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Original Article

Efficacy of Task-Oriented Circuit Training on Gait Kinematics, Pelvic Symmetry and Trunk Endurance in Children with Hemiplegia: A Randomized Controlled Trial

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Abstract

Objectives: Children with hemiplegia often experience motor problems that primarily affect one side of their body. They frequently struggle with asymmetrical gait patterns, pelvic imbalance affecting stability, and reduced trunk muscle endurance, all of which impact their overall mobility and coordination. The purpose of this study was to examine the effect of task-oriented circuit training program in improving kinematic gait parameters, pelvic symmetry, and trunk endurance in children with hemiplegia. **Methods**: A total of forty children diagnosed with hemiplegia between the ages of 7 and 10 years were randomized into both control and study groups. The control group was given a specially designed physiotherapy program, while the study group was given the identical program applied to the control group, combined with a 12-week task-oriented circuit training intervention. Gait kinematics were assessed using two-dimensional motion analysis, pelvic symmetry was evaluated through a palpation meter inclinometer, and trunk endurance was measured using four validated tests. **Results**: A significant improvement was observed in both groups in all outcome measures post-treatment when compared to the baseline mean values in favor to the study group ($p<0.05$). **Conclusions**: Task-oriented circuit training in conjunction with a designed physiotherapy program is more effective in improving gait kinematics, pelvic symmetry, and endurance of trunk muscles among children with hemiplegia. ClinicalTrials.gov ID: NCT04761263.

Keywords: Cerebral Palsy, Gait Kinematics, Pelvic Symmetry, Spastic Hemiplegia, Trunk Endurance

Introduction

Cerebral palsy (CP) is a nonprogressive motor disorder caused by a lesion or abnormality in the developing brain that impairs movement or posture and usually manifests before the age of three years old. As an umbrella diagnosis, CP involves a wide variety of impairments, severity levels, and co-morbidities, although the result must be activity limitation[1]. The worldwide prevalence of CP is thought to be between 1.5 and 4 cases per 1,000 live births, making it a prevalent motor disability in childhood[2]. Spasticity is the primary motor dysfunction observed in the majority of children with CP[3].

Hemiplegia is regarded as one of the most common types of CP. It is defined by motor and sensory impairments that predominantly affect one side of the body[4].

Children with hemiplegia have difficulties in functional activities, which severely affects the children's quality of life. Children with these conditions often experience difficulties such as compromised trunk control, pelvic asymmetry, imbalance, and asymmetrical gait[5]. They tend to develop impaired coordination of movement, diminished synchronization between limbs, and less weight-bearing on the involved side, which sequentially can influence the capacity to keep an upright weight-bearing position, as well as gait. Later in adulthood, their diminished strength

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and endurance in the primary muscular groups are a result of their restricted movement patterns. Furthermore, due to motor disorders affecting half of the body, children may exhibit restricted ability to change their lower extremities' posture in response to certain external disruptions[6].

Hemiplegic children with GMFCS levels I and II exhibited weak frontal and dorsal trunk muscles, which led to poor core stability. Therefore, training programs for ambulant children should continue to focus on strengthening both their trunk and their limbs[7].

More recently, task-oriented circuit training (TCOT) has emerged as a method of rehabilitation that relies on motor control theory. Therapeutic interventions focused on motor learning provide patients with sensory stimulation and functional activities. Therapists create activities or tasks to help children with CP improve their motor skills, taking into account their specific capabilities and training goals. Increasing daily life operational skills has been shown to be a more effective therapy technique[8]. In school-aged children with hemiplegia, intensive task-oriented motor skill acquisition interventions increase motor function and everyday activities more than normal care[9]. Interventions promote function through neuroplasticity[10]. Early in life, environmental experience causes the most activity-dependent brain reconfiguration. This window of opportunity to intervene in children with hemiplegia may optimize functional changes, improve the developmental curve, and reduce problems[11].

Targeted interventions like TOCT may influence gait quality, pelvic alignment, and trunk muscle endurance, enhancing functional mobility and preventing discomfort or pain[12]. Most researchers agreed that TOCT effectively improves motor performance[13,14]. Despite the benefits of this type of training, there was not enough evidence to figure out how TOCT affects children with hemiplegia in terms of their ability to walk and endurance compared to other conventional methods. The present study hypothesizes that TOCT may improve gait kinematics, pelvic symmetry, and trunk endurance among children with hemiplegia. So, this study aimed to identify the impact of TOCT on gait kinematics, pelvic symmetry, as well as endurance in children with hemiplegic CP.

Materials and Methods

Study Design

This study was a prospective single-blinded randomized controlled trial that was carried out in the outpatient clinic of the pediatric physical therapy department at the Faculty of Physical Therapy, Cairo University, between October 2021 and January 2023.

Participants

Forty children of both genders diagnosed with hemiplegic CP were enrolled in this study. The sample size for this study was calculated utilizing the G*power program 3.1.9 (version 3.1, Heinrich-Heine-University, Düsseldorf, Germany). Calculations were done using α=0.05, power 80%, effect size = 1.104 and allocation ratio N2/N1 =1 with 2 independent groups comparison. The minimal proper sample size for this study was 36 children, which was increased to 40 children for possible dropout (20 children in each group).

The children were between 7 and 10 years old. Their motor function was at a level I or II based on the GMFCS[15], while the degree of spasticity was grade 1 to 1+ based on the Modified Ashworth Scale[16]. Children were excluded from the study if they had visual or hearing loss, mental retardation, seizures, cardiovascular or pulmonary problems, a botulinum toxin injection in the previous six months, a lower extremity surgery, musculoskeletal disorders, or structural deformities in the spine and/or lower limbs.

Randomization

Sixty-seven children with hemiplegic CP were enrolled in this study. Eligibility, inclusion, and exclusion criteria were initially determined by screening and evaluation. Twelve of the 67 children selected for this study failed to fulfill the inclusion criteria, whereas the parents of another ten refused to participate, and five had difficulties with transportation. Forty children participated in the study (15 boys and 25 girls). As highlighted in the study's flowchart (Figure 1), A blind individual selected sealed opaque envelopes from a box in numerical order to randomly assign the children into two groups of twenty; each envelope included a letter identifying whether the child was part of the control group or the study group.

Children in the control group were given a specially designed physiotherapy program for 90 minutes, 3 sessions a week for 3 sequential months, while children in the study group were given the identical program applied to the control group for 45 minutes, combined with a 12-week TOCT intervention, according to the protocols of Kumar and Ostwal (2016)[17] and Schranz et al. (2018)[18].

Outcome Measures

At baseline as well as 3 months post-treatment, all children were assessed for kinematic gait parameters such as spatiotemporal (step length, stride length, walking speed and cadence) and lower limb joints' angular displacement (ankle joint's angle at initial contact, knee joint angle at midstance as well as hip joint angle at terminal stance) by using the Kinovea software. The isometric tests reported for testing trunk endurance were the prone blank test, timed partial curl-up test, unilateral bridge test as well as the front abdominal power test. Pelvic symmetry, including anterior and lateral tilting as well as height discrepancy, was measured using the palpation meter inclinometer (PALM).

Procedures of evaluation

<u>1. Kinematic gait parameters</u>

Step length and stride length were measured using Kinovea software, a free 2D motion analysis software that

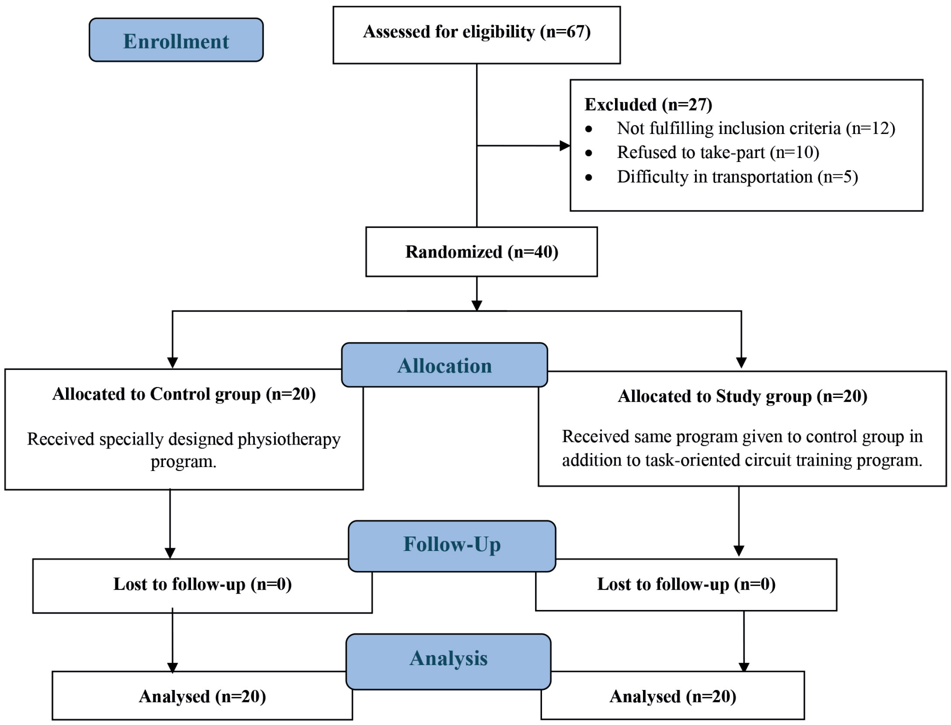

Figure 1. Flow chart of study participants.

uses angle and tracks path tools to analyze position, velocity, and acceleration data. It is a valid, precise, and reliable program with which we can obtain angles and distance data from coordinates[19].

a. Spatio-temporal parameters

A video camera placed on a tripod was positioned five meters from the ten-meter walkway. The next step was to have the children walk at a speed that felt appropriate for them. The recording area should be 10 meters in diameter (6 meters for data collecting, with 2 meters for acceleration and 2 meters for deceleration). The recording began upon the children's entrance into the recording area and ended upon their leaving it[19,20].

The Kinovea software was used to mark the initial contact for each limb in the video. The step length was calculated by measuring the distance between the initial contact between the two limbs. Stride length was calculated by measuring the distance between the initial contacts of a single limb. The child's walking speed was calculated by dividing the distance (6m) by the time it takes to traverse the distance. In contrast, cadence was calculated by dividing the number of steps completed in the 6m by time.

b. The angular displacement of lower limb's joints

For measuring lower limb joints' angles, the video was analyzed in slow motion and monitored frame by frame. Proper frames were selected; lines and arrows were added to measure angles of ankle dorsiflexion during initial contact, knee extension during midstance, and hip extension during terminal stance[20]. These three angles were selected because they are the most common gait deviations concerning kinematic gait parameters in children with hemiplegic CP[21].

- Measuring hip joint's angle

A line was marked between the ASIS and the PSIS. An additional line is drawn through the greater trochanter at a right angle to this one. The angle created by the latter and the line from the greater trochanter to the lateral femoral condyle determines the range of motion (ROM) of the hip joint[20].

- Measuring knee joint's angle

A line was delineated connecting the reference points of the greater trochanter and femoral condyle, and a 2nd line connecting the femoral condyle and lateral malleolus. The angle generated by the intersection of the two lines was utilized to determine the ROM of the knee joint. A knee angle of 180° was designated as the neutral position. The joint range is determined using the following equation:

The ROM of the knee joint is calculated as 180 degrees minus the angle acquired using Kinovea®. Positive values indicate knee flexion, while knee extension is indicated by negative values[20].

- Measuring ankle joint's angle

A line was delineated connecting the markers located at the head of the 2nd metatarsal with the calcaneus. The ankle joint range was determined using the angle created between this and the line that passes through the lateral malleolus and femoral condyle; 90° was thought to be the ankle's neutral position. The joint range is determined using the following equation:

The ROM of the ankle joint is calculated as 90 degrees minus the angle measured using Kinovea® software. Positive values indicate dorsiflexion, while plantar flexion is indicated by negative values[20].

2. Pelvic symmetry

Anterior, lateral tilting as well as height discrepancy, were measured using PALM. It involves two caliper arms and an inclinometer. The device is valid and reliable for measuring pelvic inclination. Pelvic tilting angles were measured in a standing position. The caliper determines the distance in centimeters between the fingers, and the inclinometer determines the degrees of inclination between them[22].

- Measurement of anterior pelvic tilting

The measurement was taken by contacting the ipsilateral ASIS and PSIS with the caliper points of the inclinometer. A positive (+) number indicates the anterior pelvic tilt angle, whereas a negative (-) value indicates the posterior pelvic tilt angle[23].

- Measurement of lateral pelvic tilting and height difference

The measurement was taken by placing the inclinometer's caliper tips on both ASIS. It was developed that the inclinometer ball should move to the side of the lower leg. Then, the PALM calculator was used to determine the magnitude of the difference in the height of the pelvic crest. Using the unique slide ruler calculator, the examiner can discover the height discrepancy between the two chosen landmarks[24].

3. Trunk muscles' endurance

The four tests used to determine the endurance of the isometric trunk muscles were the prone plank, timed partial curl-up, front abdominal power, as well as unilateral supine bridge tests.

- Prone plank test

In a prone position, the child was directed to lift his or her weight onto their toes and forearms. As in a "plank" position, the scapulae should be adducted, the elbows beneath the shoulders, while the hips should be level with the spine. Count the number of seconds the child assumes a plank position[25].

- A timed partial curl-up test

The child's position was in a crock-lying position with arms at the sides. The child was asked to do trunk flexion. Count the number of seconds the child can assume this position[26].

- The front abdominal power test

Provide the child with a 2-kg medicine ball. By maintaining their arms straight, the child was instructed to explosively throw the medicine ball forward while raising their arms high. All children are required to keep both feet flat on the floor. Measure the path the ball took from the child's toes to the ground[27].

- The Unilateral supine bridge test

The child is lying supine with his arms across his chest and his legs flexed. The therapist asked the child to make a double-leg bridging by raising both hips. Once the child has reached a neutral position of the spine and pelvis, the child was instructed to raise one knee so their leg is straight and their thighs are parallel. Measure how long they can hold this position. When the child can no longer maintain a neutral pelvic position, the test is ended[28].

- Intervention

a. Specially designed physiotherapy program

The following exercises were included in the specially designed physiotherapy program according to Page (2012)[29] and Macias-Merlo et al. (2015)[30] that was given to both groups:

- Proprioceptive and balance training in different directions from standing position.
- Stretching exercises for short muscles such as hip flexors and adductors, knee flexors, and ankle plantar flexors.
- Strengthening exercises include functional training for trunk as well as both lower extremities.
- Facilitation of postural mechanisms, including counterpoising, rising, postural fixation and postural reaction from different positions.
- Gait training activities in different directions using different obstacles, including walking on a balance board, balance beam, and stepper and ascending & descending stairs.

b. Task-oriented circuit training program (TOCT)

Children in the study group were given the identical program applied in the control group for 45 minutes combined with 45 minutes of TOCT intervention, which was 3 sessions per week for 3 successive months. It consisted of 14 workstations according to the protocol of Kumar and Ostwal (2016)[17] and Schranz et al. (2018)[18]. The workstations and their progressions are mentioned in Table 1. Each station required 1.5 minutes. After finishing an activity at one station, the child proceeded to the next. With a three-minute rest in between each circuit, the whole circuit takes about twenty-one minutes to complete and is repeated two times in each session[17,18].

Table 1. Task-oriented circuit training program.

Workstations	Progression
1. Standing and reaching in different directions for objects located beyond arm's length.	-At various distances from their body (near, far). - At various heights from their body (above head, at shoulder level, below shoulder level).
2. Sit to stand.	- On several chair heights. - Carrying an object during the task.
3. Stepping in different directions.	- On various heights of the blocks - On firm and soft surface.
4. Alternating heel and toes raising and lowering.	- Increasing the number of repetitions completed within the station.
5. Squatting exercise.	- Reducing the depth of squat. - Increasing the time. - Adding weights to hands.
6. Supine straight leg raising exercise.	- Adding a small cuff weight to child's leg.
7. Ascending & descending stairs.	- Increasing the number of repetitions completed within the station. - Adding a small cuff weight to child's leg. - Carrying an object during the task.
8. Backward walking.	- Start near the wall then progress to the center of the workstation. - Shuttle runs.
9. Walking on a balance beam.	- Increasing the speed of movement. - Changing the surface (hard then soft).
10. Crunch core exercises.	- Increasing the number of repetitions completed within the station.
11. Supine bridge exercises.	- Increase knee flexion. - Increasing the number of repetitions completed within the station.
12. Prone opposite arm/leg raise exercise.	- Increasing the number of repetitions completed within the station for each side.
13. Side bridge exercises.	- Increasing the number of repetitions completed within the station.
14. Cycle training using a stationary bicycle.	- Changing direction. - Increasing resistance.

Table 2. Children's general characteristics in both groups.

Variables	Groups (Mean ±SD)		*p*-value
	Control group (n=20)	Study group (n=20)	
Age (years)	8.43 ±1.07	8.70 ±1.14	0.438
Weight (kg)	27.46 ±8.70	27.20 ±7.02	0.914
Height (cm)	122.20 ±11.48	125.20 ±10.63	0.397
BMI (kg/m²)	18.18 ±4.15	17.11 ±2.98	0.353
Gender (Boys: Girls)	7 (35%): 13 (65%)	9 (45%): 11 (55%)	0.519
GMFCS (Level I: Level II)	14 (70%): 6 (30%)	15 (75%): 5 (25%)	0.723
Degree of spasticity (1: 1+)	3 (15%): 17 (85%)	6 (30%): 14 (70%)	0.256
Affected side (Right: Left)	14 (70%): 6 (30%)	11 (55%): 9 (45%)	0.327

Quantitative data (age, weight, height) are reported as mean ±standard deviation and compared by t-independent test. Qualitative data (gender, GMFCS, Degree of spasticity, affected side) are reported as frequency (percentage) and compared by Chi-square test. p-value: probability value. p-value > 0.05: non-significant.

Table 3. Within and between groups comparison for kinematic parameters of gait.

Variables	Items	Groups (Mean ±SD)		MD	*P*-value
		Control group (n=20)	Study group (n=20)		
Step length (m)	Pre-treatment	0.42 ±0.03	0.43 ±0.03	0.01	0.767
	Post-treatment	0.43 ±0.04	0.49 ±0.02	0.06	0.0001*
	Change (MD)	0.01	0.06		
	Change %	2.38%	13.95%		
	P-value	0.526	0.0001*		
Stride length (m)	Pre-treatment	0.80 ±0.08	0.84 ±0.05	0.04	0.103
	Post-treatment	0.85 ±0.09	0.90 ±0.03	0.05	0.040*
	Change (MD)	0.05	0.06		
	Change %	6.25%	7.14%		
	P-value	0.028*	0.0001*		
Cadence (steps/min)	Pre-treatment	117.70 ±17.30	120.20 ±13.22	2.50	0.592
	Post-treatment	107.35 ±17.50	97.70 ±8.94	9.65	0.041*
	Change (MD)	10.35	22.50		
	Change %	8.79%	18.72%		
	P-value	0.029*	0.0001*		
Walking speed (m/min)	Pre-treatment	0.60 ±0.16	0.58 ±0.16	0.02	0.718
	Post-treatment	0.67 ±0.17	0.80 ±0.13	0.13	0.012*
	Change (MD)	0.07	0.22		
	Change %	11.67%	37.93%		
	P-value	0.183	0.0001*		
Ankle joint angle in initial contact (degrees)	Pre-treatment	-12.75 ±2.02	-13.20 ±1.47	0.45	0.384
	Post-treatment	-10.84 ±1.94	-7.70 ±0.73	3.14	0.0001*
	Change (MD)	1.19	5.50		
	Change %	14.98%	41.67%		
	P-value	0.0001*	0.0001*		
Knee joint angle in mid stance (degrees)	Pre-treatment	5.62 ±1.38	5.52 ±1.61	0.10	0.795
	Post-treatment	4.16 ±0.89	1.88 ±0.74	2.28	0.0001*
	Change (MD)	1.46	3.66		
	Change %	25.98%	65.94%		
	P-value	0.0001*	0.0001*		
Hip joint angle in terminal stance (degrees)	Pre-treatment	6.72 ±1.63	7.92 ±2.98	1.20	0.063
	Post-treatment	6.04 ±1.50	3.30 ±1.59	2.74	0.0001*
	Change (MD)	0.68	4.62		
	Change %	10.12%	58.33%		
	P-value	0.295	0.0001*		

*Data are reported as mean ± standard deviation (SD) and compared statistically by 2x2 MANOVA test. MD: Mean difference. P-value: probability value. * Significant (P<0.05).*

Statistical analysis

Children's demographic characteristics were compared between groups utilizing independent t-tests. The chi-squared test was adopted to compare the gender, affected side, and spasticity grade distribution among groups. To check if the data followed a normal distribution, the Shapiro-Wilk test was used. The homogeneity of variance among groups was checked utilizing Levene's test. The mixed design 2 x 2 MANOVA test has been employed to compare between and within group impacts on kinematic gait parameters, pelvic symmetry, and trunk endurance tests. For the subsequent multiple comparisons, post hoc tests with the Bonferroni correction test were conducted. Every one of the statistical tests had a significant level of *p*-value ≤ 0.05. SPSS version 28 for Windows (*IBM SPSS, Chicago, IL, USA*) was used to conduct all of the statistical analyses.

Table 4. Within and between groups comparison for pelvic symmetry.

Variables	Items	Groups (Mean ±SD)		Change	*P*-value
		Control group (n=20)	Study group (n=20)		
Anterior pelvic tilting angle (degrees)	Pre-treatment	12.00 ±4.28	13.60 ±3.61	1.60	0.159
	Post-treatment	9.65 ±3.63	9.15 ±2.47	0.50	0.030*
	Change (MD)	2.35	4.45		
	Change %	19.58%	32.72%		
	P-value	0.040*	0.0001*		
Lateral tilting angle (degrees)	Pre-treatment	2.20 ±1.67	1.70 ±0.80	0.50	0.156
	Post-treatment	1.67 ±1.04	1.10 ±0.57	0.57	0.021*
	Change (MD)	0.53	0.60		
	Change %	24.09%	35.29%		
	P-value	0.136	0.089		
Height discrepancy (cm)	Pre-treatment	0.76 ±0.54	0.63 ±0.32	0.13	0.297
	Post-treatment	0.61 ±0.43	0.44 ±0.22	0.17	0.043*
	Change (MD)	0.15	0.19		
	Change %	19.74%	30.16%		
	P-value	0.229	0.137		

*Data are reported as mean ± standard deviation (SD) and compared statistically by 2x2 MANOVA test. MD: Mean difference. P-value: probability value. * Significant (P<0.05).*

Results

Children's general characteristics

Children in both groups showed similar baseline characteristics, with no significant differences observed between them (p>0.05), as shown in Table 2.

Kinematic parameters of gait

The results of this study reported no statistically significant changes between both groups in any of the measured outcomes pre-treatment. Also, the results revealed notable improvement in spatiotemporal parameters in both groups post-treatment, with the study group demonstrating superior improvements. Both groups experienced notable improvements in stride length and cadence post-treatment, as compared to pre-treatment. However, it is important to note that only the study group exhibited considerable increases in step length and walking speed. In contrast, the control group did not demonstrate any such gains, as seen in Table 3.

However, there were significant decreases among particular joint angles post-treatment in both groups. The results of the study group reported significant reductions in knee joint angle at mid stance and hip joint angle during terminal stance. There was an apparent increase in the angle of the ankle joint at initial contact. The control group exhibited a significant reduction in knee joint angle, but there was no significant change in the angle of the hip joint. Moreover, the control group had a significant rise in the angle of the ankle joint. Upon comparing the two groups post-treatment, it was seen that the study group had significant differences in all measured joint angles, as seen in Table 3.

Pelvic symmetry parameters

Pre- and post-treatment angles of anterior pelvic tilting were significantly reduced in both groups, although the study group showed significantly better improvement. However, neither group showed any significant differences in the lateral pelvic tilting angle or height discrepancy. The study group showed a greater percentage of improvement in all pelvic symmetry variables than the control group. Although there were no notable distinctions between the groups pre-treatment, the post-treatment outcomes revealed significant differences in favor of the study group for all assessed pelvic symmetry, as demonstrated in Table 4.

Trunk muscle endurance tests

All tests that were examined did not show any significant differences between the two groups. Additionally, post-treatment, both groups had statistically significant improvements in trunk muscle endurance tests, while the study group demonstrated a more pronounced improvement, as seen in Table 5.

Table 5. Within and between groups comparison for trunk muscle endurance.

Variables	Items	Groups (Mean ±SD)		Change	*P*-value
		Control group (n=20)	Study group (n=20)		
Prone plank test (sec)	Pre-treatment	60.90 ±4.31	61.25 ±4.24	0.35	0.776
	Post-treatment	66.00 ±3.11	71.35 ±3.73	5.35	0.0001*
	Change (MD)	5.10	10.10		
	Change %	8.37%	16.49%		
	P-value	0.0001*	0.0001*		
Partial curl up test (sec)	Pre-treatment	57.60 ±1.81	58.50 ±3.67	0.90	0.321
	Post-treatment	61.40 ±1.50	65.50 ±3.66	4.10	0.0001*
	Change (MD)	3.80	7.00		
	Change %	6.60%	11.97%		
	P-value	0.0001*	0.0001*		
Unilateral bridge test (sec)	Pre-treatment	15.90 ±1.61	17.30 ±3.71	1.40	0.134
	Post-treatment	18.55 ±1.79	24.60 ±3.80	6.05	0.0001*
	Change (MD)	2.65	7.30		
	Change %	16.67%	42.20%		
	P-value	0.0001*	0.0001*		
Front abdominal power test (cm)	Pre-treatment	67.25 ±16.01	68.25 ±7.51	1.00	0.296
	Post-treatment	79.50 ±7.23	83.00 ±5.93	3.50	0.0001*
	Change (MD)	12.25	14.75		
	Change %	18.22%	21.61%		
	P-value	0.0001*	0.0001*		

*Data are reported as mean ± standard deviation (SD) and compared statistically by 2x2 MANOVA test. MD: Mean difference P-value: probability value * Significant (P<0.05).*

Discussion

According to the International Classification of Functioning, Disability, and Health (ICF), rehabilitation efforts should concentrate on addressing restrictions in activity and involvement[31]. The TOCT highlights the value of establishing "functional tasks" and how individuals, tasks, as well as the environment in which tasks are done interact with each other. Children with CP are capable of making an effort to carry out functional tasks, adapting to environmental circumstances, and applying what they've learned to the real environment[32]. The current study examined the impact of TOCT on gait kinematics, pelvic symmetry, and endurance in children with hemiplegic cerebral palsy. The results of this study offer useful information into the potential of TOCT to enhance the efficacy and function of movement in this population.

The results of this study demonstrated significant improvements regarding gait kinematics after completing the TOCT program. The children of the study group demonstrated enhanced stride length, step length, cadence, as well as walking speed. Furthermore, there was an improvement in the ankle dorsiflexion angle during initial contact, knee extension angle during midstance, in addition to hip extension angle during terminal stance. The findings indicate that TOCT has the potential to improve gait efficiency and decrease compensatory movement patterns commonly seen in children with hemiplegic CP. These findings are consistent with previous studies[33,34], suggesting that task-oriented training can lead to positive changes in gait patterns and functional mobility in these children. This finding was also reported by Soke et al. (2021), who found that TOCT could enhance gait performance and balance, which in turn would enhance functional mobility, confidence in one's balance, severity of the disease, as well as quality of life for individuals who have Parkinson's disease[35]. Through repetitive training of functional activities, the task-oriented feature of the training contributed to motor learning. More effective gait patterns may have resulted from this or better neuromuscular control and coordination among the trunk and the lower extremities. A recently published systematic review and meta-analysis suggests TOCT can greatly improve the gross motor function, balance, along with ADLs of children with CP[8].

The TOCT established the integration of training into daily activities as a way to attain motor control. This theory could provide the basis for improvements in gait kinematics. As a result, children are able to walk with longer strides and actively push off their ankles because their hip, knee, along with ankle joints are more stable during the stance phase.

This is consistent with the findings of Tramonti et al. (2020), who reported that intensive TOCT positively impacts multiple sclerosis patients' gait biomechanics[36]. Furthermore, it was previously noted in a study executed by Abo-Zaid et al. (2021) that TOCT significantly improves gait among children with hemiplegic CP[37].

An important finding of this study was that pelvic symmetry improved. Asymmetrical movement patterns are common among children having hemiplegic CP, especially in their pelvis, which can affect the stability and quality of their gait as a whole[38]. The TOCT intervention reduced both the anterior and lateral pelvic tilts during gait. Consistent with the current findings, previous studies have indicated that enhanced pelvic stability and core control are essential for preserving optimal alignment and lowering the risk of subsequent musculoskeletal problems[39,40]. The TOCT program focused on specific exercises to improve symmetrical movement patterns and posture. The noted improvements in pelvic symmetry show that this intervention is successful at addressing imbalances and improving overall posture control[40].

The results also show that trunk endurance significantly improved after the training session, which is a major finding. Trunk control is essential for maintaining balance and stability when performing activities like walking. Children diagnosed with hemiplegic CP frequently face difficulties associated with trunk stability, which might restrict their capacity to carry out everyday activities independently. The improvements observed in the study group align with the findings of El Shemy (2018), who stated that improvements in trunk endurance are linked to increased core strength and stability. This, in turn, leads to improved postural control as well as functional performance[7].

After completing the TOCT, children showed significant improvements in each test of trunk endurance. Additionally, this suggests improved core strength and muscle endurance, which may lead to a greater general ability to carry out daily tasks. The results of Sah et al. (2019) provide some explanation for these findings[41]. They stated that when choosing the activities for the TOCT program, the components that were considered included trunk stability using active weight shifts, trunk lengthening in an ideal position to accomplish controlled mobility, and a facilitated hands-on approach. These elements would have helped children with UCP improve their trunk endurance by recruiting appropriate muscles.

In addition, the TOCT has played a role in enhancing muscle strength and endurance, especially in the core muscles. The enhanced core stability may account for the decrease in pelvic tilt and the overall improvement in trunk endurance scores.

According to Mendoza-Sengco et al. (2023), the guideline protocol based on neurodevelopmental treatment has a direct impact on facilitating postural control and development of the lower limbs along with trunk normal movement patterns varieties[1]. This can explain the significant improvements found in both groups, which may be due to neuro-development training, which modulates muscle tone and improves postural alignment. Children with CP can gain more functional independence as well as general physical capacity through rehabilitation programs that rely on neuro-developmental principles[42].

Implications for future studies include determining the long-term effect of TOCT as well as investigating the role of factors including child age, CP severity, along with treatment program adherence in determining treatment outcomes. To further understand the impact of these therapies on functional outcomes, it would be beneficial to include quality of life and involvement in everyday activities. To further establish the role of TOCT in the treatment of children with CP, subsequent studies should concentrate on larger trials with longer follow-up periods.

Limitations

The lack of a long-term follow-up assessment, which makes it difficult to determine the sustainability of the achievable improvements. Additionally, the study may be limited by its focus on a specific age group, which may limit the generalization of the study outcomes.

Conclusion

The TOCT program significantly improves gait parameters, pelvic symmetry, and trunk endurance in children with hemiplegic CP, offering a promising intervention strategy for mobility, function, and quality of life. It can be tailored to individual needs and implemented in clinical and home settings.

Ethics approval

This study was approved by the Ethical Committee of the Faculty of Physical Therapy, Cairo University, Egypt (P.T.REC/012/003060) and it is in accordance with the Declaration of Helsinki and its later amendments.

Consent to participate

All children and their parents were given a thorough explanation of the study's goals and procedures before participation. Written informed consent to participate in this study was obtained from the parents or legal representatives of all participating children.

Authors' contributions:

El-Sayed MS and El Shemy SA made significant contributions to the research concept and design, data collection, and article writing. Both also participated in the drafting of the article, statistical analysis and critical revision of important intellectual content. Kilany A contributed to the assembly of data. All authors participated in data analysis and interpretation, and provided final approval of the article, ensuring a comprehensive and collaborative effort.

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