

ORIGINAL ARTICLE

Effect of robot assisted gait training on motor performance in cerebral palsy: a pilot study

Devrim TARAKÇI¹, Ahmet EMİR¹, Eren AVCIL², Ela TARAKÇI³

Purpose: Children with Cerebral Palsy (CP) have significantly impaired motor performance. There are various rehabilitation methods in rehabilitation in CP. Robot Assisted Gait Training (RAGT) is an alternative rehabilitation system in addition to other therapies. This study aims to investigate effects of RAGT in children with CP.

Methods: Seventeen patients with spastic type CP, mean age 12.83±5.41 years, participated in this study. Muscles' tone were assessed with "Modified Ashworth Scale", motor developmental level was analysed by "Gross Motor Function Scale (GMFM)", motor performance was assessed by "Gross Motor Performance Measure (GMPM)" balance and coordination was assessed with "Paediatric Balance Scale (PBS)". GEO robotic systems designed by Reha-Technology was used in treatment for 10 weeks (45 minutes-3 days a week), which was composed of treadmill and stair training.

Results: The level of motor development, motor performance and balance has been detected to change positively at the end of RAGT (p<0.05).

Conclusion: Robotic rehabilitation method such as walking, climbing stairs has a positive effect on the motor performance and the balance parameters in patients with CP. However, there is not a certain protocol in which to define the level and duration of application of RAGT for these patients.

Keywords: Cerebral palsy, Robotics, Motor performance, Gait.

Robot yardımlı yürüme eğitiminin serebral palside motor performans üzerine etkisi: pilot çalışma

Amaç: Serebral palsili (SP) çocukların motor performansları ciddi derecede bozulmuştur. Sp rehabilitasyonunda pek çok rehabilitasyon metodu kullanılmaktadır. Robot yardımlı yürüyüş eğitimi konvansiyonel rehabilitasyonlara ek olarak uygulanan alternatif bir rehabilitasyon sistemidir. Çalışmanın amacı Robot Yardımlı Yürüyüş Eğitiminin (RYYE) SP'li çocuklarda motor performans üzerine etkisini araştırmaktır.

Yöntem: Spastik tip tanılı, 12.83±5.41 yıl yaş ortalamasında olan 17 hasta çalışmaya dahil edildi. Kas tonusu "Modifiye Ashworth Skalası" ile, motor gelişim seviyesi "Kaba Motor Fonksiyon Ölçütü" ile değerlendirildi, Motor performansı değerlendirmek için "Kaba Motor Performans Ölçütü", denge ve koordinasyonu değerlendirmek amacıyla "Pediatrik Denge Skalası" kullanıldı. Düz zeminde yürüme ve merdiven çıkma olarak iki ayrı modda 10 hafta süreyle haftada 3 gün 45 dk olarak tedavi protokolü uygulandı. Eğitimlerde GEO robotik sistemi (Reha-Technology) kullanıldı.

Bulgular: RYYE sonunda motor gelişim seviyesi, motor performans ve denge parametrelerinde anlamlı pozitif değişimler görüldü (p<0.05).

Sonuç: Yürüme ve merdiven çıkma gibi aktiviteleri içeren robot destekli rehabilitasyonun motor performans ve denge üzerine olumlu etkileri vardır. Bununla birlikte RYYE'nin serebral palside uygulanabilirliği açısından, uygulamanın seviyesi veya durasyonu ile ilgili olarak belirli bir protokol veya görüş birliği bulunmamaktadır.

Anahtar kelimeler: Serebral palsy, Robotik, Motor performans, Yürüme.

Tarakçı D, Emir A, Avçıl E, Tarakçı E. Effect of robot assisted gait training on motor performance in cerebral palsy: a pilot study. J Exerc Ther Rehabil. 2019;6(3):156-162. Robot yardımlı yürüme eğitiminin serebral palside motor performans üzerine etkisi: pilot çalışma.



1: Istanbul Medipol University of Health Sciences, Department of Ergotherapy, Istanbul, Turkey

2: Dilbade Special Education and Rehabilitation Centre, Istanbul, Turkey

3: Istanbul University Cerrahpaşa Faculty of Health Sciences, Division of Physiotherapy and Rehabilitation, Department of Neurological Rehabilitation, Istanbul, Turkey

Corresponding author: Ela Tarakçı: fztela@hotmail.com

ORCID IDs (order of authors): 0000-0001-9804-368X; 0000-0002-5993-4153; 0000-0001-5477-240X; 0000-0003-1330-2051

Received: December 25, 2018. Accepted: July 05, 2019.

Cerebral palsy (CP) is defined as a complex condition that involves motor impairments, activity limitations, and participation restrictions that are caused by a lesion in the immature brain.¹ CP is a heterogeneous diagnosis united by the hallmark symptom of a motor control deficit of varying severity across individuals. The treatment goal of physical therapy in CP is to improve motor function and promote independence.² Children with CP have significantly impaired walking capacity because of their motor impairments. These motor impairments are multifactorial such as spasticity, loss of selectivity, and muscle weakness.³

In most cases, children with spastic CP have at least two limbs affected, resulting in impaired gross motor function, hand dexterity, and ambulatory function, decreasing the abilities for self-care and activities of daily living (ADLs).⁴

Walking disorders are a common problem in patients with CP. This motor task has essential role in one's mobility. With new advances in neurorehabilitation, use of body weight-supported treadmill training (BWSTT) gave rise to achieve high repetition and optimal gait pattern in locomotion training. To facilitate delivery of BWSTT, motorized robotic systems which called robot assisted gait training (RAGT) was developed. Accordingly; robot-assisted gait training is used to increase the dose of task-specific gait training in neuro-rehabilitation.⁵ Robot-assisted gait training (RAGT) is increasingly being used to complement conventional physical therapy in paediatric neuro-rehabilitation.^{6,7}

RAGT allows repeating a very large number of steps during a single training session and promotes the movement of limbs and trunk to generate sensory information consistent with locomotion, to enhance neuroplasticity and, thus, to improve the potential for the recovery of walking disability related to CP.⁸

Two types of robotic gait's devices are developed as end-effector and exoskeleton devices. End-effector devices are basically based on a system which works by applying mechanical forces to distal segments of lower limbs. Patient is secured with harness and placed onto footplates which symmetrically stimulate stance and swing phase of walking according to normal gait pattern. Exoskeleton-

type devices consist of robotic gait orthosis to provide simulation of normal walking. In these devices, robotic arms are aligned with anatomical axes of the patient limb thus robotic system can control both distal and proximal segments of the patient lower limb. We used The G-EO System (Reha Technology AG; Olten, Switzerland) in this study, which is an end-effector robotic device with fully programmable footplates for gait and stairs climbing training.^{7,9}

There are randomized controlled studies and pilot studies which aim to investigate effects of RAGT on motor parameters in different neurological disorders such as stroke, spinal cord injuries.¹⁰ However, there are very few studies which come along in CP compared to studies with stroke and spinal cord injuries. And also, no studies specifying utilisation of G-EO system in children with CP was found. Furthermore, the literature is still not clear on which approach to RAGT protocol (treatment duration, intensity etc.) is superior. Additionally, more research is required to explore how the therapy can be improved by changing training intensity as rehabilitation intervention for CP.

The aim of the present study was to investigate the effects of RAGT on muscle tonus, motor performance and balance parameters in children diagnosed with CP.

METHODS

Participants

Seventeen patients (8 females, 9 males) with spastic CP are included in this pilot study. Inclusion criteria were (1) diagnosis of a CP and classified at level II or III according to Gross Motor Function Classification System (GMFCS), (2) ambulatory with or without the use of an assistive device or ankle-foot orthosis, (3) able to follow verbal instructions, (4) physician approval to enter an exercise program. The patients were excluded if they have (1) any other neurologic disorders, (2) complications from other health conditions (cardiovascular or musculoskeletal conditions), (3) contracture or muscle tonus ≥ 3 according to Modified Ashworth Scale (MAS), (4) severe osteoporosis and, (5) mental retardation preventing them from following instructions.

This study was approved by the Istanbul Medipol University Institutional Review Board (10840098-604.01.01-E.7039) and conducted according to the Helsinki Declaration.

Outcome measures

The measurements were performed before the intervention and after the intervention. All assessments were made by the same investigator. Demographic information of individuals recorded to assessment form that is prepared by researchers, iliopsoas, adductor, hamstring, and gastrocnemius muscle tonus assessed with MAS; motor developmental level was assessed with Gross Motor Function Measurement (GMFM); motor performance was assessed with Gross Motor Performance Measurement (GMPM); and balance and coordination was measured with Paediatric Balance Scale (PBS).

MAS is a 6- grade assessment method evaluating muscle tonus by recording resistance against passive motion which is most frequently used method in international platforms. Patients were evaluated in supine and relaxed. Resistance was graded according to evaluation findings of performance through repetitive and rapid movements.

GMFM is an evaluation scale which shows gross motor functions in children and changings in these functions. It consists of successional activities such as supine, prone, crawling position, sitting, kneeling, standing, walking and using stairs. During normal physiological development. It is divided into 5 stages. There are 17 items in Lying-rolling stage, 20 in sitting, 14 in crawling and kneeling, 13 in standing, 24 items in walking-running-climbing stage, thus, there are 88 items in total.

GMPM is a valid and reliable evaluation scale which evaluates movement quality alterations in children with CP which is used on children. Test includes 20 items from GMFM and each one of these items are scored between 1 (severe abnormal) and 5 (normal) according to 3 features which determine performance. These features include, stability, coordination, weight shifting, dissociated movements and smoothness.¹¹

PBS, consists of 14 items, is a modified version of Berg Balance Scale for adults, which is used for children. This test evaluates balance in regard to function and has parameters such as rise from sitting, standing, transfers,

stepping, rotation.^{12,13} This scale is a functional assessment which consists of many maneuver including passing from stable positions to different positions and upright positions. Each one of questions was scored between 0-4. Total score is 56. Higher scores show better balance performance.

Training protocol

After initial assessments, participants who were receiving conventional physiotherapy for 2 days a week were trained for 10 weeks with sessions of 45 minutes consisting treadmill and stairs trainings and supervised by physical therapist 3 times a week, using G-EO robotic systems were designed by Reha Technology. Participants were fitted with a security belt so that a portion of their body weight could be supported when walking in the device Figure 1. Each session was lasted 45 minutes, and included setup, instructions, rest breaks. Manual assistance was not provided by the physical therapist to promote an optimal gait pattern. Verbal encouragement was provided as needed. Participants did not wear their ankle-foot orthosis or use a handrail during training. Body weight support was set as 50% of individual's body weight and ground walking speed was 1.5 km/h constantly.

Statistical analysis

Data which obtained from participants who undergone this training protocol were analysed statistically. The data were evaluated using the Statistical Package for Social Science (SPSS) v.21.0 software for Windows and by analysing descriptive statistics (frequency, mean (X), and standard deviation (SD)). The Mann-Whitney U Test was used to determine the effects of the exercise program. A significance level of 0.05 was used.

RESULTS

A total 27 patients were assessed for eligibility, 6 of them failed to meet the inclusion criteria and 4 patients refused to participate in the study. There was not any dropped-out from the training group during 10 weeks follow up period; a total of 17 patients completed our study.

Demographic and clinical characteristics of patients have shown at Table 1. The comparison



Figure 1. RAGT with G-EO systems including walking and stair climbing.

Table 1. Demographic and clinical characteristics of the children with spastic cerebral palsy.

	X±SD
Age (year)	12.83±5.41
	n
Gender (Female/Male)	8/9
Assistive devices (Yes/No)	4/13
Orthotic devices (Yes/No)	9/8

of the baseline-after training outcome measures (muscle tone values of left-right iliopsoas, adductor, hamstring, gastrocnemius muscles,

supine, prone, sitting, crawling, kneeling, standing, walking values and total values related to GMFM, GMPM and PBS) was presented in Table 2. There was no statistically significant difference is observed in muscle tone after the treatment ($p>0.05$).

Total value of GMFM has found 117.33 ± 66.33 , 126.50 ± 67.92 , before and after training respectively. Biggest differences have seen in standing and walking parameters.

There was significant difference observed in movement quality related to GMPM after the training ($p<0.05$). Statistically significant differences have found after the training related to PBS parameters such as standing from sitting, standing, transfers, stepping, rotation ($p<0.05$).

No adverse events have occurred during the study period of the current study.

DISCUSSION

Present evidences commonly show effects of robot assisted gait training on adults. Therefore, robotic rehabilitation is used more frequently in cases such as traumatic brain injury, stroke, and spinal cord injuries.¹⁴⁻¹⁶ It is observed that in the disease groups mentioned in the robotic rehabilitation, RAGT works with various systems (Lokomat, Volketswil, Switzerland; G-EO Systems, Reha Technology, Olten, Switzerland).¹⁷ But there are limited amount of study in literature using robotic systems which mentioned above on children with CP. On the other hand, the studies in which investigates effect of RAGT in CP have low-level evidence.

Carvalho et al. have investigated effects of RAGT on different motor aspects of CP with a meta-analysis. They included 10 study which is RAGT was used in CP. They suggest that RAGT has positive effect on motor performance in CP, especially on gait speed, endurance and gross motor functioning. They also stated that there is no optimal training protocol or device configuration regarding the studies in this meta-analysis.¹⁸

Borggraffe et al. have found significant improvements on GMFM parameters after 3 weeks robotic-assisted treadmill therapy in children and adolescents with gait disorders.¹⁹

In another study, Ming Wu et al. used a 3D cable driven BWSTT (body weight supported

Table 2. Muscle tone, motor performance and balance parameters baseline and after training.

	Baseline Training X±SD	After Training X±SD	p
Muscle tone			
Iliopsoas- Right	1.99±1.24	1.04±1.12	0.064
Iliopsoas- Left	1.77±0.89	1.11±0.59	0.068
Adductor- Right	1.16±1.16	1.14±1.06	0.789
Adductor- Left	1.12±1.09	1.00±0.49	0.725
Hamstring- Right	1.83±1.16	1.44±1.12	0.074
Hamstring- Left	1.66±1.03	1.43±1.13	0.456
Gastrocnemius- Right	2.00±0.89	1.18±0.99	0.056
Gastrocnemius- Left	1.83±0.98	1.63±0.68	0.869
Gross Motor Function Measurement			
Supine	20.66±10.30	20.38±9.22	0.689
Prone	17.83±9.68	17.53±8.78	0.678
Sitting	40±19.55	41.16±19.11	0.456
Crawl and kneel	19±13.95	19.83±13.70	0.687
Standing	9.00±8.80	12.16±9.45	0.046*
Walking	9.00±8.98	11.83±10.16	0.043*
Total	117.33±66.33	126.50±67.92	0.024*
Gross Motor Performance Measure	102.50±42.87	112.50±44.38	0.038*
Paediatric Balance Scale	11.33±13.41	16.33±14.69	0.045*

* p<0.05.

treadmill training) with a purpose of improving locomotor function. 5 children with spastic CP included in this study and they found improvements on over ground gait speed although these were not significant, GMFM score had improved with no significance.²⁰ Our study has shown similar findings in standing and gait subscales also total score of GMFM according to literature as well, although no significant improvements occurred in muscle tone, significant improvements recorded in gait, standing, subscales and total score of GMFM and PBS.

There is also significant evidence about body weight-supported treadmill training association with neuromagnetic activity of the somatosensory cortices in literature.²¹

Van Hedel et al. studied 67 children with CP retrospectively. They found significant improvements in children with GMFM level IV; however there was no significance between different GMFM level groups in walking related

outcomes.²²

Another study shows effect of BWSTT which compared to over ground walking training improve mobility equally. Therefore robot assisted gait training which uses gait orthoses could be more beneficial to improve mobility.²³

In the view of such information our study was designed to see robot assisted gait training as a dynamic impulse to trigger cortical mapping in cerebrum. As a result of this study, significant changes were obtained particularly on standing and walking parameters. Clinical evaluation parameters were used due to absence of particular evaluation protocol.

Improving walking ability to normal patterns which is given utmost importance to parents and rehabilitation experts is seen as the primary goal of treatment for children with CP.^{19,24} Therefore, treatment and rehabilitation approaches aiming this subject have importance. According to studies, parents may

have very different perspective to medical and rehabilitation interventions.^{21,23,25}

At recently, robot assisted gait training has become popular and preference of parents and physiotherapists with the lack of any specific classification. RAGT which is applied as an addition to neurodevelopmental treatment methods positively effects motor performance and balance activities such as walking, climbing stairs in children with CP. However, there is no specific protocol in which defines robot assisted gait training at what level should be used or how long should be maintained to use. The use of specific, valid and reliable tests for robot assisted gait training could be quite beneficial for planning treatment.

Limitations

The most limiting factors in our study were insufficient number of subjects and absence of a control group to compare. Reasons of these limitations are lack of numbers of institutes which use robot assisted gait training in pediatrics, and transfer difficulties of patients to institutes. Despite the small number of subjects, it is promising to observe positive effects of robot assisted gait training. More studies which have a great number of subjects with CP are needed.

Conclusions

The RAGT has positive effects on the motor performance and the balance parameters in patients with CP. However, there is absence of certain protocol in which to define the level and duration of application of application of RAGT for these patients. There is a need for studies which include more patients with CP regarding the effect of robotics rehabilitation.

Acknowledgement: *We thank to the Dilbade Special Education and Rehabilitation center for performing the conventional training. The authors declare no conflicts of interest.*

Conflict of Interest: *None.*

Funding: *None.*

REFERENCES

- Rosenbaum P, Paneth N, Leviton A, et al. A report: the definition and classification of cerebral palsy April 2006. *Dev Med Child Neurol Suppl.* 2007;109:8-14.
- O'Shea TM. Diagnosis, treatment, and prevention of cerebral palsy in near-term/term infants. *Clin Obstet Gynaecol.* 2008;51:816.
- Graham HK, Rosenbaum P, Paneth N, et al. Cerebral palsy. *Nat Rev Dis Primers.* 2016;2:15082.
- Van Zelst B, Miller MD, Russo RN, et al. Activities of daily living in children with hemiplegic cerebral palsy: a cross-sectional evaluation using the assessment of motor and process skills. *Dev Med Child Neurol.* 2006;48:723-727.
- Beretta E, Romei M, Molteni E, et al. Combined robotic-aided gait training and physical therapy improve functional abilities and hip kinematics during gait in children and adolescents with acquired brain injury. *Brain Inj.* 2015;29:955-962.
- Aurich-Schuler T, Grob F, van Hedel HJ, et al. Can Lokomat therapy with children and adolescents be improved? An adaptive clinical pilot trial comparing Guidance force, Path control, and FreeD. *J Neuroeng Rehabil.* 2017;14:76.
- Schwartz I, Meiner Z. Robotic-Assisted Gait Training in Neurological Patients: Who May Benefit? *Ann Biomed Eng.* 2015;43:1260-1269.
- Hidler J, Wisman W, Neckel N. Kinematic trajectories while walking within the Lokomat robotic gait-orthosis. *Clin Biomech.* 2008;23:1251-1259.
- Mazzoleni S, Focacci A, Franceschini M, et al. Robot-assisted end-effector-based gait training in chronic stroke patients: A multicentric uncontrolled observational retrospective clinical study. *NeuroRehabil.* 2017;1-10.
- Alwardat M, Etoom M, Al Dajah S, et al. Effectiveness of robot-assisted gait training on motor impairments in people with Parkinson's disease: a systematic review and meta-analysis. *Int J Rehabil Res.* 2018;41:287-296.
- Boyce W, Gowland C, Rosenbaum P, et al. Gross motor performance measure for children with cerebral palsy: study design and preliminary findings. *Can J Public Health.* 1991;83:S34-S40.
- Kembhavi G, Darrach J, Magill-Evans J, et al. Using the berg balance scale to distinguish balance abilities in children with cerebral palsy. *Pediatr Phys Ther.* 2002;14:92-99.
- Franjoine MR, Gunther JS, Taylor MJ. Pediatric balance scale: a modified version of the berg balance scale for the school-age child with mild to moderate motor impairment. *Pediatr Phys Ther.* 2003;15:114-128.
- Hayes SC, James Wilcox CR, Forbes White HS, et al. The effects of robot assisted gait training on temporal-spatial characteristics of people with spinal cord injuries: A systematic review. *J Spinal Cord Med.* 2018;1-15.

15. Bergmann J, Krewer C, Bauer P, et al. Virtual reality to augment robot-assisted gait training in non-ambulatory patients with a subacute stroke: a pilot randomized controlled trial. *Eur J Phys Rehabil Med.* 2018;54:397-407.
16. Han EY, Im SH, Kim BR, et al. Robot-assisted gait training improves brachial-ankle pulse wave velocity and peak aerobic capacity in subacute stroke patients with totally dependent ambulation: Randomized controlled trial. *Medicine.* 2016;95:e5078.
17. Esquenazi A, Lee S, Wikoff A, et al. A Comparison of Locomotor Therapy Interventions: Partial Body Weight-Supported Treadmill, Lokomat, and G-EO Training in People With Traumatic Brain Injury. *PM R.* 2017;9:839-846.
18. Carvalho I, Pinto SM, Chagas DD, et al. Robotic Gait Training for Individuals With Cerebral Palsy: A Systematic Review and Meta-Analysis. *Arch Phys Med Rehabil.* 2017;98:2332-2344.
19. Borggraefe I, Klaiber M, Schuler T, et al. Safety of robotic-assisted treadmill therapy in children and adolescents with gait impairment: a bi-centre survey. *Dev Neurorehab.* 2010;13:114-119.
20. Wu M, Kim J, Arora P, et al., editors. Locomotor training through a 3D cable-driven robotic system for walking function in children with cerebral palsy: A pilot study. 2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society; 2014: IEEE.
21. Kurz MJ, Wilson TW, Corr B, et al. Neuromagnetic Activity of the Somatosensory Cortices Associated With Body Weight-Supported Treadmill Training in Children With Cerebral Palsy. *J Neurol Phys Ther.* 2012;36:166-172.
22. Van Hedel HJ, Meyer-Heim A, Rüsç-Bohtz C. Robot-assisted gait training might be beneficial for more severely affected children with cerebral palsy: Brief report. *Dev Neurorehab.* 2015:1-6.
23. Gibson BE, Teachman G. Critical approaches in physical therapy research: investigating the symbolic value of walking. *Physiother Theory Pract.* 2012;28:474-484.
24. Wiart L, Darrah J. Changing philosophical perspectives on the management of children with physical disabilities--their effect on the use of powered mobility. *Disabil Rehabil.* 2002;24:492-498.
25. Garth B, Aroni R. 'I value what you have to say'. Seeking the perspective of children with a disability, not just their parents. *Disabil Soc.* 2003;18:561-576.