Impact of robotic gait orthosis training on kinematic parameters in hemiplegic children

Impacto del entrenamiento ortopédico robótico de la marcha en parámetros cinemáticos en niños hemipléjicos

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Abstract

Background: gait disturbance is one of the most common consequences of hemiplegic cerebral palsy characterized by asymmetrical step length and reduced walking speed, robotic gait orthosis therapy is the most effective in gait training and enhance kinematic gait parameters.
Purpose: to evaluate the effect of robotic gait orthosis on kinematic gait parameters in hemiplegic children.
Patient and methods: 40 Cerebral palsy children with spastic hemiplegia ranged from 7 to 12 years old. They were selected from the outpatient clinic of Haven physical therapy center on 6th October city. They were allocated randomly in two groups (20 children each). Group I (control group): received a selected physical therapy program for 3 times weekly for 8 successive weeks. Group II (Study group): received the selected physical therapy program as the control group for 30 minutes in addition to Lokomat gait training for 30 minutes. This program was performed 3 times weekly for 8 successive weeks. Both 3-D kinematic gait analysis and robotic gait orthosis were carried out before and after intervention.
Results: we found statistically significant increase in hip flexor (p=0.05) &hip extensor (p=0.018) & significant decreased in ankle at initial contact (p=0.001) &increase in single limb support (p=0.001) &decreased in cadence (p=0.020) and decreased in speed (p=0.020) at post treatment in study group compared to control group.
Conclusion: Robotic gait orthosis is effective modalities in rehabilitation of children with hemiplegic cerebral palsied, combination between Lokomat and physical therapy program plays an important role in muscle strength and kinematic gait parameters thus improving patient gait pattern.

Keywords

Cerebral palsy; kinematic gait analysis; robotic gait orthosis.

Resumen

Antecedentes: la alteración de la marcha es una de las consecuencias más comunes de la parálisis cerebral hemipléjica caracterizada por una longitud de paso asimétrica y una velocidad de marcha reducida, la terapia ortopédica robótica para la marcha es la más efectiva en el entrenamiento de la marcha y mejora los parámetros cinemáticos de la marcha.
Propósito: evaluar el efecto de la ortesis robótica de la marcha sobre los parámetros cinemáticos de la marcha en niños hemipléjicos.
Paciente y métodos: 40 niños con parálisis cerebral y hemiplejía espástica tenían edades comprendidas entre 7 y 12 años. Fueron seleccionados de la clínica ambulatoria del centro de fisioterapia Haven el 6 de octubre city. Se asignaron al azar en dos grupos (20 niños cada uno). Grupo I (grupo de control): recibió un programa de fisioterapia seleccionado 3 veces por semana durante 8 semanas sucesivas. Grupo II (grupo de estudio): recibió el programa de fisioterapia seleccionado como grupo de control durante 30 minutos, además del entrenamiento de la marcha con Lokomat durante 30 minutos. Este programa se realizó 3 veces por semana durante 8 semanas sucesivas. Tanto el análisis cinemático de la marcha en 3D como la ortesis robótica de la marcha se llevaron a cabo antes y después de la intervención.
Resultados: encontramos un aumento estadísticamente significativo en el flexor de la cadera (p=0,05) y el extensor de la cadera (p=0,018) y una disminución significativa en el tobillo en el contacto inicial (p=0,001) y un aumento en el soporte de una sola extremidad (p=0,001) y una disminución en la cadencia (p=0,020) y una disminución en la velocidad (p=0,020) después del tratamiento en el grupo de estudio en comparación con el grupo de control.
Conclusión: La ortesis robótica para la marcha es una modalidad efectiva en la rehabilitación de niños con parálisis cerebral hemipléjica, la combinación entre lokomat y el programa de fisioterapia juega un papel importante en la fuerza muscular y los parámetros cinemáticos de la marcha, mejorando así el patrón de marcha del paciente.

Palabras clave

Parálisis cerebral; análisis cinemático de la marcha; órtesis robótica de la marcha.

Introduction

Cerebral palsy (CP) is a complex condition that involves motor impairments, activity limitations, and participation restrictions that were caused by a lesion in the immature brain. It is a heterogeneous diagnosis. The physical therapy treatment goal for CP children is to improve motor function and promote independence. 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 (Graham et al., 2016).

Spastic hemiplegia is characterized by affection of one side of the body while the upper limb is more than the lower limb due to larger cortical representation of the hand and the arm (Aicardi, 2009). Voluntary movements are impaired with hand function being most affected. In the lower limb, dorsiflexion and the eversion of the foot are most impaired. There was an increase in flexor tone with hemi paretic posture, flexion at the elbow and wrist, knee and equines position of the foot (Chitra & Nandini, 2005).

Hemiplegic gait is characterized by reduced stride length, gait velocity, cadence and increased energy consumption when compared to normal subjects (Chen et al., 2005). Abnormal patterns in spastic hemiplegia include reduced hip flexion, reduced knee flexion, knee hyperextension during stance and excessive ankle plantar flexion (equinus) during both the swing and stance phase of the gait (De Quatrain et al., 1996). The ankle equinus predisposes to dynamic knee recurvatum (Rose & Gamble, 2006). This can lead to compensatory maneuvers like hip circumduction, hip hiking and contralateral side (Kerrigan et al., 1996).

The children with hemiplegic gait pattern were classified into four types based on sagittal plane kinematics of hemiplegic gait, type 1 characterized by weak or paralyzed dorsiflexors, leading to drop foot. type 2 characterized by problems seen in Type 1 along with triceps surae (calf muscle) contracture, which leads to limited ankle dorsi flexion. type 3 is characterized by problems seen in type 2, in addition to hamstring and rectus fomoris spasticity. Type 4 is characterized by problems seen in type 3, along with spasticity of the hip flexors and adductors (muscles that moves the leg forward and to word midline (Winter et al., 1987).

Kinematic gait analysis studies joint angles and body segment orientation during walking to identify deviation from normal gait. It also helps clinicians understand the specific gait deviations associated with different types of hemiplegic gait (Esquenazi & Talaty, 2011).

Robotic-assisted gait training (lokomat) gives the child the chance to get more walking practice with mechanical help from robots instead of therapists in cases where the child may not be able to make the right movement enough times to improve their gait (Sophie et al., 2017). Numerous studies show evidence that robotic gait orthosis training helps motor recovery also functional improvement (Alcobendas-Maestro et al., 2012).

Moreover, robotic gait orthosis devices have been established to diminish the physical effort as well as time of physiotherapists, also to lengthen the amount of time that gait kinematics are repeated. A device called robotic gait orthosis, which is intended to produce regular walking patterns in the patient's lower limbs (Picelli et al., 2013), is helping patients with gait disorders. Patients walk more quickly and complete more gait cycles during robotic gait orthosis training than they would during traditional gait training (Van Nunen et al., 2012).

Lokomat training is now widely regarded as a viable option for treating a variety of diseases, including SCI, stroke, multiple sclerosis, as well as cerebral palsy, and can be incorporated into the standard therapy program (Riener et al., 2010).

The aim of the study was to quantify the impact of robotic gait orthosis training on kinematic gait parameters during walking in children with hemiplegia.

Did robotic gait orthosis (lokomat) training produce significant improvement in gait kinematic parameters in hemiplegic child?

Method

Study design

The design of the study was Pre- test, post-test randomized controlled trial design. The study was caried out from December 2021 to October 2024. The procedures were carried out according to the Research Ethical Committee of Faculty Physical Therapy, Cairo University, with approval number (P.T.REC\012\003334). Pan African Clinical Trial Registry with the number (PACTR 202202830392683). A signed written consent form authorized children's participation, with parent's or legal guardian's acceptance before starting the study procedures.

Subjects

Forty-eight spastic hemiplegic CP children were selected from 7 to 12 years and were assessed for eligibility. They were randomly assembled into two equal groups (20 children each). A blindfolded independent person selected a piece of paper from a box indicating assigning the child to study or control group odd numbers were assigned to the control group and even numbers were assigned to the study group randomization of subjects (Fig. 1). Children were enrolled in his study if they had grade 1 or 1+ according to modified Ashworth scale and grade I or II according to according to gross motor function classification system (GMFCS). They can understand and follow verbal commands and instructions included in the test, and they had no sensory impairment or other neurological or psychological problems. All participants were excluded from his study if they had any other neurological deficits such as convulsions, involuntary movements, children with impairment of sensation (superficial, deep and cortical), Children with any other diseases such as cardiac disease and with severe mental retardation. Fixed contracture, bone and joint deformities, bone articular instability (joint dislocation). Inflammation of skin (psoriasis or Eczema) and open skin lesion around the trunk or limb.

Sample size

The sample size for this study was calculated using the G*power program (version 3.1.9.2., Franz Faul, Universität Kiel, Germany) for two tailed test. Sample size calculation based on alpha = 0.05, Beta=0.2, and effect size=0.82, and allocation ratio N2/N1=1. The appropriate minimum sample size for this study was 40 children with spastic hemiplegia.

Materials

Materials for assessment and treatment programs:

1. The robotic gait orthosis (Lokomat System V5.0. Hocom AG. Industriestrasse 4CH-8604 Volketswil Switzerland).
2. The gait analysis system: This system was used to evaluate kinematic gait parameters (ankle joints angle at initial contact, single limb support, cadence, and speed).
3. Physical therapy tools (suspension, treadmill and wedge and roll).

Procedures

Procedure for subject selection: The procedures were used for subject selection for both groups as follows:

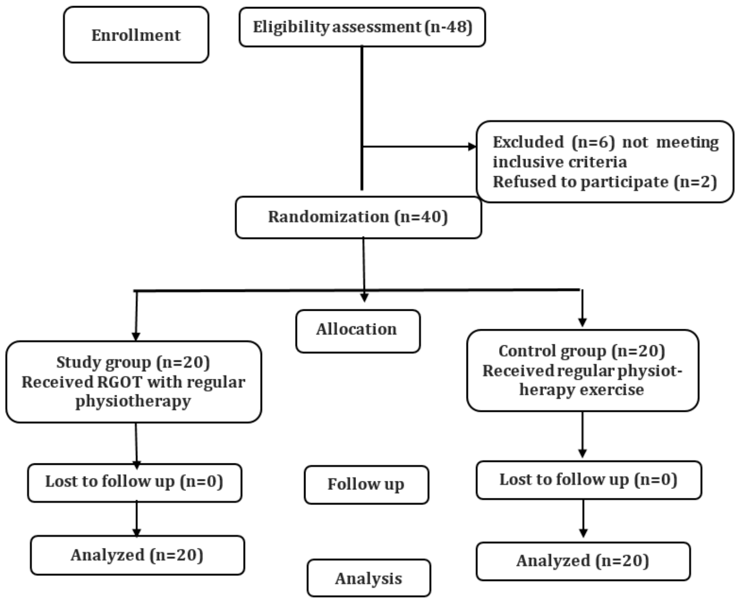
1. Modified Ashworth Scale:

Modified Ashworth Scale was used to determine the degree of spasticity assessment for inclusion criteria. The therapist directed the patient to place the patient in supine position on mate table. The flexor muscle of the joint is placed in a maximally flexed position and moved to maximally extended position over a 1-second span. The extensor muscles of joint are elevated in the beginning position of maximal extension and taken to a maximally flexed (Baunsgaard et al., 2016)

2. Gross Motor Function Classification System:

It was used to assess gross motor function. It is five level classification system focusing on wheelchair mobility, walking and sitting. A child is classified based on their ability to perform certain functional activities such as a child's performance in school, home and community setting and their need for assistive technology (such as canes, crutches, walkers and wheelchair) (Palisano et al., 2008).

Figure 1. Randomization of subjects



3. Weight and height scale:

A universal weight and height scale was used to determine the children's weight and height. (Detecto 448 Eye- level Mechanical Beam Physical scale). made in (USA)

a) Assessment procedure:

1-The gait analysis system: This system was used to evaluate kinematic gait parameters (ankle joints angle at initial contact, single limb support, cadence, and speed) and included the Software, which consists of camera system with three cameras, reflective dots, and a personal computer with installed software (Husemann et al., 2007). Made in Sweden with Serial Number: DAK3EL 15000573.

• Preparation of patient

The patient was asked to take off his/her clothes to expose both lower limbs up to pelvis. Seven reflective dots were placed on the selected bony landmarks by sticky material (at hip, supra patellar, knee, tibial tuberosity, ankle, heel and toes).

• Camera Placement

The three cameras which were used in capturing the patient's motion were arranged on one side of the treadmill at a height of 1.5 to 2 meters.at the level of patient waist.

• Calibration

Before any three-dimensional (3D) capture performance, the camera system was calibrated to assure accuracy of the obtained values.

• Analysis

Dots used for the calculations were then identified. Finally, the calculations were initiated with the run button. When the calculations were completed, the results were displayed showing the calculated gait parameters in tables and figures.

2- Lokomate was used to assess the muscle power (L- force) and range of motion (L-ROM). A maximum voluntary isometric contraction can be measured for 4 muscle groups: hip flexors and extensors, knee flexors and extensors for both right and left legs (Husemann et al., 2007).

1- Engage in the lokomat

The Lokomat passively moves both legs to a 30° hip and45° knee flexion and remains fixed in that position.

Instruct the patient to exert maximum force in the indicated movement direction at the end of the countdown.

2- [Start]

3- Three-second countdown begins:

After the countdown the patient should build up maximum force and hold

b) Training procedures

Group I (control group): received selected physical therapy program for 1 hour (warm up 5 to 7 minutes) and at the end there was (cool down at slow speed for 5 minutes). three times weekly for successive eight weeks. This program includes

Stretching exercise for lower limbs from different positions (supine, sitting and standing). Strengthening exercise in spider cage with different weights & strengthen exercise for back and abdominal muscles. Balance exercise on balance board. standing on one leg with eye open then with eye closed. Gait training on balance beam and stepper walking on wedges. stair climbing, walking on treadmill. generally performing 1 to 3 sets of (8 to 15) repetition for each exercise the gradually increase the repetition (Hollis & Fletcher-Cook, 1999).

Group II (study group): received lokomat gait training in addition to the selected physical therapy program for 1hour.then Lokomat training was performed 3 times weekly for 1 hour (include set up for robotic for 20 minutes and gait training on treadmill for 40 minutes) to total training time, the treadmill speed starts to walk at low speed 0.5 kmph and increased up to 1 kmph as tolerated .distance and amount of loading was recorded during each session to further increase patient's engagement and motivation, virtual reality and computer game technique may be used to provide virtual environment that encourage active participation during treatment.

Robotic gait orthosis was used to train the subjects in gait pattern. The motorized exoskeleton is attached to the patient's knee (4 fingers above knee and 2 fingers below knee) and hip and a spring-loaded stirrup supports the ankle, while a harness for the torso and pelvis provides dynamic body weight support and another cuff above ankle by 2 fingers lowering the child to reach (Husemann et al., 2007).

Data analysis

Data were screened, for normality assumption test and homogeneity of variance. Normality test of data using Shapiro-Wilk, that reflect the data was normally distributed (P>0.05) after removal outliers that detected by box and whiskers plots. Additionally, Levene's test for testing the homogeneity of variance revealed that there was no significant difference (P>0.05). All these findings allowed to conducted parametric and non-parametric analysis. The data is normally distributed and parametric analysis is done. The statistical analysis was conducted by using statistical SPSS Package program version 25 for Windows (SPSS, Inc., Chicago, IL). Quantitative data age, Lokomat force, and gait parameters. Qualitative data are expressed as frequency (percentage) for children gender, MASc, GMFS, and affected side parameters. To compare between both groups for children age used to independent-t test and for categorical variable (gender, MASc, GMFS, and affected side) compared statistically by Chi-square test. The mixed design 2 x 2 MANOVA-test was used for the first independent variable (between subject factors) was the tested groups with 2 levels (study group vs. control group) and the second independent variable (within subject factor) was measuring periods with 2 levels (pre-treatment vs. post-treatment) for compare the tested main test was used to compare between pairwise within and between groups of the tested variables which F was significant from MANOVA test. All statistical analyses were significant at level of probability (P≤0.05).

Results

The results of spastic hemiplegia children for clinical general demographic data (Table 1) and figure (2&3) showed that no significant differences (P>0.05) between study group and control group in mean values of children age (P=0.724) and distributions of children gender (P=0.527), MASc (P=1.000), GMFS (P=0.311), and affected side (P=0.342).

Table 1. Children demographic data in both groups

Items	Groups (Mean ±SD)		P-value
	Study group (n=20)	Control group (n=20)	
Age (year)	10.60 ±1.46	10.45 ±1.19	0.724
Gender (boys : girls)	11 (55.0%) : 9 (45.0%)	9 (45.00%) : 11 (55.0%)	0.527
MASc (1)	20 (100%)	20 (100%)	1.000
GMFS (1 : 2)	1 (5.0%) : 19 (95.0%)	0 (0.0%) : 20 (100%)	0.311
Affected side (right : left)	12 (60.0%) : 8 (40.0%)	9 (45.0%) : 11 (55.0%)	0.342

Quantitative data (age) are expressed as mean ±standard deviation and compared by t-independent test.
Qualitative data (gender, MASc, GMFS, affected side) are reported a frequency (percentage) and compared by Chi-square Test P-value: probability value P-value > 0.05: non-significant

Figure 2. Age of subjects

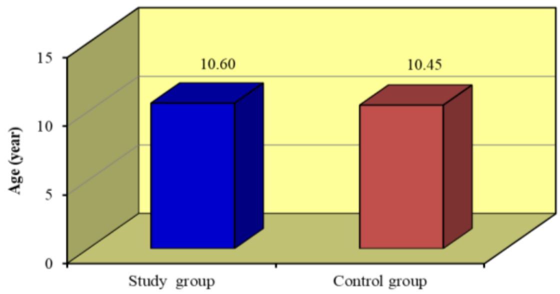
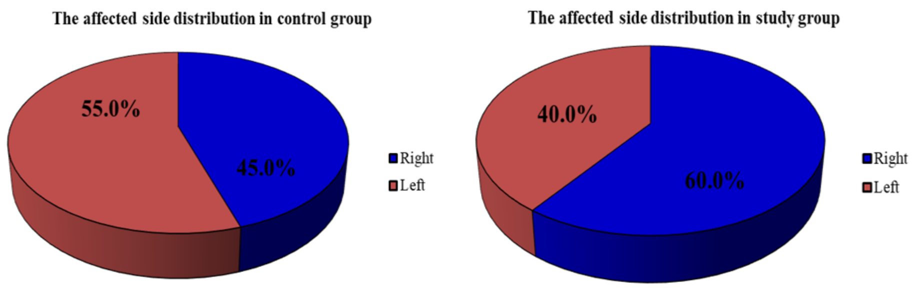


Figure 3. Affected side between groups



The statistical multiple pairwise comparison tests for lokomat force parameters (hip flexors and hip extensors) in spastic hemiplegic children between both groups is presented in Table (2). Fig(4&5) No significant statistical differences (P>0.05) between study group and control group at pre-treatment of hip flexors (P=0.723) and hip extensors (P=0.882). However, there were significant statistical differences (P<0.05) between study group and control group at post-treatment hip flexors (P=0.008) and hip extensors (P=0.042). Moreover, considering the effect of the tested group these significant increases in mean values of hip flexors and hip extensors at post-treatment is favorable for children in study group (19.95 ±8.23 and 16.73 ±7.24, respectively) which received exercise program in addition to lokomat gait training than children in control group (12.59 ±4.12 and 12.08 ±5.21, respectively) which received exercise program only.

The statistical multiple pairwise comparison tests for lokomat force parameters (hip flexors and hip extensors) within each group is shown in Table (2). There were significantly (P<0.05) increased in hip flexors (P=0.005) and hip extensors (P=0.018) at post-treatment compared to pre-treatment within study group. However, there were insignificantly (P>0.05) increased in hip flexors (P=0.614) and hip extensors (P=0.618) at post-treatment compared to pre-treatment within control group. Moreover, children in (study group) more improved hip flexors and hip extensors percentages (63.79 and 48.05%, respectively) than (12.21 and 12.00%, respectively) children in (control group).

Table 2. Within and between groups' comparison for lokomat force parameters

Variables	Items	Groups (Mean ±SD) Study group (n=20)	Control group (n=20)	Change	95% CI	Effect size (η^2)	P-value[2]
Hip flexors	Pre-treatment	12.18 ±5.41	11.22 ±3.86	0.96	-4.44 – 6.37	0.00	0.723
	Post-treatment	19.95 ±8.23	12.59 ±4.12	7.36	1.95 – 12.76	0.09	0.008*
	Change (MD)	7.77	1.37				
	95% CI	2.36 – 13.17	-4.03 – 6.78				
	Improvement %	63.79%	12.21%				
	Effect size (η^2)	0.10	0.01				
	P-value[1]	0.005*	0.614				
Hip extensors	Pre-treatment	11.30 ±5.03	10.96 ±4.45	0.34	-4.13 – 4.80	0.00	0.882
	Post-treatment	16.73 ±7.24	12.08 ±5.21	4.65	0.18 – 9.11	0.05	0.042*
	Change (MD)	5.43	1.12				
	95% CI	0.96 – 9.90	-3.34 – 5.59				
	Improvement %	48.05%	12.00%				
	Effect size (η^2)	0.07	0.01				
	P-value[1]	0.018*	0.618				

Data are reported as mean ± standard deviation (SD) and compared statistically by 2x2 MANOVA test...
MD: Mean difference CI: confidence interval η^2: Eta[2] P-value: probability value * Significant (P<0.05); P-value[1]: Probability value within each gr
P-value[2]: Probability value between both groups

Figure 4. Hip flexor between groups

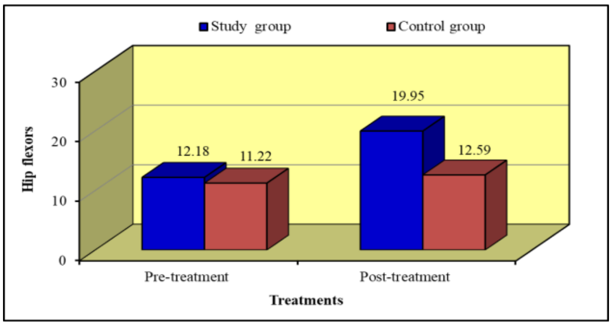
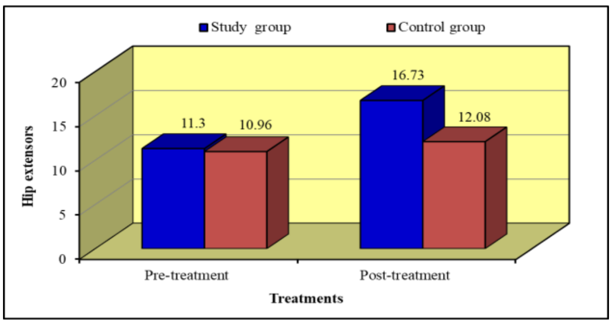


Figure 5. Hip extensor between groups



The statistical multiple pairwise comparison tests for gait parameters (ankle at initial contact, single limp support, cadence, and speed) in spastic hemiplegic children between both groups is presented in Table (3). No significant statistical differences (P>0.05) between study group and control group at pre-treatment of ankle at initial contact (P=0.226), single limp support (P=0.366), cadence (P=0.054), and speed (P=0.578). However, there were significant statistical differences (P<0.05) between study group and control group at post-treatment ankle at initial contact (P=0.010), single limp support (P=0.002), cadence (P=0.0001), and speed (P=0.033). Moreover, considering the effect of the tested group these significant decrease in ankle at initial contact and increases in mean values of single limp support, cadence, and speed at post-treatment is favorable for children in study group (8.19 ±2.57, 19.20 ±5.70, 63.00 ±14.62, and 40.16 ±7.74, respectively) than children in control group (11.65 ±4.13, 14.60 ±3.40, 48.20 ±11.20, and 35.09 ±9.39, respectively).

The statistical multiple pairwise comparison tests for gait parameters (ankle at initial contact, single limp support, cadence, and speed) in children within each group is shown in Table (3). There was significantly (P<0.05) decreased in ankle at initial contact (P=0.0001) at post-treatment compared to pre-treatment within study group. But, in control group, there was insignificantly (P>0.05) decreased in ankle at initial contact (P=0.121) at post-treatment compared to pre-treatment. A significant (P<0.05) increased in single limp support at post-treatment compared to pre-treatment within study group (P=0.0001) and control group (P=0.003). Moreover, there were significantly (P<0.05) decreased in cadence (P=0.020) and speed (P=0.0001) at post-treatment compared to pre-treatment within study group. But, in control group, there were insignificantly (P>0.05) increased in cadence (P=0.505) and speed (P=0.177) at post-treatment compared to pre-treatment. The children in (study group) more improved in ankle at initial contact, single limp support, cadence, and speed percentages (46.44, 67.69, 17.98, and 33.24%, respectively) than children in control group (14.96, 43.84, 5.93, and 11.11%, respectively).

Figure 6. Ankle initial contact between groups

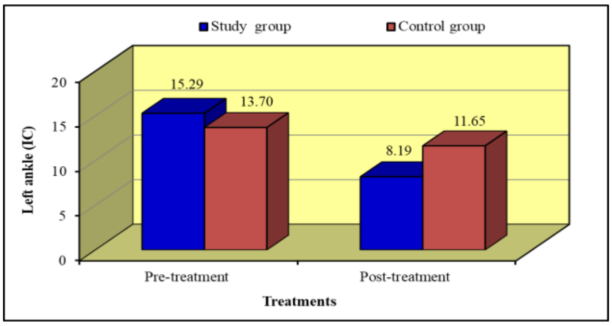


Table 3. Within and between groups comparison for gait parameters

Variables	Items	Groups (Mean ±SD) Study group (n=20)	Groups (Mean ±SD) Control group (n=20)	Change	95% CI	Effect size (η²)	P-value²
ankle at initial contact	Pre-treatment	15.29 ±5.39	13.70 ±3.92	1.59	-1.00 – 4.19	0.02	0.226
	Post-treatment	8.19 ±2.57	11.65 ±4.13	3.45	0.85 – 6.05	0.08	0.010*
	Change (MD)	7.10	2.05				
	95% CI	4.49 – 9.70	-0.55 – 4.65				
	Improvement %	46.44%	14.96%				
	Effect size (η²)	0.28	0.03				
	P-value¹	0.0001*	0.121				
Single limp support	Pre-treatment	11.45 ±4.32	10.15 ±4.35	1.30	-1.54 – 4.14	0.01	0.366
	Post-treatment	19.20 ±5.70	14.60 ±3.40	4.60	1.75 – 7.44	0.12	0.002*
	Change (MD)	7.75	4.45				
	95% CI	4.90 – 10.59	1.60 – 7.29				
	Improvement %	67.69%	43.84%				
	Effect size (η²)	0.28	0.11				
	P-value¹	0.0001*	0.003*				
Cadence	Pre-treatment	53.40 ±13.62	45.50 ±11.16	7.90	-0.12 – 15.92	0.05	0.054
	Post-treatment	63.00 ±14.62	48.20 ±11.20	14.80	6.77 – 22.82	0.15	0.0001*
	Change (MD)	9.60	2.70				
	95% CI	1.57 – 17.62	-5.32 – 10.72				
	Improvement %	17.98%	5.93%				
	Effect size (η²)	0.07	0.01				
	P-value¹	0.020*	0.505				
Speed	Pre-treatment	30.14 ±6.17	31.58 ±8.90	1.44	-3.69 – 6.57	0.00	0.578
	Post-treatment	40.16 ±7.74	35.09 ±9.39	5.07	1.06 – 9.06	0.05	0.033*
	Change (MD)	10.02	3.51				

	95% CI	4.88 – 15.14	-1.62 – 8.64
	Improvement %	33.24%	11.11%
	Effect size (η^2)	0.17	0.02
	P-value[1]	0.0001*	0.177

Data are reported as mean ± standard deviation (SD) and compared statistically by 2x2 MANOVA test.
MD: Mean difference CI: confidence interval η^2: Eta² P-value: probability value * Significant (P<0.05)
P-value[1]: Probability value within each group; P-value[2]: Probability value between both groups

Figure 7. Single limb support between groups

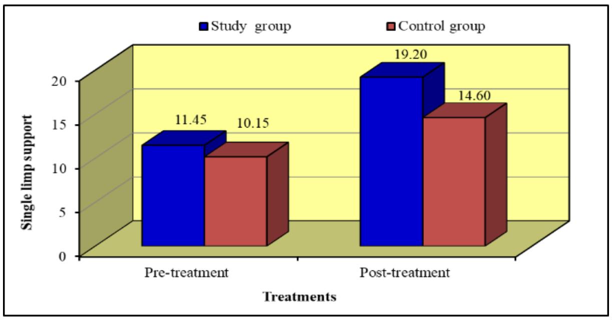


Figure 8. Cadence between groups

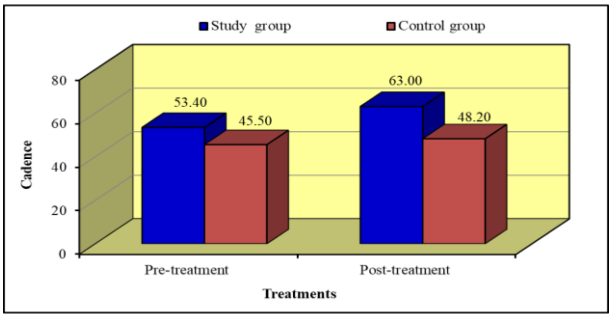
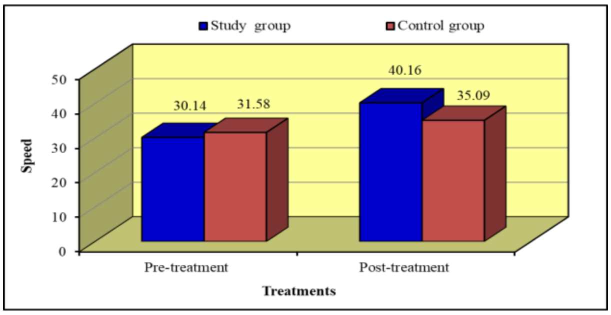


Figure 9. Speed between groups



Discussion

The current study was conducted to explore the effect of robotic gait orthosis training (lokomat) on muscle strength and kinematic gait parameters for hemiplegic cerebral palsied children after eight weeks of treatment. The results obtained from this study clearly demonstrated the positive effects of using robotic gait orthosis (lokomat) training in addition to the physical therapy program in improving Muscle strength and thus improving gait pattern and kinematic gait parameters in hemiplegic cerebral palsied children more than the physical therapy program alone, important methodological and population – related difference should be considered when comparing these finding with previous studies.

The result of the study comes in agreement with Morone et al. (2011) who suggested that combining robotic therapy with conventional therapy may be more effective than conventional therapy alone and utilized higher training intensities and longer intervention periods which may have contributed to larger reported improvements in gait speed and endurance compared with the present study

The hemiplegic gait was characterized by reduced speed, cadence and shortened single limb support on paretic leg dye to muscle weakness and sensory impairment while prolonged single limb support on healthy leg.

Difference in participant's characteristics may also explain variability in outcomes across studies. Several cited studies included children with spastic diapelgia cerebral palsy, who typically present with bilateral lower –limb involvement and different compensatory gait strategies compared with children with hemiplegia included in the present study. Hemiplegic children often exhibit asymmetrical gait patterns, reduced single limb support on paretic side, and greeter inter-limb discrepancies, which may limit direct comparison of effect sizes across populations.

While many previous studies reported statically significant improvement in gait parameters following lokomat training the magnitude of these effects varied substantially .studies with larger sample size and higher training doses generally reported greater effect size, practically for walking speed and endurance.in the present study although significant improvement were observed especially in single limb support , cadence and gait symmetry – the effect sizes may be more modest due to the relative small sample size and shorter intervention duration.

The post treatment results of this study revealed significant improvement in the mean value of all measuring variables of control group receiving traditional exercise program. This significant improvement may be attributed to effect of traditional exercise programs, especially neurodevelopmental approach which was directed toward inhibiting the abnormal muscle tone and abnormal postural reflexes, facilitating normal pattern of postural control (righting and equilibrium reaction), developing a greater variety of normal movement patterns particularly in the trunk and lower extremities (Mattson & Leak, 2024).

Physical therapy program also develops weight shift and reciprocal coordinated movement of the lower limbs, providing postural adapting and finally using these adaptable motor patterns as a basis for the development of skilled functional abilities (Levitt, 2004).

As physical therapy is concerned with resolution of function, quantifying functional progress by assessing clinical changes in motor function in children with cerebral palsy is important, though it is complex task. The accurate detection of changes in function is the essential purpose of an evaluation outcome measure (Guyatt et al., 1987).

These findings are in line with the findings of recent research work done by Fernandes et al. (2012), who stated that Cerebral palsy children carrying spastic diplegia increase their capacity to generate strength when submitted to resistive training not only on lower limbs but also on upper limbs. Several studies have shown that diplegic Children improve their motor ability due to strength training, though it remains to be proved that strength training leads to a substantial change for the better allowing that there is ascension of category for functional capacity.

In the present study, our choice to use stretching exercises was supported by Salem et al. (2010), How reported that prolonged standing imposed stretching on the plantar flexor muscles and resulted in improvement ankle dorsiflexion during midstance. Improvement in this impairment may have resulted in greater excursion of the ankle and foot throughout the stance phase. Allowing the subject to assume better foot alignment, thus enabling proper placement of the foot on the ground for weight acceptance during stance phase.

In our study there was improvement in single limb support for both group, but the most significant improvement was for study group whom received lokomat training in addition to physical therapy program as the patient are able to support their body weight for longer period of time on the paretic leg thus their gait pattern becomes more symmetric that comes in agree with Hassid et al. (1997) : who state that improvement in single limb support due to forced use effect of lokomat or in general of treadmill training .

In the present study there was improvement in cadence and speed for both groups but there was significant improvement in study group due to repetitive task specific training as lokomat training which in agree with Westlake & Patten (2009) who state that lokomat therapy provides repetitive task-specific training that helps improve muscle strengthen, coordination and motor control. Also, it comes in agreement with Lamontagne & Fung (2004) who state that improve in gait speed is probably due to large steps induced by the robot on the paretic side

The results of the study are in line with the findings of recent research work done by Sophie et al. (2017), they stated that robotic assisted gait training (lokomat) affords an opportunity to increase walking practice with mechanical assistance from robotic devices, rather than therapists, where the child may not be able to generate enough or correct motion with sufficient repetitions to promote gait improvement.

The results of the study came in agreement with Andreas et al. (2009), who reported that children with CP benefit from robotic assisted gait training in improving functional gait parameters, so driven gait orthosis training offers a promising treatment option for improvement of walking abilities in children with cerebral palsy. The results of present study supported by Pájaro et al. (2013), who stated that robotic assisted gait training in children with CP results in improvements in walking speed and walking endurance.

In the present study, the mean ankle ROM at initial contact was (study control groups) (15.29 ±5.39&13.70 ±3.92) Pretreatment the ankle remained in plantar flexion at initial contact. Which comes in agree with Frontera & DeLisa (2010) who state that A plantar flexed ankle will result in a forefoot contact or toe strike instead of a heel strike. This may be due to weakness of the tibialis anterior and other Dorsiflexors or due to gastro soleus spasticity or tendon Achilles contracture.

According to Bonnyaud et al. (2014) who state that robotic gait training system can help strengthen ankle muscles through repetitive movement of legs which help improve muscle strength and endurance and provide proprioceptive feedback, which improve muscle activation and strength of ankle joint muscles which lead to increase ankle stability.

Conclusions

Robotic gait orthosis is effective modalities in rehabilitation of children with hemiplegic cerebral palsied, combination between Lokomat and physical therapy program plays an important role in muscle strength and kinematic gait parameters thus improving patient gait pattern.

Limitations

The study was limited to the high cast of robotic gait orthosis(Lokomat)device and limited of physical therapy centers where the device present. There is limited research studying the impact of robotic gait orthosis training on muscle strengthen and gait improvement in hemiplegic cerebral palsy children and there is no research studying its intermediate effect.

Despite the positive findings of the present study, several limitations should be acknowledged. First, the small sample size limits the statically power of the study and increases the ability to detect smaller but clinically meaningful differences between groups and limits the robustness of the findings.

Second, the study design involved a lack of blinding of participants and therapists, which is difficult to avoid in rehabilitation interventions but may have introduced performance and measurement bias.

Third, the shorter follow up period restricts interpretation of the long – term effectiveness and sustainability of the observed improvements.

References

Aicardi, J. (2009). Diseases of the nervous system in childhood (3rd ed.). MacKeith Press.
Alcobendas-Maestro, M., Esclarin-Ruz, A., Casado-López, R. M., Muñoz-González, A., Pérez-Mateos, G., González-Valdizán, E., et al. (2012). Lokomat robotic-assisted versus overground training within 3 to 6 months of incomplete spinal cord lesion: Randomized controlled trial. *Neurorehabilitation and Neural Repair*, 26, 1058–1063.
Andreas, M., Ammann, R., Schmartz, A., et al. (2009). Improvement of walking abilities after robotic-assisted locomotion training in children with cerebral palsy. *Archives of Disease in Childhood*, 94, 615–620.
Baunsgaard, B., Nissen, U. V., & Christensen, B. (2016). Modified Ashworth Scale and spasm frequency score in spinal cord injury: Reliability and correlation. *Spinal Cord*, 54(9), 702–708.
Bonnyaud, C., Zory, R., Boudarham, J., et al. (2014). Effect of robotic restraint gait training versus conventional gait training on gait parameters in stroke patients. *Experimental Brain Research*, 232(1), 31–42.
Chen, G., Patten, C., Kothari, D., et al. (2005). Gait differences between individuals with post-stroke hemiparesis and non-disabled controls at matched speeds. *Gait & Posture*, 22(1), 51–56.
Chitra, S., & Nandini, M. (2005). Cerebral palsy: Definition, classification, etiology and early diagnosis. *Indian Journal of Pediatrics*, 72, 865–868.
De Quatrain, I. A., Simon, S. R., Lauran's, S., et al. (1996). Gait pattern in the early recovery period after stroke. *The Journal of Bone and Joint Surgery*, 78(10), 1506–1514.
Esquenazi, A., & Talaty, M. (2011). Gait analysis: Technology and clinical applications. *Physical Medi-cine and Rehabilitation*, 99–116.
Fernandes, M., Maifrino, L., Monte, K., et al. (2012). Effectiveness of resistance training exercises in spastic diplegic cerebral palsy: A systematic review. *[Journal Name]*, 29(3), 125–128.
Frontera, W. R., & DeLisa, J. A. (2010). Human walking. In DeLisa's physical medicine & rehabilitation: Principles and practice (5th ed., pp. 121–139). Lippincott Williams & Wilkins.
Graham, H. K., Rosenbaum, P., Paneth, N., et al. (2016). Cerebral palsy. *Nature Reviews Disease Primers*, 2, 15082. https://doi.org/10.1038/nrdp.2015.82
Guyatt, G., Walter, S., & Norman, G. (1987). Measuring change over time: Assessing the usefulness of evaluative instruments. *Journal of Chronic Diseases*, 40, 171–180.
Hassid, E., Rose, D., Commisarow, J., Guttry, M., & Dobkin, B. H. (1997). Improved gait symmetry in hemiplegic stroke patients induced by body weight-supported treadmill stepping. *Neurorehabilitation and Neural Repair*, 11, 21–26.
Hollis, M., & Fletcher-Cook, P. (1999). Practical exercise therapy (4th ed.).
Husemann, B., Müller, F., Krewer, C., et al. (2007). Effects of locomotion training with assistance of a robot-driven gait orthosis in hemiparetic patients after stroke. *Stroke*, 38, 349–354.
Kerrigan, D. C., Deming, L. C., & Holden, M. K. (1996). Knee recurvatum in gait: A study of associated knee biomechanics. *Archives of Physical Medicine and Rehabilitation*, 77(7), 645–650.
Lamontagne, A., & Fung, J. (2004). Faster is better: Implications for speed-intensive gait training after stroke. *Stroke*, 35(11), 2543–2548.
Levitt, S. (2004). Treatment of cerebral palsy and motor delay (4th ed.). Blackwell Scientific Publications.
Mattson, M. P., & Leak, R. K. (2024). The hormesis principle of neuroplasticity and neuroprotection. *Cell Metabolism*, 36, 315–337. https://doi.org/10.1016/j.cmet.2023.12.022
Morone, G., Bragoni, M., Iosa, M., De Angelis, D., Venturiero, V., Coiro, P., et al. (2011). Who may benefit from robotic-assisted gait training? A randomized clinical trial in patients with sub-acute stroke. *Neurorehabilitation and Neural Repair*, 25, 636–644.
Pájaro, M., Shetye, R., Gallegos, J., Pons, J., Torricelli, D., et al. (2013). Robotic-assisted gait training in children with cerebral palsy in clinical practice. In Converging Clinical and Engineering Research on Neurorehabilitation (Vol. 1, pp. 29–33). Springer.
Palisano, R., Rosenbaum, P., Bartlett, D., & Livingston, M. (2008). Content validity of the expanded and revised Gross Motor Function Classification System. *Developmental Medicine & Child Neurology*, 50(10), 744–750.
Picelli, A., Melotti, C., Origano, F., Neri, R., Waldner, A., & Smania, N. (2013). Robot-assisted gait training versus equal intensity treadmill training in patients with mild to moderate Parkinson's disease: A ran-domized controlled trial. *Parkinsonism & Related Disorders*, 19, 605–610.

Riener, R., Lunenburger, L., Maier, C., et al. (2010). Locomotor training in subjects with sensorimotor deficits: An overview of the robotic gait orthosis Lokomat. *Journal of Healthcare Engineering*, 1(2), 197–216.
Rose, J., & Gamble, J. G. (2006). Human walking (3rd ed.). Lippincott Williams & Wilkins.
Salem, Y., Lovelace-Chandler, V., Zabel, R., et al. (2010). Effects of prolonged standing on gait in cerebral palsy. *Physical & Occupational Therapy in Pediatrics*, 30(1).*
Sophie, L., Remo, R., & Susan, H. (2017). The effectiveness of robotic-assisted gait training for pediatric gait disorders: A systematic review. *Journal of NeuroEngineering and Rehabilitation*, 14, 1.
Van Nunen, M. P. M., Gerrits, K. H. L., De Haan, A., & Janssen, T. W. J. (2012). Exercise intensity of robot-assisted walking versus overground walking in non-ambulatory stroke patients. *Journal of Re-habilita-tion Research and Development*, 49, 1537–1546.
Westlake, K. P., & Patten, C. (2009). Pilot study of Lokomat versus manual-assisted treadmill training for locomotor recovery post-stroke. *Journal of NeuroEngineering and Rehabilitation*, 6, 18.
Winter, D. A., Gage, J. R., & Hicks, R. (1987). Gait patterns in spastic hemiplegia in children and young adults. *The Journal of Bone and Joint Surgery*, 69, 437–441.

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