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Original article

Effect of Robotic-Assisted Gait Training as Adjunct to Traditional Therapy on Motor Impairments in Children with Cerebral Palsy

Dragana Djurić[1], Snežana Ilić[2], Alameri Shaima[3], Almenhali Ameera[3], Al Yamani Tariq[3]

[1]Insitute of Applied Techology, Fatima College of Health Sciences, Abu Dhabi, UAE
[2]Faculty of Special Education and Rehabilitation, Belgrade, Serbia
[3]Zyed Higher Organisation for People of Determination, Abu Dhabi, UAE

SUMMARY

Aims. The aim of the study was to assess the effectiveness of robotic-assisted gait treadmill training (Lokomat) as an adjunct to traditional physiotherapy in improving the range of motion, muscle strength and decreasing spasticity in lower extremities in children with cerebral palsy.
Materials and Methods. Twenty-six participants, with mean 7.69 ± 2.90 years, levels I-IV on Gross Motor Classification System (38.5% level I-II and 61.5% level III-IV) with a bilateral and unilateral form of cerebral palsy underwent intensive 20 Lokomat and 20 traditional physiotherapy sessions, each training session lasting 40 minutes. Pre- and post-testing was done using goniometer measure, manual muscle testing and modified Ashworth scale.
Results. Positive effects were seen in participant who underwent a combination of Lokomat training and traditional therapy. An increase in the range of motion was minimal (2 - 4 degrees) in hip flexion, extension, and abduction. A significant improvement was achieved in ankle dorsiflexion on the right (p = 0.003) and left side (p = 0.006), while the values of knee extension for the left and right extremity were p = 0.062 left and p = 0.075, respectively. An increase in muscle strength of the lower limb was seen in 30.8% - 80% of participants. Reduction of spasticity in adductors, hamstrings and gastrocnemius were seen in 26.9% of participants.
Conclusion. Lokomat training is an adjunct to conventional physiotherapy treatment. It has a negligible effect on the increase in the range of motion and muscle strength of the lower limb and reduction of spasticity in children with cerebral palsy.

Keywords: **robotic-assisted gait training, cerebral palsy, motor impairments, children**

Corresponding author:
Dragana Djurić
e-mail: dragana.djuric11@gmail.com

INTRODUCTION

Cerebral palsy (CP) is the most common neurodevelopmental disorder involving heterogeneous motor impairments caused by a damage to the fetal or developing brain with an incidence of 2.1. per 1000 born children (1). International Classification of Functioning, Disability and Health (ICF) described impairments as significant deviations or losses in body function and structures of the organism (2). ICF offers a framework for collecting data about the dimensions of impairments, activity limitation, and their correlations and influence on participation restriction. In CP, dysfunction of muscle control leads to spasticity, decreased range of motion (ROM), decreased muscle strength, pathological postures, and gait (3). The relation of neuromusculoskeletal impairments between spasticity, ROM, selective motor control and their influence on activity was discussed in the study of Ostensja et. al. (4). Furthermore, the correlation between gait deviation and motor impairments in children with CP was explored (5).

Robotic-assisted gait training (RAGT) treadmill device, such as Lokomat®Pro (HocomaAG, Switzerland, www.hocoma.com), is the most recognized robotic device for gait training of the neurological patients. LokomatPro consists of two exoskeletons for both legs, suspension system which controls body weight support (BWS), treadmill, monitor for the therapists and a monitor for augmented feedback (6). Control force of Lokomat allowed a physiological walking pattern and intensive training. Motivation and children's active participation are increased by video games, which makes the treatment more amusing (7 - 9). LokomatPro is a safe intervention (10), easier for therapists, involving reduced manual effort in comparison with overground gait training.

The aim of this study was to assess the effectiveness of RAGT (Lokomat), as an adjunct to traditional physiotherapy, in improving the range of motion, muscle strength and decreasing spasticity in children with CP.

PATIENTS AND METHODS

This study was conducted at the Health Care Department, Zayed Higher Organisation for People of Determination, Abu Dhabi, UAE, from 2020 - 2021. The study was approved by the Ethics Committee of Fatima College of Health Sciences, Abu Dhabi, (INTSTF018PHY20). The consent form was signed by the participants' parents before the study started.

This study included 26 children with bilateral and unilateral form of cerebral palsy. Inclusion criteria were: cerebral palsy with spastic and mixed form, levels I to IV on Gross Motor Function Classification System (GMFCS), age range from 4.5 to 14 years, and children able to follow simple instructions. Exclusion criteria were: botox injection within the last six months, surgery on the lower limb within the last year, fixed contractures and bone instability, baclofen infusion pumps in situ, seizure disorder that is not controlled by medication, general contraindication as fracture, open skin lesions or vascular disorders of lower extremities, osteoporosis (11), having participated in another Lokomat training regime within the previous three months.

Demographic data on age, gender, functional level, comorbidities, type of gait, and assistive devices were collected. Assessments were done at two different points – at the baseline and after completing all the treatment sessions. The following outcome measures were used for impairment-based assessment: passive ROM using a goniometer, Manual Muscle Testing using the Oxford scale and Modified Ashworth Scale (MAS) (12) for spasticity of the lower limb muscles. Four physiotherapists were trained in a single, two-hour workshop for accuracy in measuring. All assessors were trained physiotherapists who had experience working with cerebral palsy children and who followed standardized written assessment instructions. To avoid inter-rater bias, all measurements were performed by the same blinded assessors for the same participant. The baseline measures were taken 1 - 2 days prior to the start of the study and again one or two days after completing the 20-treatment sessions.

The Lokomat training included a total of 20 sessions, 5 sessions per week with a training duration of 40 minutes. The conventional training had the same frequency and timing. RAGT protocol included individual adjustment of Lokomat parameters as body weight support and a guiding force, according to the functional level of participants, ROM of hip and knee joints, setting the gait speed all advised by the Practical recommendations for RAGT (11). During the sessions, children were continuously encouraged by the physiotherapist's verbal instruction in addition to supervising the walking posture and speed. Conventional therapy protocol included 20 minutes of individual strengthening exercises (functional strengthening, resistance training, bicycling, isolated strengthening exercises, isometric contractions), 5 minutes of stretching exercise (30 seconds passive or active hold per spastic muscle), 10 minutes of balance exercises (in different positions and different pad softness) and 10 minutes of gait training (parallel bars, over grounded walking, sidewalk, treadmill walk, backward walking). The same therapists have treated the children during the 20 treatment sessions.

Results are presented as count (%), means ± standard deviation. Repeated measurements are compared using a parametric paired-samples t-test. All p values less than 0.05 were considered significant. All data were analyzed using SPSS 20.0 (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.).

RESULTS

The study included 26 participants. As shown in Table 1, the majority of the participants were between 6 and 11.9 years old, and the number of boys was higher than girls. Half of the participants were with diplegia followed by hemiplegia, quadriplegia, mix and triplegia. Most participants were on level II to IV and the least in our study were on level I on Gross Motor Function Classification System (GMFCS).

ROM of the hip, knee, and ankle is presented in Table 2. All results indicated slight improvements in flexion, extension and abduction on both sides of the hip with the p-value closer to the conventional level of significance. No significant differences were observed in knee flexion, but the differences regarding the knee extensions were near the conventional level of significance. Knee extension was increased in six participants; on the initial assessment, 4 participants on level IV had knee contracture of 25 degrees which decreased by 10 degrees with the treatment, and in two of the participants, knee extension was increased by 5 degrees. The results of plantar flexion and dorsiflexion of the ankle indicated a significant improvement on both sides. Dorsiflexion in post-assessment improved between 5 to 10 degrees for seven participants on levels I - IV.

The improvement of muscle strength of hip, knee, and ankle is shown in Table 3. The distribution reveals improvement in at least one third of the

Table 1. *Characteristics of the study population*

	n (%)/mean ± sd
Age	7.69 ± 2.90
< 6	8 (30.8%)
6 - 11.9	14 (53.8%)
12+	4 (15.4%)
Gender male	16 (61.5%)
Form	
Diplegia	13 (50%)
Hemiplegia	7 (26.9%)
Quadriplegia	3 (11.5%)
Mix	2 (7.7%)
Triplegia	1 (3.8%)
GMFCS level	
I	2 (7.7%)
II	8 (30.8%)
III	7 (26.9%)
IV	9 (34.6%)

Results are presented as mean ± sd or count (%)

Table 2. *The range of motion before and after the therapy*

	Before	After	p-value
Hip			
Flex. L	127.8 ± 8.8	129.0 ± 9.1	0.056
Flex. R	127.6 ± 8.6	129.0 ± 8.8	0.070
Ext. L	23.9 ± 8.9	27.0 ± 11.9	0.011
Ext. R	25.0 ± 9.3	27.5 ± 11.9	0.021
Abd. L	30.0 ± 8.8	31.4 ± 8.8	0.018
Abd. R	30.5 ± 7.2	31.7 ± 6.8	0.031
Knee			
Flex. L	141.3 ± 9.1	141.5 ± 8.8	0.327
Flex. R	141.4 ± 9.4	141.8 ± 8.8	0.204
Ext. L	-3.9 ± 8.1	-2.2 ± 4.5	0.062
Ext. R	-4.7 ± 9.5	-2.8 ± 6.1	0.075
Ankle			
Plant. Flex. L	64.6 ± 7.8	66.6 ± 10.0	0.015
Plant. Flex. R	62.4 ± 8.5	65.2 ± 8.9	0.025
Dorsiflex. L	15.5 ± 14.8	22.0 ± 13.0	0.006
Dorsiflex. R	18.4 ± 13.3	22.4 ± 10.2	0.003

Results are presented as mean±sd; paired-samples t test is used in all testing.
Flex – flexion; Ext – Extension; L – Left; R – Right

Table 3. *Distribution of participants with the improvement of muscle strength of hip, knee, and ankle*

	Side	
	Left	Right
Hip		
Iliopsoas	10 (38.5%)	13 (50%)
Gluteus Maximus	8 (30.8%)	8 (30.8%)
Gluteus Medius	10 (38.5%)	10 (38.5%)
Knee		
Quadriceps	17 (68.0%)	20 (80.0%)
Hamstrings	10 (40.0%)	9 (34.6%)
Ankle		
Gastrocnemius	8 (30.8%)	10 (38.5%)
Tibialis Anterior	11 (42.3%)	12 (46.2%)

*Results are presented as count (%)
Percentages are calculated as numbers in table divided by 26 (total number of participants)

Table 4. *Distribution of participants with reduction of spasticity of hip, knee, and ankle muscles*

	Side	
	Left	Right
Hip		
Adductor	7 (26.9%)	7 (26.9%)
Knee		
Quadriceps	2 (7.7%)	5 (19.2%)
Hamstrings	7 (26.9%)	5 (19.2%)
Ankle		
Gastrocnemius	7 (26.9%)	7 (26.9%)

*Results are presented as count (%)
Percentages are calculated as a number in the table divided by 26 (total number of participants)

participants in both hip and ankle. Most of our participants (68% - 80%) showed increase in quadriceps strength.

Reduction in spasticity was seen in participants as shown in Table 4. A quarter of participants revealed a reduction of spasticity of the adductor on both sides. A similar situation was seen in hamstrings and gastrocnemius, while quadriceps showed a lower percentage of improvement.

DISCUSSION

To our knowledge, there are limited studies assessing the impact of RAGT on motor impairments for children with CP using clinical outcome measures. The main reason is the subjectivity of the assessment in children, which depends on their cognitive level, motivation, and attention span (13). Testing by an unfamiliar assessor might also influence results and create inaccuracies in the measurements.

A clinically negligible change in the range of motion of hip joint (less than 4 degree) was recorded in our study. To notice clinically significant difference, an improvement of at least 5 degrees should be seen in CP (14). An in-depth study on adult hemiplegia shows that for minimal clinically important differences (MCID) (15), a minimum of 5.18 degrees in the hip (16) and 8.48 in the knee (17) improvement should be achieved. However, the data is very limited in children with CP.

Knee flexion contracture is seen mostly in CP children with bilateral form, levels III-IV, and ankle contracture in levels I-II (18). Limitation of knee extension of 15 - 25 degrees is considered as mild contracture (19). The exoskeletons allow a degree of flexibility to correct and maintain hip and knee angles during RAGT sessions (10). Fifty percent of the participants in our study walked with excessive hip and knee flexion, and there was no increase in hip extension after RAGT and traditional training. This is contrary to findings of Gelder (14) who found improvement in hip and knee extension with real time visual feedback. This is because our study utilized goniometer, whereas the study by Gelder used gait analysis lab which can measure small changes.

An improvement of knee extension by 10 degree was noticed in our study for a few participants on level IV on GMFCS. An improvement of over 5 degree was seen in milder cases. It is not always possible to identify if this improvement was due to RAGT or regular hamstring stretching during the traditional therapy.

RAGT offers intensive training while maintaining a physiological gait pattern. Elastic foot straps on RAGT allowed stretching of spastic and tight gastrocnemius during initial contact of gait cycle. A significant improvement in ankle dorsi flexion in our study was seen after RAGT sessions and regular stretching exercises of gastrocnemius.

A recent study showed a significant increase of muscle strength in hip abductors and knee flexors on both sides in adult hemiplegic after RAGT (20). Our study showed an overall improvement of strength in all the lower limb muscles. In the majority of participants, an increase in muscle strength of quadriceps was recorded. One of the goals of RAGT is to promote muscle activation by decreasing BWS or adjusting the gait parameters (speed, guidance force). This is to enhance muscle strength and endurance required for their activities of daily living. A similar goal can be achieved through other methods using external resistance and functional exercises (21), which makes it difficult sometimes to determine the exact effect of RAGT. Therefore, this further demonstrates a need for a strict control group for comparisons.

Spasticity is one of the main characteristics in children with CP that increases in the first 5 years of life in all lower limb muscles (22). Hamstring muscle in particular shows a rapid increase not only during the first four years but again during early adolescent years, which leads to knee flexion contracture (23). The level of spasticity in diplegic children is generally high in foot and ankle muscles, which is evident with ankle plantar flexion contracture (24). We noticed a slight reduction of spasticity in adductors, hamstrings, and gastrocnemius muscles. A previous study on spinal cord injury (SCI) shows that Lokomat system is a sensitive device for the evaluation of stiffness and spasticity (25) and is also beneficial for normalizing muscle tone and improving the lower extremity function in people with SCI (26). However, the extent to which RAGT decreases spasticity in CP is still unclear and more research is needed in this area. Improving muscle strength in comparison to reduction of spasticity will result in better physical activity in diplegic children with levels I-III on GMFCS (13, 24).

CONCLUSION

RAGT is an adjunct to conventional physiotherapy. It has a negligible effect on the range of motion, muscle strength, and spasticity of the lower extremities in children with cerebral palsy.

The limitation of this study is the lack of the control group due to the issue of recruiting participants during the Covid-19 pandemic. Lokomat assessment of ROM, isometric strength, and stiffness in hip and knee joints was not done due to the cognitive inabilities of participants. The Three-Dimensional Gait Analyses (3 DGA) was not available to us, which could have given accurate data on the effect of RAGT on motor impairments in children with CP.

More quality randomised controlled studies with better methodology are needed to explore the effects of RAGT on motor impairments in children with CP. The impairments aligned with activity limitation, and participation restriction as per ICF framework should be explored.

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Efekat robotski potpomognutog hoda i tradicionalnog treninga na motorička oštećenja kod dece sa cerebralnom paralizom

Dragana Đurić[1], Snežana Ilić[2], Alameri Shaima[3], Almenhali Ameera[3], Al Yamani Tariq[3]

[1]*Insitut za primenjenu tehnologiju, Fakultet zdravstvenih nauka Fatima, Abu Dabi, Ujedinjeni Arapski Emirati*
[2]*Fakultet za specijalnu edukaciju i rehabilitaciju, Beograd, Srbija*
[3]*"Zajed" rehabilitaciono-obrazovna ustanova za osobe sa posebnim potrebama , Abu Dabi, Ujedinjeni Arapski Emirati*

SAŽETAK

Cilj. Cilj ovog rada bio je da utvrdi efikasnost robotski potpomognutog hoda (Lokomat) i tradicionalnog tretmana na povećanje obima pokreta, mišićne snage i smanjenja spasticiteta na donjim ekstremitetima kod dece sa cerebralnom paralizom.
Metod. Dvadeset šest ispitanika prosečne starosti 7,69 ± 2,90 godina, nivoa I–IV na Sistemu klasifikacije grubih motoričkih funkcija (38,5% nivoa I – II i 61,5% nivoa III – IV) sa bilateralnom i unilateralnom formom cerebralne paralize imali su intenzivni trening od 20 Lokomat i 20 tradicionalnih fizioterapeutskih tretmana, koji su trajali po 40 minuta. Inicijalno i završno testiranje obuhvatilo je merenje obima pokreta goniometrom, manualeni mišićni test i modifikovanu Ašvort skalu.
Rezultati. Pozitivan efekat primećen je kod ispitanika koji su imali Lokomat i tradicionalnu fizioterapiju. Povećanje obima pokreta fleksije, ekstenzije i abdukcuje u zglobu kuka je minimalno (2 – 4 stepena). Značajno povećanje obima dorzifleksije sa vrednostima p = 0,003 na desnoj i p = 0,006 na levoj strani, dok je ekstenzija u kolenu sa vrednostima p = 0,062 na levom i p = 0,075 na desnom ekstremitetu. Povećanje mišićne snage imalo je 30,8 – 80% ispitanika. Smanjenje spasticitea u aduktorima, hamstringsu i gastrocnemiusu je zabeleženo kod 26,9% ispitanika.
Zaključak. Lokomat trening kao dopuna tradicionalnom tretmanu ima zanemarljiv efekat na povećanje obima pokreta, mišićne snage i smanjenja spasticiteta kod dece sa cerebralnom paralizom.

Ključne reči: **robotski potpomognuti trening hoda, cerebralna paraliza, motorička oštećenja, deca**