akım stimülasyonu

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Spinal cord injury (SCI) is a disastrous condition which has a major impact on all aspects of a person's life. Decreased mobility following SCI can have a negative impact on both life satisfaction and quality.[1] Achieving a sufficient level of mobility following SCI is imperative to maintain patient participation in activities of daily living (ADL) and social activities.[2]

Intensive gait training following incomplete SCI aims to promote motor function by encouraging plastic change in both the spinal cord and sensory motor cortex. Studies have shown that this can be achieved using conventional overground walking training (OGT), body weight-supported treadmill training and robot assisted gait training (RAGT).[3] RAGT aids the patient in adopting a symmetric, correct gait pattern. A recent systematic review concluded that RAGT improves walking distance, strength and functional level of mobility to a greater degree than OGT following SCI as well as being more practical and less labour intensive.[4]

More recently, transcranial direct current stimulation (tDCS) has emerged as a non-invasive brain stimulation (NIBS) technique which enhances the ability of the motor cortex to undergo neuroplastic change; its potential ability to improve upper extremity motor function and ADL when given alongside physical therapy (PT) in neurological conditions such as stroke has been shown.[5] The role of tDCS in enhancing locomotion in patients with incomplete SCI remains inadequately addressed and results to date are contradictory with one sham controlled study showing a significant between group difference in changes in muscle strength and the other not.[6,7]

The aim of this case series was to document the outcomes of treating patients with chronic incomplete SCI with tDCS alongside RAGT and PT in our clinic with regards to developments in muscle power, locomotor skills, balance and ADL.

CASE REPORT

Patients between the ages of 18-65 with a history of incomplete SCI according to the American Spinal Injury Association Impairment Scale (AIS B, C or D) of at least one years' duration were included in this case series.[8] Those who had received PT elsewhere within the last three months, those with poor congnition, lack of imaging supporting the diagnosis of SCI, history of cranial surgery, presence of a cardiac or neural pacemaker or metallic material in the cranium, contractures or severe spasticity, pressure sores which would affect the tieing of RAGT harnesses, severe osteoporosis or orthostatic hypotension were excluded from the study.

All patients received two hours of conventional PT (neurofacilitation techniques, range of motion and progressive resistance and strengthening exercises) with a physiotherapist, twenty minutes of tDCS followed by thirty minutes of RAGT five times a week to a total of thirty sessions.

tDCS was applied using a double channeled direct current stimulator (ZMI Electronics Ltd. Taiwan 2012) via 22 cm^2 saline soaked electrodes. The anode was placed in the lower extremity motor cortex area (Cz), in accordance with the International EEG 10/20 system, situated in the midline of the cranium half way between the nasion and occipital protruberance.[9] The cathode was placed in the supraorbital area (Figure 1). The stimulator was then activated and the current increased to 2mA for a total of twenty minutes. This was followed by thirty minutes of RAGT using the HIWIN Robotic Gait Training System MRG-P100 supervised by a physiotherapist trained in its use. The cadence was increased every five minutes for the first fifteen minutes and decreased back

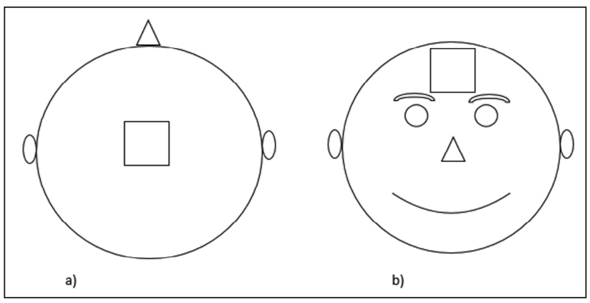

FIGURE 1: Placement of transcranial direct current stimulation electrodes. The anode (a) was placed in the lower extremity motor cortex area (Cz), in accordance with the International EEG 10/20 system. The cathode (b) was place supraorbitally.

to baseline in the second fifteen minutes of RAGT to 40-70 steps/minute according to the patient's walking ability.

All patients were evaluated before and at the end of the treatment program by the same physician. Verbal and written consent was obtained from each patient prior to evaluation. Muscle power of the ten motor key muscle groups used in the American Spinal Injury Association Impairment Scale (bilateral elbow flexors, wrist and elbow extensors, finger flexors and abductors, hip flexors, knee extensors, ankle dorsiflexors, long toe extensors and ankle plantar flexors) were evaluated using manual muscle testing (MMT).[10-12] Each muscle group was given a score from 0 (no movement) to 5 (active movement against full resistance) and the total score out of fifty for the right and left sides recorded. The ten meter walking test (10MWT) was used to evaluate over ground walking speed.[13] Balance and function whilst sitting was evaluated using the Function in Sitting Test (FIST) in which a higher score shows increased functionality. The Walking Index for Spinal Cord Injury (WISCI) was used to describe the patients' use of physical assistance and devices when walking.[14] The Spinal Cord Independence Measure III (SCIM III) rating scale was used as a functional assessment of ADL.[15,16]

Statistical analysis was performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean±standard deviation (SD) or median (minimum-maximum) for continuous variables and in numbers for categorical variables. Since the study population was small in size, no normality test was performed.

The mean age of the patients was 28.4±5.13 years. The mean time since SCI was 5.8±1.30 years. The aetiology of SCI was trauma in all cases. Details of SCI level and AIS scores are presented in Table 1.

There was an improvement in MMT, 10 MWT, FIST, WISCI, SCIM in all patients (Table 2). All patients adhered to the treatment program. No side effects of treatment were recorded.

TABLE 1: Patient demographics and clinical findings.

Age (years)	Sex (M/F)	Time since SCI (years)	AIS score	Level of SCI
22	M	5	C	T12
30	M	8	C	T10
36	M	6	C	L3
27	M	5	B	T11
27	M	5	C	C6

M: Male; F: Female; SCI: Spinal cord injury; AIS: American Spinal Injury Association Impairment Scale.

TABLE 2: Outcome measures before and after treatment.

Outcome measure	Before treatment (n=5)	After treatment (n=5)
MMT R	33.40±7.23	34.20±8.87
MMT L	29.20±4.32	30.60±3.20
10 MWT (s)	82.50±53.64	90.80±71.79
FIST	44.20±7.25	48.00±4.74
WISCI	5.20±6.87	8.20±6.68
SCIM	56.60±12.34	66.00±13.78

MMT: Manual muscle testing; R: Right; L: Left; 10 MWT: 10 metre walking test; FIST: Function in sitting test; WISCI: Walking Index for Spinal Cord Injury; SCIM: Spinal cord independence measure III.

DISCUSSION

Treatment of patients with chronic incomplete SCI with tDCS and RAGT alongside PT with an aim to improve muscle power, locomotor skills, balance and ADL is a topic which remains scarcely covered in the literature. In patients with incomplete SCI, it is believed that enhancing the activity of the motor cortex using NIBS techniques such as tDCS, has the potential to increase the activity of intact descending corticospinal pathways.[17] Anodal tDCS increases the discharge of action potentials from neurons of the primary motor cortex by hyperpolarizing the dendrites and depolarizing the cell bodies of pyramidal neurons. This increases corticospinal excitability and promotes the sprouting of new connections from remaining axons to denervated regions of the spinal cord.[18] This, in turn, will encourage developments in motor function.

All patients included in this small case series showed an improvement in muscle power, locomotor skills, balance and ADL following treatment with a combination of tDCS, RAGT and PT, despite being in the chronic stage of incomplete SCI. This may suggest that this combination of treatment is a good option when rehabilitating patients with chronic incomplete SCI when aiming to improve motor function. These findings are in agreement with the study of Raithatha et al. conducted in 2016.[6] However, around the same time, the study by Kumru et al. reported no difference in developments in lower extremity muscle power and locomotor skills in the tDCS group when compared to the sham tDCS group.[7] Of course, one of the many methodological differences such as timing of the tDCS sessions in conjuction with the RAGT session (preceding versus simultaneous administration), total number of tDCS sessions (thirty six versus twenty) may have resulted in the contradictory findings.

The authors of this case series report felt that sharing the outcomes of this treatment regimen was a worthwhile undertaking as it is important to further investigate the use and benefits of easily accessible treatments such as tDCS in neurological rehabilitation; especially in patients with SCI in the chronic stage of injury in which improvements in motor function often wanes.[19] Indeed, the patients did improve with regard to muscle power, locomotor ability and balance but of course these findings need to be further consolidated with a larger patient sample and compared to patient groups receiving sham tDCS, RAGT and PT and PT alone. Methodological variants such as optimum coordination of timing of RAGT and tDCS administration, number and frequency of tDCS sessions, and the transcranial current applied need to be standardized. In this way, not only will the benefits of RAGT and tDCS administered alongside PT be clearer, but also the ability of tDCS to potentiate the effects of RAGT can be established.

PATIENT CONSENT

Verbal and written consent was obtained from all patients prior to the drafting of the manuscript.

Conflict of Interest

No conflicts of interest between the authors and/or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

REFERENCES

1. Hu XL, Tong KY, Li R, et al. Effectiveness of functional electrical stimulation (FES)-robot assisted wrist training on persons after stroke. Annu Int Conf IEEE Eng Med Biol Soc. 2010;2010:5819-22. [Crossref] [Pubmed]
2. Rushton PW, Miller WC, Mortenson WB, et al. Satisfaction with participation using a manual wheelchair among individuals with spinal cord injury. Spinal Cord. 2010;48:691-6. [Crossref] [Pubmed] [PMC]
3. Dietz V, Wirz M, Curt A, et al. Locomotor pattern in paraplegic patients: training effects and recovery of spinal cord function. Spinal Cord. 1998;36:380-90. [Crossref] [Pubmed]
4. Nam KY, Kim HJ, Kwon BS, et al. Robot-assisted gait training (Lokomat) improves walking function and activity in people with spinal cord injury: a systematic review. J Neuroeng Rehabil. 2017;14:24. [Crossref] [Pubmed] [PMC]
5. Alisar DC, Ozen S, Sozay S. Effects of Bihemispheric Transcranial Direct Current Stimulation on Upper Extremity Function in Stroke Patients: A randomized Double-Blind Sham-Controlled Study. J Stroke Cerebrovasc Dis. 2020;29:104454. [Crossref] [Pubmed]
6. Raithatha R, Carrico C, Powell ES, et al. Non-invasive brain stimulation and robot-assisted gait training after incomplete spinal cord injury: A randomized pilot study. NeuroRehabilitation. 2016;38:15-25. [Crossref] [Pubmed]
7. Kumru H, Murillo N, Benito-Penalva J, et al. Transcranial direct current stimulation is not effective in the motor strength and gait recovery following motor incomplete spinal cord injury during Lokomat(®) gait training. Neurosci Lett. 2016;620:143-7. [Crossref] [Pubmed]
8. Gündüz B, Erhan B. Omurilik yaralanması nörolojik sınıflaması için uluslararası standartlar değerlendirme formunun güncellenmesi [Update for examination sheet of international standards for neurological classification of spinal cord injury]. Turk J Phys Med. 2015;61:91-4. [Crossref]
9. Chatrian GE, Lettich E, Nelson PL. Ten percent electrode system for topographic studies of spontaneous and evoked EEG activity. Am J EEG Technol. 1985;25:83-92. [Crossref]
10. Gündüz B. ASIA Update-ASIA Impairment Scale: Level Determination, Classification, and Case Examples. Turk J Phys Med Rehab 2015;61:25-31. [Crossref]
11. Wadsworth CT, Krishnan R, Sear M, et al. Intrarater reliability of manual muscle testing and hand-held dynametric muscle testing. Physical Therapy. 1987;67:1342-7. [Crossref] [Pubmed]
12. Cuthbert, SC, Goodheart Jr GJ. On the reliability and validity of manual muscle testing: A literature review. Chiropr Osteopat. 2017;15:4. [Pubmed] [PMC]
13. van Hedel HJ, Wirz M, Dietz V. Standardized assessment of walking capacity after spinal cord injury: the European network approach. Neurol Res. 2008;30:61-73. [Crossref] [Pubmed]

14. Ditunno JF Jr, Ditunno PL, Graziani V, et al. Walking index for spinal cord injury (WISCI): an international multicenter validity and reliability study. Spinal Cord. 2000;38:234-43. [Crossref] [Pubmed]
15. Kesiktas N, Paker N, Bugdayci D, et al. Turkish adaptation of Spinal Cord Independence Measure--version III. Int J Rehabil Res. 2012;35:88-91. [Crossref] [Pubmed]
16. Unalan H, Misirlioglu TO, Erhan B, et al. Validity and reliability study of the Turkish version of Spinal Cord Independence Measure-III. Spinal Cord. 2015;53:455-60. [Crossref] [Pubmed]
17. Martin JH. Harnessing neural activity to promote repair of the damaged corticospinal system after spinal cord injury. Neural Regen Res. 2016;11:1389-1. [Crossref] [Pubmed] [PMC]
18. Gunduz A, Rothwell J, Vidal J, et al. Non-invasive brain stimulation to promote motor and functional recovery following spinal cord injury. Neural Regen Res. 2017;12:1933-8. [Crossref] [Pubmed] [PMC]
19. de Araújo AVL, Ribeiro FPG, Massetti T, et al. Effectiveness of anodal transcranial direct current stimulation to improve muscle strength and motor functionality after incomplete spinal cord injury: a systematic review and meta-analysis. Spinal Cord. 2020;58:635-46. [Crossref] [Pubmed]