EFFECT OF THE FORWARD, BACKWARD AND SIDEWAYS GAIT TRAINING INTERVENTION ON BALANCE AND GAIT IN CHILDREN WITH SPASTIC DIAPLEGIC CEREBRAL PALSY

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Resumo

Background: Cerebral palsy (CP) causes movement and posture issues, affecting balance and independence. Rehab aims to improve motor function. Multidirectional gait training boosts balance and gait, as daily movement involves all directions Backward and sideways walking enhance strength, balance, and joint control. This study aimed to compare the effects of forward, backward, and sideways gait training interventions on balance and gait parameters in children with spastic diplegic CP.

Methods: This prospective randomized research included 60 children diagnosed with diplegic CP by pediatricians or Pediatric neurologists. Participants exhibited spasticity graded between 1 and 1+ on the MAS, were classified as level I or II on the Gross Motor Function Classification System (GMFCS), and had no history of Orthopedic surgery. The children were randomly assigned into four equal groups (GPs). GP I received forward gait training on the floor; GP II received backward gait training; GP III underwent sideways gait training; and GP IV received a combination of forward and sideways gait training. All interventions were conducted on the floor and supplemented with a traditional physiotherapy program. Training was performed in both closed and open environments across all GPs.

Results: Post hoc analysis showed the combination training GP significantly outperformed others. In static balance (surface area and length), it differed from forward (P3), backward (P5), and sideway (P6) GPs (all $p < 0.0016$). In dynamic balance, significant differences were found in surface area (vs. backward, P5 = 0.0242) and length (vs. forward, backward, and sideway; all $p < 0.0012$). For motor function, gross motor function measure (GMFM-D) was higher than sideway (P6 = 0.0259), and GMFM-E was higher than forward (P3 = 0.0028) and sideway (P6 = 0.0041). The combination GP also showed longer stride length and faster gait speed than all others (all $p < 0.0021$), and had narrower step width than forward, backward, and sideway GPs (P3 = 0.0461, P5 = 0.0127, P6 = 0.0011).

Conclusions: Multi-directional gait training, which includes walking forward, backward, and sideways, is better for balance, gross motor function, and gait performance in children with spastic diplegic CP than single-directional training methods. After the intervention, the improvements were due to the specific training regimens. The combined training GP had far bigger decreases in balancing surface area and path length, as well as superior GMFM scores and gait parameters. This means they had better control over their posture, were more mobile, and walked more efficiently.

Keywords: Forward, Backward and Side, Gait Training Intervention, Balance and Gait, Spastic Diaplegic Cerebral Palsy

Introduction

Cerebral palsy (CP) encompasses a GP of permanent disorders resulting from a non-progressive lesion in the developing brain, characterized primarily by movement and postural impairments that lead to limitations in functional activities [1].

Balance and gait impairments, which are common in children with CP, contribute to a loss of independence in activities of daily living and negatively impact psychosocial well-being by limiting the child's functional abilities [2]. Enhancing functional independence is the primary objective of CP rehabilitation; therefore, improving motor capacity is of paramount importance [3].

Clinical rehabilitation programs incorporating forward, backward, and sideways walking exercises on varied surfaces have been shown to enhance balance and improve kinematic gait parameters [4].

While forward walking may appear to be a straightforward progression toward a target, everyday locomotion is not strictly unidirectional. It often requires frequent changes in direction, including turns, lateral movements, and backward steps to adapt to environmental and social demands. This is especially true for children, who commonly engage in sideways and backward stepping nearly as often as forward walking [5].

Unlike forward gait, backward walking does not involve heel contact during the early stance phase. As a result, it may reduce stress on the lower limb joints by avoiding the rapid weight loading typically associated with the initial phase of gait [6]. Moreover, backward gait facilitates more efficient recruitment of motor units [7]. Furthermore, it provides sufficient loading to the lower limb joints, contributing to increased muscular strength and improved balance control in the periauricular muscles of the knee [8]. Lateral walking represents an asymmetrical pattern of locomotion, requiring distinct neuromuscular control between the right and left limb musculature [9].

This study aimed to compare the effects of forward, backward, and sideways gait training interventions on balance and gait parameters in children with spastic diplegic CP.

Patients and Methods

This prospective randomized research was carried on 60 children (aged 5 to 7 years) of both sexes, diagnosed with diplegic CP by pediatricians or Pediatric neurologists. Participants exhibited spasticity graded between 1 and 1+ on the Modified Ashworth Scale (MAS), were classified as level I or II according to the GMFCS, and had no history of Orthopedic surgery. The study was approved by the Ethical Committee of Kafr El-Sheikh University Hospitals, Kafr El-Sheikh, Egypt. Written informed consent was obtained from the patients' legal guardians prior to participation.

Exclusion criteria included the presence of permanent musculoskeletal deformities (bony or soft tissue contractures), visual or auditory impairments, history of botulinum toxin injections to the lower limbs within the past six months, prior surgical interventions involving the ankle or knee, epileptic seizures, or any diagnosed cardiac or Orthopedic conditions that could interfere with assessment procedures. In addition, children who were absent from two consecutive therapy sessions were also excluded from the study.

Randomization

An online randomization program (http://www.randomizer.org). A randomization list was generated, and each patient's allocation code was concealed within an opaque, sealed envelope to ensure allocation concealment. Participants were randomly allocated with 1:1:1:1 allocation ratio into four equal GPs in a parallel manner: GP (I): Children received forward gait training intervention on the floor (closed and open environment) plus the traditional physiotherapy program, Study GP (II): Children received backward gait training intervention on the floor (closed and open environment) plus the traditional physiotherapy program, Study GP (III): Children received sideways gait training intervention on the floor (closed and open environment) plus the traditional physiotherapy program and Study GP (IV): Children received forward and sideways gait training intervention on the floor (closed and open environment) plus the traditional physiotherapy program.

Evaluation of balance using PBS

The PBS is a modified version of the Berg Balance Scale (BBS), designed specifically to assess functional balance in children with mild to moderate motor impairments. It consists of 14 items, each scored on a scale from 0 to

4, based on the quality of performance and the time required to complete each task. The PBS is a reliable tool for detecting balance deficits in Pediatric populations and for tracking progress over time. Final score interpretation is as follows: scores between 56 and 41 indicate independent function, scores between 40 and 21 suggest the need for assistance, and scores below 20 reflect a requirement for wheelchair support [10].

Evaluation of gait using Kinovea software

Kinovea is a free, two-dimensional motion analysis software commonly used for assessing kinematic parameters. It enables video-based analysis without the need for active markers, although its reliability may be enhanced through the use of passive markers. Kinovea® has been employed in various studies for the evaluation of movement patterns and gait analysis [11].

Evaluation of standing progress using GMFCS

The GMFCS provides an accurate representation of a child's actual gross motor function. It categorizes functional performance in everyday activities, particularly focusing on sitting, transfers, and mobility. The classification is divided into four age bands: under 2 years, 2–4 years, 4–6 years, and 6–12 years. In 2007, the system was expanded and revised (GMFCS-E&R) to include adolescents aged 12 to 18 years. The GMFCS employs a five-level classification, with Level I indicating minimal motor impairment and Level V indicating severe limitations in self-initiated movement. This standardized system is widely used for predicting prognosis and guiding treatment planning in children with CP [12].

Treatment Procedures

Core Stability (Given to GP A only)

Core stability exercises were implemented to enhance static balance, improve gait, and correct pelvic tilt abnormalities. The program consisted of 30-minute sessions conducted three times per week, with all exercises performed in three sets and specified repetitions or holding durations. Exercises included abdominal contractions in supine, prone, and squat positions (3 sets × 20 reps), wall squats using a Swiss ball on the shoulders (3 sets × 15 reps), abdominal holds while sitting on a Swiss ball (3 sets × 15 seconds), and balance tasks involving lifting one or both feet off the floor while seated on a Swiss ball (3 sets × 15 seconds). Additional activities included trunk rotations while lying supine on a Swiss ball, both with and without handheld weights (3 sets × 15 reps), and single-leg raises during supine core holds (3 sets × 20 reps). Bridging exercises were performed with one leg elevated or with feet on a Swiss ball while lifting one leg (3 sets × 15 reps or 15-second holds). Plank exercises involved supporting body weight on hands and toes (3 sets × 15 seconds), while the "Superman" exercise was executed in a quadruped position, extending opposite arm and leg simultaneously and holding (3 sets × 15 seconds). All exercises were aimed at improving trunk control and functional motor performance in children with spastic diplegic CP.

Designed Program (Given to all GPs)

The intervention program included a series of therapist-guided functional and balance exercises designed to improve postural control, gait, and lower limb coordination in children with spastic diplegic CP. The squat-to-stand exercise was performed with the child in a squatting position and the therapist positioned behind, providing verbal instructions and manual guidance to ensure correct execution of the movement. Pelvic fixation was applied when necessary to assist with proper alignment during the transition to standing. In standing exercises, the child was instructed to stand upright while the therapist, positioned behind or beside, stabilized the pelvis and encouraged knee extension, gradually reducing support as the child maintained proper posture. For balance training, the child was assisted in mounting a swaying balance board by alternately lifting each leg. Once on the board, pelvic stabilization was used as needed, and intermittent release of fixation was applied when the child demonstrated stability in an upright stance. Walking practice was conducted with the therapist guiding pelvic alignment from behind, correcting improper gait patterns and gradually reducing support as steady walking was achieved. Additional components included sustained passive stretching of the hamstrings, tendo-Achilles, and adductors (30-second holds, 3 repetitions), facilitation of sit-to-stand transitions, multidirectional reach-outs in sitting, as well as step-up and step-down training using a stepper and bolster, accompanied by half-kneeling exercises to promote dynamic postural control and functional strength [13].

The intervention also incorporated principles from established neurodevelopmental and motor control approaches. The Bobath concept, a neurodevelopmental therapy, was employed to address postural abnormalities, abnormal movement patterns, and delays in developmental milestones, while simultaneously enhancing sensory integration. Stepping exercises were integrated within this framework to facilitate functional motor skills. Motor learning principles were applied, particularly beneficial for infants and young children with CP, to promote skill acquisition through repetition, feedback, and task-specific practice. Additionally, the Margaret Rood approach was utilized, which involves the application of both superficial and deep sensory stimulation techniques to facilitate or inhibit motor responses, thereby promoting improved motor control and functional performance [14].

The treatment protocol was repeated for 3 sessions per week, for 12 weeks.

Sample Size Calculation

In order to determine the required sample size (n), the following equation was applied: where α = 0.05, p =0.35, d = 0.148, σ = 0.48

So the total sample size was 60 children (15 in each GP).

Statistical analysis

Statistical analysis was carried on using SPSS software, version 27 (IBM©, Chicago, IL, USA). The normality of data distribution was assessed using the Shapiro-Wilk test and visual inspection of histograms. Quantitative data with a normal distribution were shown as mean ± standard deviation (SD) and analyzed using one-way analysis of variance (ANOVA), followed by Tukey's post hoc test for pairwise comparisons. Non-parametric quantitative data were reported as median and interquartile range (IQR) and related using the Kruskal-Wallis test, with the Mann-Whitney U test employed for post hoc comparisons between individual GPs. Categorical variables were summarized as frequencies and percentages and analyzed using the Chi-square test. A two-tailed p-value of less than 0.05 was considered statistically significant.

Results

Regarding Demographic Characteristics, there were no significant difference. Table 1

Table 1. Comparison of Demographic Characteristics among Gait Training GP.

Variable		Forward Gait Training	Backward Gait Training	Sideway Gait Training	Combination Gait Training	P-value
Age (years)		5.91 ± 0.56	5.75 ± 0.56	5.75 ± 0.56	5.99 ± 0.61	0.5084
P1 = 0.889, P2 = 0.876, P3 = 0.9859, P4 = 0.4623, P5 = 0.9818, P6 = 0.6943						
Sex	**Male**	7 (46.67%)	6 (40%)	6 (40%)	7 (46.67%)	0.7514
	Female	8 (53.33%)	9 (60%)	9 (60%)	8 (53.33%)	
P1 = 0.8913, P2 = 0.9843, P3 = 0.99, P4 = 0.7089, P5 = 0.8913, P6 = 0.9843						
Height (cm)		106.73 ± 5.80	104.47 ± 5.94	104.47 ± 5.94	106.93 ± 5.26	0.1210
P1 = 0.185, P2 = 0.7196, P3 = 0.9997, P4 = 0.7555, P5 = 0.1546, P6 = 0.6635						
Weight (kg)		18.25 ± 2.46	18.76 ± 2.92	18.76 ± 2.92	17.76 ± 2.55	0.8206
P1 = 0.99, P2 = 0.9622, P3 = 0.9649, P4 = 0.9516, P5 = 0.9735, P6 = 0.7743						
BMI (kg/m²)		16.22 ± 3.15	17.32 ± 3.12	17.32 ± 3.12	15.61 ± 2.52	0.3141
P1 = 0.6735, P2 = 0.7857, P3 = 0.9549, P4 = 0.9974, P5 = 0.3624, P6 = 0.473						
Gestational age (weeks)		35.07 ± 3.38	36.33 ± 2.65	36.33 ± 2.65	36.53 ± 2.99	0.4025
P1 = 0.9995, P2 = 0.7082, P3 = 0.604, P4 = 0.6392, P5 = 0.5334, P6 = 0.9983						
Birth weight (kg)		2.51 ± 0.81	2.68 ± 0.74	2.68 ± 0.74	2.80 ± 0.89	0.6621
P1 = 0.9967, P2 = 0.9473, P3 = 0.7924, P4 = 0.8739, P5 = 0.6706, P6 = 0.9814						

Data are shown as mean ± SD or frequency (%). BMI: Body mass index P1: Forward vs Backward, P2: Forward vs Sideway, P3: Forward vs Combination, P4: Backward vs Sideway, P5: Backward vs Combination, P6: Sideway vs Combination

Data are shown as mean ± SD or frequency (%). BMI: Body mass index P1: Forward vs Backward, P2: Forward vs Sideway, P3: Forward vs Combination, P4: Backward vs Sideway, P5: Backward vs Combination, P6: Sideway vs Combination

Regarding MAS Grades and GMFCS Levels, there were no marked differences among studied GPs. Table 2

Data were shown as frequency (%). GMFCS: Gross Motor Function Classification System. P1: Forward vs Backward, P2: Forward vs Sideway, P3: Forward vs Combination, P4: Backward vs Sideway, P5: Backward vs Combination, P6: Sideway vs Combination.

Post hoc comparisons revealed significant differences primarily involving the combination training GP. For static balance surface area, marked differences were documented among the combination GP and the forward GP (P3 = 0.0016), the backward GP (P5 < 0.0001), and the sideway GP (P6 = 0.0001). Similarly, for static balance length, post hoc tests showed significant differences for P3, P5, and P6 (all < 0.0001).

In dynamic balance parameters, significant differences were noted in surface area between the combination GP and the backward GP (P5 = 0.0242), and in dynamic balance length between the combination GP and both the backward (P5 = 0.0003) and sideway (P6 = 0.0011) GPs and between combination GP and the forward GP (P3 = 0.0119) and the sideway GP. Other pairwise comparisons were not statistically significant. Post hoc analysis revealed that the combination GP scored significantly higher than the sideway GP in GMFM-D (P6 = 0.0259). For gross motor function measure (GMFM-E), marked differences were documented among the combination GP and the forward GP (P3 = 0.0028) as well as the sideway GP (P6 = 0.0041). Post hoc comparisons revealed that the combination GP had significantly longer stride length than the forward (P3 = 0.0001), backward (P5 < 0.0001), and sideway (P6 < 0.0001) G[s. It also had significantly higher gait speed compared to the forward (P3 = 0.0021), backward (P5 < 0.0001), and sideway (P6 = 0.0004) GPs. Regarding step width, the combination GP had markedly narrower steps relative to the forward (P3 = 0.0461), backward (P5 = 0.0127), and sideway (P6 = 0.0011) GPs. Table 3

Discussion

CP represents a GP of permanent neurological conditions that impair motor development and result in activity limitations [15]. CP is marked by abnormalities affect muscle tone, posture, and movement. Clinically, CP is classified based on the dominant motor impairment, which may present as spastic hemiplegia, spastic diplegia, spastic quadriplegia, or as extrapyramidal (dyskinetic) subtypes [13].

One significant factor is the increased survival rates of preterm and low birth weight infants have been linked to a heightened probability of developing neurodevelopmental disorders, including CP. Advances in neonatal care, while beneficial in reducing mortality, may inadvertently increase the number of children living with long-term neurodevelopmental conditions such as CP [16]

At baseline, balance assessment using PBS showed static ellipse areas of 91–130 cm² and dynamic ellipse areas of 93–150 cm². Static and dynamic lengths ranged from 23–34 cm and 21–35 cm, respectively. Functional ability, measured by GMFM, showed scores of 65–79 (dimension D), 55–75 (dimension E), and 60–76 (total). Gait parameters included stride lengths of 50–70 cm, gait speed of 0.6–0.9 m/s, and step widths of 6–10 cm. This ensured that any observed post-treatment differences could be attributed to the gait training protocols rather than pre-existing disparities.

This complies with one of the earliest studies about the effects of backward walking training (Backward Walking Training) which was conducted by Kim et al. in 2013. This study, which included 12 children aged 5 to 15 years and lacked a control GP, employed real-time, video-based gait analysis. The findings reported modest enhancements in both gait speed and balance, particularly in dimensions D (standing) and E (walking, running, and jumping) of the GMFM-

Table 2. Comparison of MAS Grades and GMFCS Levels and between Pre-Treatment Balance, Functional, and Gait Parameters among Gait Training GPs.

		Forward Gait Training	Backward Gait Training	Sideway Gait Training	Combination Gait Training	P-value
MAS	**Grade 1**	7(46.67%)	8 (53.33%)	8 (53.33%)	9 (60%)	0.7364
	Grade 1+	8 (53.33%	7 (46.67%)	7 (46.67%)	6 (40%)	
P1 = 0.9843, P2 = 0.9843, P3 = 0.8913, P4 = 0.8913, P5 = 0.7089, P6 = 0.9843						
GMFCS Level	**Level I**	6 (40%)	4 (26.67%)	4 (26.67%)	6 (40%)	0.7349
	Level II	9 (60%)	11 (73.33%)	11 (73.33%)	9 (60%)	
P1 = 0.9829, P2 = 0.8831, P3 = 0.9900, P4 = 0.6906, P5 = 0.9829, P6 = 0.8831						
Pre-Treatment Balance, Functional, and Gait Parameters Between Gait Training GPs						
Static Balance – Surface Area Ellipse (cm²)		107.79 ± 11.09	110.80 ± 11.25	110.80 ± 11.25	112.73 ± 9.97	0.1611
P1 = 0.1216, P2 = 0.8729, P3 = 0.6019, P4 = 0.447, P5 = 0.7446, P6 = 0.9619						
Static Balance – Length (cm)		27.97 ± 2.95	28.80 ± 2.60	28.80 ± 2.60	29.21 ± 2.25	0.1451
P1 = 0.1043, P2 = 0.8323, P3 = 0.5864, P4 = 0.4561, P5 = 0.7166, P6 = 0.9743						
Dynamic Balance – Surface Area Ellipse (cm²)		115.64 ± 12.62	121.02 ± 16.66	121.02 ± 16.66	124.75 ± 13.78	0.2758
P1 = 0.3283, P2 = 0.7368, P3 = 0.3174, P4 = 0.9016, P5 = 0.9900, P6 = 0.8933						
Dynamic Balance – Length (cm)		26.36 ± 2.84	27.80 ± 3.90	27.80 ± 3.90	28.53 ± 2.95	0.1619
P1 = 0.1576, P2 = 0.6162, P3 = 0.2670, P4 = 0.8025, P5 = 0.9916, P6 = 0.9265						
GMFM-D (Standing)		71.55 ± 4.61	70.47 ± 4.70	70.47 ± 4.70	72.13 ± 3.88	0.7732
P1 = 0.9999, P2 = 0.9102, P3 = 0.9843, P4 = 0.8832, P5 = 0.9917, P6 = 0.7382						
GMFM-E (Walking/Running/Jumping)		64.35 ± 5.25	64.47 ± 5.43	64.47 ± 5.43	65.73 ± 4.35	0.6297
P1 = 0.6769, P2 = 0.9999, P3 = 0.8923, P4 = 0.7142, P5 = 0.9762, P6 = 0.9154						
GMFM Total Score		67.95 ± 4.81	67.47 ± 4.94	67.47 ± 4.94	68.93 ± 3.93	0.7469
P1 = 0.9099, P2 = 0.9924, P3 = 0.9412, P4 = 0.7820, P5 = 0.9997, P6 = 0.8322						
P1 = 0.9099, P2 = 0.9924, P3 = 0.9412, P4 = 0.7820, P5 = 0.9997, P6 = 0.8322		P1 = 0.9099, P2 = 0.9924, P3 = 0.9412, P4 = 0.7820, P5 = 0.9997, P6 = 0.8322	P1 = 0.9099, P2 = 0.9924, P3 = 0.9412, P4 = 0.7820, P5 = 0.9997, P6 = 0.8322	P1 = 0.9099, P2 = 0.9924, P3 = 0.9412, P4 = 0.7820, P5 = 0.9997, P6 = 0.8322	P1 = 0.9099, P2 = 0.9924, P3 = 0.9412, P4 = 0.7820, P5 = 0.9997, P6 = 0.8322	P1 = 0.9099, P2 = 0.9924, P3 = 0.9412, P4 = 0.7820, P5 = 0.9997, P6 = 0.8322
P1 = 0.1002, P2 = 0.9885, P3 = 0.6001, P4 = 0.1915, P5 = 0.6924, P6 = 0.7909						
Gait Speed (m/s)		0.75 ± 0.07	0.74 ± 0.06	0.74 ± 0.06	0.71 ± 0.08	0.1021
P1 = 0.1084, P2 = 0.9915, P3 = 0.6253, P4 = 0.1931, P5 = 0.6900, P6 = 0.7953						
Step Width (cm)		7.50 ± 1.02	8.33 ± 1.09	8.33 ± 1.09	7.94 ± 1.19	0.2737
P1 = 0.9435, P2 = 0.2284, P3 = 0.7351, P4 = 0.5245, P5 = 0.9661, P6 = 0.8040						

Data were shown as frequency (%). GMFCS: Gross Motor Function Classification System. P1: Forward vs Backward, P2: Forward vs Sideway, P3: Forward vs Combination, P4: Backward vs Sideway, P5: Backward vs Combination, P6: Sideway vs Combination

Table 3. Comparison of (Post-Treatment Balance Parameters, Post-Treatment GMFM Scores and Post-Treatment Gait Parameters) among Gait Training GPs.

	Forward Gait Training	Backward Gait Training	Sideway Gait Training	Combination Gait Training	p
Static Balance – Surface Area Ellipse (cm²)	95.13 ± 11.38	98.99 ± 11.95	98.99 ± 11.95	78.01 ± 10.59	**<0.0001***
P1 = 0.2123, P2 = 0.8192, **P3 = 0.0016***, P4 = 0.6933**, P5 = <0.0001***, **P6 = 0.0001***					
Static Balance – Length (cm)	23.35 ± 3.51	23.55 ± 3.92	23.55 ± 3.92	17.26 ± 2.38	**<0.0001***
P1 = 0.1842, P2 = 0.9985, **P3 = <0.0001***, P4 = 0.246, **P5 = <0.0001***, P6 = <**0.0001***					
Dynamic Balance – Surface Area Ellipse (cm²)	104.32 ± 12.73	110.46 ± 16.46	110.46 ± 16.46	97.08 ± 13.74	**0.0216***
P1 = 0.4095, P2 = 0.6504, P3 = 0.520, P4 = 0.9791, **P5 = 0.0242***, P6 = 0.0644					
Dynamic Balance – Length (cm)	22.16 ± 3.29	24.45 ± 4.32	24.45 ± 4.32	19.13 ± 3.70	**0.0002***
P1 = 0.1509, P2 = 0.3262, P3 = 0.1194, P4 = 0.9725, **P5 = 0.0003*, P6 = 0.0011***					
Post-Treatment GMFM Scores					
GMFM-D (Standing)	72.28 ± 4.88	71.39 ± 4.95	71.39 ± 4.95	76.22 ± 3.83	**0.0268***
P1 = 0.9986, P2 = 0.9494, P3 = 0.0944, P4 = 0.8988, P5 = 0.1315, **P6 = 0.0259***					
GMFM-E (Walking/Running/Jumping)	63.83 ± 5.15	64.07 ± 5.42	64.07 ± 5.42	70.95 ± 4.32	**0.0015***
P1 = 0.682, P2 = 0.9993, **P3 = 0.0028***, P4 = 0.7554, P5 = 0.0595, **P6 = 0.0041***					
GMFM Total Score	68.09 ± 4.89	67.75 ± 5.01	67.75 ± 5.01	73.61 ± 3.88	**0.0044***
P1 = 0.8988, P2 = 0.9974, **P3 = 0.0119***, P4 = 0.8114, P5 = 0.0702, **P6 = 0.0068***					
Post-Treatment Gait Parameters					
Stride Length (cm)	69.33 ± 5.82	68.32 ± 4.96	68.32 ± 4.96	79.09 ± 6.21	**<0.0001***
P1 = 0.125, P2 = 0.9638, P3 **= 0.0001***, P4 = 0.3018, P5 < **0.0001***, P6 < **0.0001***					
Gait Speed (m/s)	0.91 ± 0.07	0.90 ± 0.05	0.90 ± 0.05	1.02 ± 0.10	**<0.0001***
P1 = 0.0522, P2 = 0.9549, **P3 = 0.0021***, P4 = 0.1613, P5 < 0.0001*, **P6 = 0.0004***					
Step Width (cm)	6.14 ± 1.02	6.74 ± 1.10	6.74 ± 1.10	4.91 ± 1.47	**0.0013***
P1 = 0.9604, P2 = 0.5639**, P3 = 0.0461***, P4 = 0.8486, **P5 = 0.0127*, P6 = 0.0011***					

Data are shown as mean ± SD.PBS: Pediatric Balance Scale; SD: Standard Deviation.*A p value < 0.05 was considered indicative of statistical significance

88, indicating potential benefits of Backward Walking Training in improving gross motor performance [17].

Following the 12-week intervention, significant improvements were observed across multiple outcome measures. Post-treatment improvements were evident across all measures. Balance metrics improved with reduced static ellipse areas (61–121 cm²), dynamic ellipse areas (70–137 cm²), and shorter path lengths (static: 12–31 cm; dynamic: 14–33 cm), indicating enhanced postural control. GMFM scores increased (D: 65–84; E: 55–77; total: up to 79), while gait analysis showed increased stride length (56–89 cm), improved speed (0.7–1.1 m/s), and reduced step width (3–8 cm). The GP that received a combination of forward, backward, and sideways gait training demonstrated the most notable enhancements. This GP showed greater reductions in both static and dynamic balance surface area and length, reflecting improved postural control. Post hoc analysis confirmed that the combination training GP outperformed the other GPs, particularly when compared to the backward and sideway training GPs.

Pre-Treatment Comparisons between GPs no marked baseline differences were observed among the four gait training GPs in demographics or outcome measures (all p > 0.05). For instance, pre-treatment static balance surface area ranged from 107.79 ± 11.09 to 112.73 ± 9.97 cm² (p = 0.1611), and GMFM total scores from 67.47 ± 4.94 to 68.93 ± 3.93 (p = 0.7469). Gait speed ranged between 0.71 ± 0.08 and 0.75 ± 0.07 m/s (p = 0.1021), with no significant GP differences.

Post-Treatment Comparisons between GPs significant among-GP differences emerged post-intervention. The combination gait training GP demonstrated significantly greater improvements across multiple domains compared to the other intervention GPs. In terms of balance, the combination GP showed reduced static ellipse area (78.01 ± 10.59 cm² vs. 98.99 ± 11.95 cm²) and shorter static length (17.26 ± 2.38 cm vs. 23.55 ± 3.92 cm), both with p < 0.0001, along with significant enhancements in dynamic balance measures (p = 0.0216 and p = 0.0002 for area and length, respectively). Post hoc analyses confirmed notable differences among the combination GP and all others (P3, P5, P6 < 0.05). Regarding functional outcomes, the combination GP achieved higher scores on GMFM-D (76.22 ± 3.83 vs. 71.39 ± 4.95; p = 0.0268), GMFM-E (70.95 ± 4.32 vs. 63.83 ± 5.15; p = 0.0015), and total GMFM (73.61 ± 3.88 vs. 67.75 ± 5.01; p = 0.0044), with significant pairwise differences noted versus forward and sideway training. Gait parameters also favoured the combination GP, which exhibited longer stride length (79.09 ± 6.21 cm vs. 68.32–69.33 cm), faster gait speed (1.02 ± 0.10 m/s vs. ~0.90 m/s), and narrower step width (4.91 ± 1.47 cm vs. 6.14–6.74 cm), all with p < 0.0013. These differences were statistically supported by post hoc tests, confirming the combination GP's superior performance across all gait outcomes.

These functional outcomes measured by the GMFM also improved across all GPs, with the combination GP achieving significantly higher scores in standing (GMFM-D), walking/running/jumping (GMFM-E), and total performance. These results suggest that multi-directional gait training more effectively enhances both static and dynamic motor abilities in children with spastic diplegic CP.

Doğan and Mutual [3]. reported that although Backward Walking Training produced statistically significant post-intervention improvements, the magnitude of these changes was relatively modest. Most outcome measures demonstrated small effect sizes (Cohen's d ≈ 0.2), except for balance, which showed a moderate effect (d = 0.61) based on Pediatric Balance Scale (PBS) scores. These findings are notably smaller than those reported in earlier studies, where gait speed improvements exceeded 50% in the 10-Meter Walk Test (10MWT) [18-20]

In contrast, Kim et al. [17] observed a more modest gain of 7.6%, which closely aligns with the 6.1% improvement recorded in their study.

Gait parameters also improved significantly following the intervention, with the combination GP showing the longest stride lengths, fastest gait speeds, and the narrowest step widths. These changes indicate more efficient and coordinated walking patterns, likely resulting from the increased neuromuscular demand and variability introduced by the multi-directional training approach.

In comparison with our findings, multiple investigations conducted by an independent research GP, the impact of Backward Walking Training was explored in children with CP across varying age GPs and GMFCS levels. Participants aged from 5 to 7 years at GMFCS levels II–III [21, 22], 5 to 9 years at levels I–III (18), 7 to 11 years at levels II–III [19] and 10 to 14 years at levels I–II.

These studies primarily assessed gait parameters, particularly walking speed, along with static and dynamic balance outcomes. Sample sizes ranged from 12 to 30 children, with approximately half assigned to control GPs. When indicated, a body weight support system was incorporated into the intervention. Backward Walking Training was generally implemented thrice weekly over a 12-week period, with the exception of two studies [21, 22].

(24,25) where it was administered over a shorter duration of six weeks.

Overall, the findings highlight the superior efficacy of combining different gait directions (forward, backward, and sideways) within rehabilitation programs, as this strategy appears to offer more comprehensive improvements in balance, motor function, and gait mechanics than unidirectional training alone [23].

Limitations of the study included that , the study lasted only 12 weeks, which may not have been sufficient to observe long-term functional gains or sustained benefits, the sample size was relatively small, there was no post-intervention follow-up to determine whether the improvements observed were maintained over time and while the Pediatric Balance Scale and GMFM-88 are valid tools, more objective biomechanical or neurophysiological assessments (e.g., EMG or kinematic analysis) could have provided deeper insights into motor improvement mechanisms.

Conclusions

Multi-directional gait training, which includes walking forward, backward, and sideways, is better for balance, gross motor function, and gait performance in children with spastic diplegic CP than single-directional training methods. After the intervention, the improvements were due to the specific training regimens. The combined training GP had far bigger decreases in balancing surface area and path length, as well as superior GMFM scores and gait parameters. This means they had better control over their posture, were more mobile, and walked more efficiently.

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