ORIGINAL ARTICLE / ARAŞTIRMA MAKALESİ

Turk J Physiother Rehabil 2025;36(2):153-163
DOI: 10.21653/tjpr.1377555

TURKISH JOURNAL OF PHYSIOTHERAPY AND REHABILITATION
TÜRK FİZYOTERAPİ VE REHABİLİTASYON DERGİSİ

Ashirwad DASS, MPT.
Aarti GUPTA, Asst. Prof.
Vinika CHAUDHARY, Asst. Prof.
Pooja BHATI, Asst. Prof.

SGT University, Department of Physiotherapy, Gurugram, India

EFFECT OF PILATES ON MOVEMENT PATTERNS, BALANCE AND FATIGUE LEVEL IN CHILDREN WITH SPASTIC DIPLEGIC CEREBRAL PALSY

ABSTRACT

Purpose: Children with cerebral palsy (CP) exhibit varying degrees of impairments that affect the patient's mobility and ability to perform activities of daily living. It restricts the patient's capacity to stay balanced and increase energy expenditure. Although the benefits of regular exercise for patients with CP are known, there is a need for more studies, which deal with the effects of different exercise approaches in them. Therefore, the aim of the present study is to investigate the effects of Pilates on sit-to-stand (STS) movement patterns, balance and fatigue in ambulatory children with CP.

Methods: Present study was a randomised controlled trial which was conducted at the Ved Special School, Sampoorna Special School, Abhyaas Special School in Delhi and the SGT Medical College Hospital and Research Institute in Gurugram, Haryana from October 2022 to March 2023. Thirty-two children (7-12 years) with spastic diplegic CP and Gross Motor Function Classification System I and II were randomly assigned into two groups. The study group underwent pilates and conventional treatment and the control group received conventional treatment alone. Images of the subjects' STS movement pattern were shot from the side through a camera, and 15 items were used to assess the condition of the subjects' extremities. Balance and fatigue were measured with Pediatric Balance Scale and Modified Borg Scale respectively at baseline, 4th week and 8th week.

Results: Significant improvements were observed in STS movement pattern in the pilates group. Significantly, greater improvements were also observed for other variables such as balance and fatigue ($p<0.001$) in response to adding pilates exercise program to conventional treatment versus conventional treatment alone.

Conclusion: Children with diplegic CP benefit more from pilates exercises in addition to conventional therapy when it comes to improving their functional movements and fatigue than from conventional therapy alone.

Keywords: Balance, Cerebral palsy, Fatigue, Pilates, Spasticity

PİLATES'İN SPASTİK DİPLEJİK SEREBRAL PALSİLİ ÇOCUKLARDA HAREKET DÜZENLERİ, DENGE VE YORGUNLUK DÜZEYİ ÜZERİNE ETKİSİ

ÖZ

Amaç: Serebral palsili (SP) çocuklarda, hareket kabiliyetini ve günlük yaşam aktivitelerini yerine getirme becerisini etkileyen farklı derecelerde bozukluklar görülmektedir. Bu durum, hastanın dengede kalma kapasitesini kısıtlamakta ve enerji harcamasını artırmaktadır. SP'li bireylerde düzenli egzersizin faydaları bilinmesine rağmen, farklı egzersiz yaklaşımlarının etkilerini ele alan daha fazla çalışmaya ihtiyaç vardır. Bu nedenle, bu çalışmanın amacı, ayaktan tedavi gören SP'li çocuklarda Pilates'in otur-kalk (STS) hareket paternleri, denge ve yorgunluk üzerindeki etkilerini araştırmaktır.

Yöntem: Bu çalışma, Ekim 2022'den Mart 2023'e kadar Delhi'deki Ved Özel Okulu, Sampoorna Özel Okulu, Abhyaas Özel Okulu ve Gurugram, Haryana'daki SGT Tıp Koleji Hastanesi ve Araştırma Enstitüsü'nde gerçekleştirilen randomize kontrollü bir araştırmadır. Spastik diplejik SP'li ve Kaba Motor Fonksiyon Sınıflandırma Sistemi I ve II düzeyinde olan otuz iki çocuk (7–12 yaş) rastgele iki gruba ayrılmıştır. Çalışma grubuna pilates egzersizleri ve konvansiyonel tedavi, kontrol grubuna ise yalnızca konvansiyonel tedavi uygulanmıştır. Deneklerin STS hareket paternleri bir kamera aracılığıyla yandan kaydedilmiş ve ekstremitelerin durumunu değerlendirmek için 15 madde kullanılmıştır. Denge ve yorgunluk, sırasıyla başlangıçta, 4. haftada ve 8. haftada Pediatrik Denge Ölçeği ve Modifiye Borg Ölçeği ile ölçülmüştür.

Bulgular: Pilates grubunda STS hareket paterninde anlamlı iyileşmeler gözlenmiştir. Ayrıca, konvansiyonel tedaviye pilates egzersiz programının eklenmesiyle, yalnızca konvansiyonel tedaviye kıyasla denge ve yorgunluk gibi diğer değişkenlerde de daha belirgin iyileşmeler elde edilmiştir ($p<0,001$).

Sonuç: Diplejik SP'li çocuklar, fonksiyonel hareketlerini geliştirme ve yorgunluğu azaltma açısından yalnızca konvansiyonel terapiye göre, pilates egzersizlerinin de dahil edildiği tedavilerden daha fazla yarar sağlamaktadır.

Anahtar Kelimeler: Denge, Serebral palsi, Yorgunluk, Pilates, Spastisite

Address for Correspondence/Yazışma Adresi: Aarti Gupta, Asst. Prof., SGT University, Department of Physiotherapy, Gurugram, India
E-mail: physioaarti@gmail.com
ORCID: orcid.org/0000-0003-0637-8656

Received: 19.10.2023 (Geliş Tarihi)
Accepted: 21.05.2025 (Kabul Tarihi)
Publication Date: 22.09.2025 (Yayınlanma Tarihi)

Cite this article as/Atıf: Dass A, Gupta A, Chaudhary V, Bhati P. Effect of pilates on movement patterns, balance and fatigue level in children with spastic diplegic cerebral palsy. Turk J Physiother Rehabil. 2025;36(2):153-163

INTRODUCTION

Children with cerebral palsy (CP) exhibit varying degrees of impairments brought on by a non-progressive brain injury or a brain abnormality that developed in the growing foetus or infant (1). These limitations may cause movement patterns to deviate, which can decrease performance and increase energy use while engaging in functional activities (2). Standing up from a chair is one of the most basic functional actions that children carry out numerous times every day. According to reports, the sit-to-stand (STS) task is the most prevalent essential activity in daily life (3). It is a skill for upright movement and a requirement for learning functional skills (4). To govern the change from a sitting to a standing position, STS movements necessitate consistent coordination between body parts. Additionally, it involves a change from a more stable position (sitting) to a less stable one (standing), which is an antigravity movement. Therefore, STS is considered to be a more demanding movement which adequately challenges the neuromuscular system. Previous literature has pointed out that children with CP had a weakened capacity to begin the lower limb joint movements required to assume the standing posture (5,6).

One more aspect of children with CP's daily existence is fatigue. Children with CP exhibit greater energy expenditure during specific activities like walking since they have several motor deficits. Additionally, a lower anaerobic threshold in CP suggests that children with the condition walk near to or above their anaerobic threshold, which causes early tiredness. Low levels of physical activity as a preventative measure to avoid fatigue may result from the high energy demands and lower anaerobic threshold, exacerbating the previously indicated vicious circle (7).

The capacity to maintain balance is essential for mastering the majority of functional abilities. Balance control enables a child to recover from unanticipated balance disturbances caused by accidents like trips and falls or by self-inflicted instability from movements that push them close to their limit of stability. According to Tarakci et al. (8), motor abnormalities in CP frequently come with poor balance control. Children with CP frequently need intense physical therapy instruction because of their impaired motor skills. Following involvement in a range of intervention programmes, clinical research has shown considerable improvements in the balance of children with CP (9).

Key objective of therapeutic interventions is to achieve the highest level of function. Pilates is a set of exercises that include coordination, strengthening, and stretching (10). Fundamental principles of pilates exercise include breathing, attention, control, centering, precision, and fluidity. Pilates places a strong emphasis on core stability and strength while coordinating the movement of the upper and lower extremities (11). However, there exists only scarce research on the effect of pilates exercise in neurological and respiratory of children and adults. Some preliminary evidence in the form of a recent case study of a 9-year-old kid with hemiplegic CP showed that pilates intervention could enhance postural control and muscle strength in both the affected and unaffected limbs (12). These findings suggests more research to be conducted in neurological population so as to understand the pilates induced changes in detail. Therefore, objective of the present study was to examine the impact of pilates exercises on movement patterns, balance, and fatigue in children with CP.

METHOD

Study Design

This randomised controlled trial was conducted at the Ved Special School, Sampoorna Special School, Abhyaas Special School in Delhi and the SGT Medical College Hospital and Research Institute in Gurugram, Haryana from October 2022 to March 2023. Ethical clearance was obtained from Departmental Ethics Committee, Faculty of Physiotherapy, Shree Guru Gobind Singh Tricentenary University, Gurugram, before recruiting subjects (proposal ID: SGTU/FPHY/2022/421, approval date: 12 October 2022, meeting held on 8 October 2022). The subjects' parents were explained about the nature and procedures of the study and a written assent was obtained from them for participation of their ward into the study.

Participant Recruitment and Allocation

The inclusion criteria consisted of diagnosed cases of spastic diplegic CP falling into gross motor function classification system (GMFCS) level I or II, age between 7-12 years. Those children who were able to do STS movement by holding the handrail after hearing verbal command were included. Those children having recent surgery to lower limbs (within one year), botulinum toxin-A or serial casting to lower limbs within the last three months were excluded. Those children who completed a core exercise group within the previous six months and those who had neurological or orthopaedic conditions unrelated to CP were also excluded from the study.

G-Power software version 3.1 was used to determine the sample size. With alpha error of 0.05, the effect size 1.05, power of 80%, sample size came out to be 32 (13). Totally 42 subjects were screened for spastic diplegic CP and after applying the inclusion/exclusion criteria, 32 subjects were recruited in the study (Figure 1). Computerised random assignment was used to assign children at random to either study group or a control group. Group allocation was performed using numbered, sealed, and opaque black envelopes by an investigator not involved in data collection. In order to ensure concealed allocation, the group assignment was not disclosed to the physical therapist who gathered the data.

Outcome Measures

Demographic characteristics of the children were recorded. Modified Ashworth Scale was used to grade the spasticity level of hamstrings, quadriceps, hip adductors and plantar flexors (14). The GMFCS (kappa 0.76 to 0.88) was used to determine the gross motor function level of the children (15).

Movement Pattern (Sit-to-Stand Activity)

STS movement is widely performed in daily life and an important prerequisite for acquisition of functional abilities. STS is a transitional movement to the upright posture that requires movement of the center of mass from a stable position to a less stable one over extended lower extremities. It is considered a biomechanical demanding task, since it requires greater knee and hip peak joint moments, as well as high levels of neuromuscular coordination to regulate horizontal and vertical momentum transfer. The evaluation of STS activity consisted of 15 items. The evaluation's goal was to compare the joint mobility and compensatory motion of the STS motions of healthy children vs children with CP. Each of these evaluation criteria examined the sagittal plane joint movement of each child's dominant hand side. These 15 elements were used to identify typical movements, which were then classified as YES or NO (16-18).

STS movements were captured using one iPhone camera, which was positioned on the side of the subjects' dominant hand. On the lateral malleolus, lateral femoral condyle, greater trochanter, and acromion, markers were unilaterally positioned. Each individual performed the STS motions three times after hearing an oral explanation of the entire technique. These 15 factors served as the basis for identifying the characteristics of STS movements and recording them as YES or NO (Table 1).

Balance

Pediatric Balance Scale (PBS) was used to evaluate balance in children with spastic diplegic CP. It is a modified version of Berg Balance Scale, which is used to evaluate balance in children with mild to severe motor impairments. This scale comprised of 14 common functional tasks (19). The maximum score on this scale is 56. Higher score indicated greater balance abilities in children with little to no motor impairments. Lower total test scores indicated moderate balance problems (or severe if the scores are extremely low or 0) and motor impairment.

Level of Fatigue

An indication of fatigue is the rate of perceived exertion. Modified Borg Scale was used to measure level of fatigue in children with spastic CP in accordance with previous studies (20,21). "Modified Borg Scale rates perceived exertion by the subject. It starts at number 0 where breathing is causing no difficulty at all and progresses through to number 10 where breathing difficulty is maximum."

Intervention

The sessions were conducted at physiotherapy department of Shree Guru Gobind Singh Tricentenary University and Paediatric Physiotherapy Unit of Ved Special School, Sampoorna Special

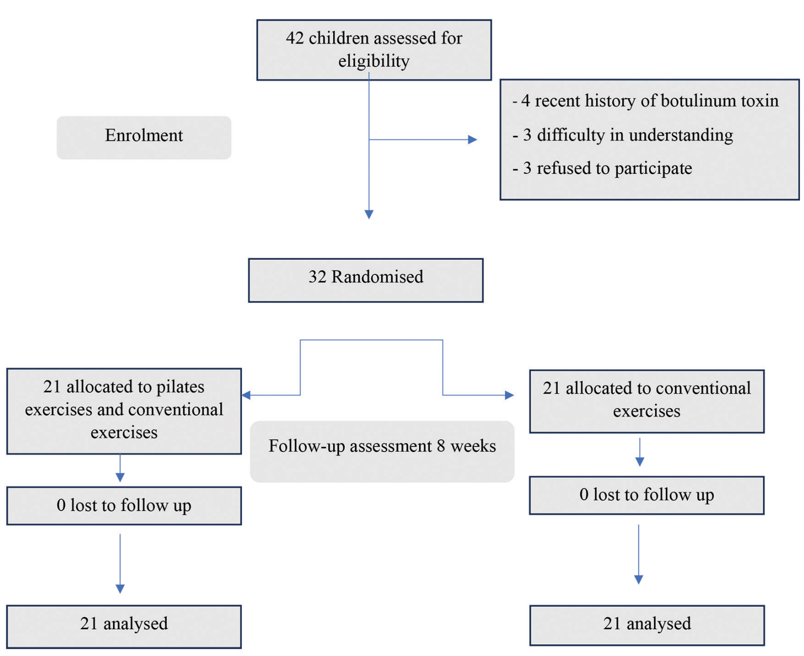


Figure 1. Flow of the participants through the study.

Table 1. Frame of reference of STS movements	
T1	The head and trunk were vertically stretched to the ground
T2	Trying to grab the handrail, the trunk tilted forward
T3	After grabbing the handrail, the trunk came to a stop
T4	After grasping the handrail, the trunk began to tilt further anteriorly
T5	When the trunk was tilted most anteriorly, the acromion was positioned ahead of the lateral malleolus
T6	After securing the handrail, the buttocks pushed forward and lifted their hips off the seat
T7	After lifting the handrail and angling the hip off the seat, the knee joint advanced
T8	While the hip is raised off the seat, the foot is dragged back
T9	Following hip off the seat, knee joint advanced
T10	After the hip left the seat, the lower thigh anteriorly inclined
T11	After lifting the hip from the seat, the foot fully grounded to the floor
T12	After lifting the hip from the seat, the head flexed more than the trunk
T13	Following hip off the seat, the acromion is placed front of the lateral malleolus
T14	In order to stand erect, the knee joint was shifted backward
T15	When in a standing position, the lower extremity and the trunk extend vertically to the ground

STS: Sit-to-Stand.

School, Abhyaas Special School under the supervision of a physiotherapist who was certified pilates therapist and had ten years of experience working with children having CP. Face-to-face intervention was given to each subject and each subject was treated individually i.e. one physiotherapist per one child. A unique “tailor made” program was created for every child based on his individual abilities.

Study Group (Pilates Programme Along with Conventional Treatment)

Each pilates session lasted for 30 minutes, and they were spaced out over the course of 8 weeks. First phase was of 4 weeks, second was of 2 weeks and third phase was also of 2 weeks. There were two sessions in a week. Sessions were made progressively challenging by changing the position or increasing the hold time. The study group also received 30 min of conventional exercises (explained under the section “conventional group”) along with pilates programme.

Pilates Programme (Appendix 1)

1. Thoracic rotation with the help of bow and arrow exercises,

2. Elongation of spine with pelvic stabilization by knee lift and aeroplane exercises,

3. Stabilisation of lumbar spine and pelvis by arm and leg lift exercises,

4. Diagonal patterns of upper limb by shoulder separation exercises,

5. Segmental spinal mobility by roll up exercises,

6. Hip dissociation by leg float exercises,

7. Bridging by pelvic curl exercises,

8. Hip abduction by clam shell exercises,

9. Spinal extension by dart exercises,

10. Superman in prone by alternate arm and leg lift exercises (22).

Control Group (Conventional Treatment)

Exercises for postural stability in various positions and surfaces were performed by both groups. These included stretching of hip flexors and adductors, knee flexors and extensors, and calf muscle. The stretching was performed three times per session, with a 30-s hold each time and an interval of 30 s. Strengthening included curl-ups and hip extension in prone, the hip abduction in side lying, knee flexion in prone, and knee extension in high sitting. Walking in all directions, standing on rough surface, standing on a soft surface, step down, step up, tandem standing, tandem walking, single leg standing, were also given. The intervention lasted for 8 weeks, with two sessions of 30 minutes each in a week. The strengthening exercise was performed in 2-3 sets with 10 repetitions per set and with a rest interval of 2-3 min between sets. A minimum rest period of 48 h was allowed between sessions. The exercise progressed uniformly throughout the 8 weeks of training by increasing the number of sets.

Both groups underwent the intervention process for a period of 8 weeks, and outcome variables were evaluated at baseline, after 4 weeks, and at the end of 8th week.

Statistical Analysis

Data analysis was performed with the software package IBM SPSS (version 20) for windows. To test the normality of the data, the Shapiro-Wilk test was used; variables which were found to be non-normal (PBS and Modified Borg) were log-transformed before further analysis. Demographic characteristics (such as age, weight, height, and body mass index), outcome variables-PBS, and Modified Borg Scale were compared between the groups using an independent t-test. Descriptive data was expressed as mean and standard deviations. Chi-square test was used to compare gender, GMFCS level, spasticity grade (measured by Modified Ashworth Scale). To assess the difference between the groups and across three time points, a 2 × 3 repeated measure analysis of variance was employed to evaluate the main effect of time (pre to post), group (study group vs. control group) and group×time interaction effect (change in the variable in the groups across two time points). Repeated measures ANOVA is a popular and most robust inferential parametric test to be applied in such research designs. Significance level was set at $p<0.05$ for the present study.

RESULTS

Demographic Characteristics and Baseline Data

No statistically significant differences were found between the groups for demographic and outcome variables at baseline ($p>0.05$) (Table 2).

At 4 weeks, **component T6** showed a significant difference with a p-value of **0.033**, indicating that the study and control groups differ significantly for this component at this time point. At 8 weeks, component T6 remained significant with a p-value of 0.028 and Component T11 showed a statistically significant difference with a p-value of 0.007, highlighting the significant effect for this component after 8 weeks. In study group**, most** components showed a **steady increase** over time, with significant improvements noted in T1, T3, T4, T7, T9, T11, and T12 while in **control group** , improvements were **less pronounced** than the study group, with some components showing minor changes or remaining stable. There is little to no increase for components such as T1, T4, T6, T7, and T11 (Table 3).

Statistical analysis revealed significant changes in the outcome variables in response to addition of pilates exercise program to conventional treatment for effects of time ($p<0.001$) and group × time interaction ($p<0.001$) in PBS. Mean values of PBS showed a significant difference [study group (49.81±2.88) versus control group (48.19±4.02)] after 8 weeks of intervention ($p<0.001$). Percentage increase in PBS was found to be 5.68 % in the study group versus 4.19% control group. Perceived exertion measured by modified borg scale also demonstrated significantly greater improvement in the study group as compared to control group ($p<0.005$). Percentage decrease in perceived exertion was found to be greater in the study group versus control group (40.26 % versus 23.78 %) (Table 4).

Findings of the post-hoc analysis revealed that pilates training program led to significant improvement in outcomes of PBS and perceived exertion at both 4 weeks and 8 weeks in spastic CP children (Table 5).

Table 2. Baseline characteristics of spastic diplegic CP children in the study

Characteristics	Study group (n=16) Mean ± SD	Control group (n=16) Mean ± SD	p-value
Age (years)	8.69±2.15	9.75±2.32	0.19
BMI (kg/m^2)	22.42±3.65	23.68±3.68	0.339
Gender, n (%)			
Male	12 (75%)	11 (68.75%)	0.694
Female	4 (25%)	5 (31.25%)	
Modified Ashworth Scale, n (%)			
Grade 1	7 (43.8%)	8 (50%)	0.771
Grade 1+	4 (25%)	3 (18.8%)	
Grade 2	5 (31.2%)	5 (31.2%)	
GMFCS			
Level I	7 (43.8%)	11	0.154
Level II	9 (56.2%)	5	
PBS	46.25±4.05	47.13±3	0.494
BORG Scale	6.56±1.26	6.06±0.92	0.212

CP: Cerebral Palsy, p-value: Probability Value, SD: Standard deviation, BMI: Body Mass Index, GMFCS: Gross Motor Function Classification System, PBS: Pediatric Balance Scale.

Table 3. Results of comparison of sit-to-stand movement at baseline, 4 weeks and 8 weeks in study and control group

Components		Study group Mean ± SD	Control group Mean ± SD	Chi-square	p-value	Study group Mean ± SD	Control group Mean ± SD	Chi-square	p-value	Study group Mean ± SD	Control group Mean ± SD	Chi-square	p-value
		Baseline				**4 weeks**				**8 weeks**			
T1	NO	5 (31.2%)	6 (37.5%)	0.1	0.71	3 (18.8%)	5 (31.2%)	0.67	0.41	2 (12.5%)	5 (31.2%)	1.65	0.2
	YES	11 (68.8%)	10 (62.5%)			13 (81.2%)	11 (68.8%)			14 (87.5%)	11 (68.8%		
T2	NO	0	0	-	-	0	0	-	-	0	0	-	-
	YES	16 (100%)	16 (100%)			16 (100%)	16 (100%)			16 (100%)	16 (100%)		
T3	NO	8 (50%)	6 (37.5%)	0.5	0.48	7 (43.8%)	5 (31.2%)	0.53	0.47	2 (12.5%)	4 (25%)	0.82	0.37
	YES	8 (50%)	10 (62.5%)			9 (56.2%)	11 (68.8%)			14 (87.5%)	12 (755)		
T4	NO	9 (56.2%)	8 (50%)	0.1	0.72	6 (37.5%)	8 (50%)	0.51	0.48	4 (25%)	7 (43.8%)	1.25	0.26
	YES	7 (43.8%)	8 (50%)			10 (62.5%)	8 (50%)			12 (75%)	9 (56.2%)		
T5	NO	0	0	-	-	2 (12.5%)	1 (6.2%)	0.37	0.54	4 (25%)	2 (12.5%)	0.82	0.37
	YES	16 (100%)	16 (100%)			14 (87.5%)	15 (93.8%)			12 (75%)	14 (87.5%)		
T6	NO	6 (37.5%)	10 (62.5%)	2	0.16	4 (25%)	10 (62.5%)	4.57	0.033*	3 (18.8%)	9 (56.2%)	4.8	**0.028***
	YES	10 (62.5%)	6 (37.5%)			12 (75%)	6 (37.5%)			13 (81.2%	7 (43.8%)		
T7	NO	8 (50%)	9 (56.2%)	0.1	0.72	6 (37.5%)	8 (50%)	0.51	0.48	3 (18.8%)	6 (37.5%)	1.39	0.24
	YES	8 (50%)	7 (43.8%)			10 (62.5%)	8 (50%)			13 (81.2%)	10 (62.5%)		
T8	NO	16 (100%)	16 (100%)	-	-	14 (87.5%)	15 (93.8%	0.37	0.54	10 (62.5%)	12 (75%)	0.58	0.45
	YES	0	0			2 (12.5%)	1 (6.2%)			6 (37.5%)	4 (25%)		
T9	NO	10 (62.5%)	9 (56.2%)	0.1	0.72	8 (50%)	7 (43.8%)	0.13	0.72	5 (31.2%)	6 (37.5%)	0.14	0.71
	YES	6 (37.5%)	7 (43.8%)			8 (50%)	9 (56.2%)			11 (68.8%)	10 (62.5%)		
T10	NO	8 (50%)	7 (43.8%)	0.1	0.72	6 (37.5%)	5 (31.2%)	0.14	0.71	4 (25%)	5 (31.2%)	0.16	0.69
	YES	8 (505)	9 (56.2%)			10 (62.5%)	11 (68.8%)			12 (75%)	11 (68.8%)		
T11	NO	4 (25%)	5 (31.2%)	0.2	0.69	3 (18.8%)	5 (31.2%)	0.67	0.41	0	4 (37.5%)	7.39	**0.007***
	YES	12 (75%)	11 (68.8%)			13 (81.2%)	11 (68.8%)			16 (100%)	10 (62.5%)		
T12	NO	5 (31.2%)	7 (43.85%)	0.5	0.47	3 (18.8%)	7 (43.8%)	2.33	0.13	2 (12.5%)	6 (37.5%)	2.67	0.1
	YES	11 (68.8%)	9 (56.2%)			13 (81.2%)	9 (56.2%)			14 (85.5%)	10 (62.5%)		
T13	NO	8 (50%)	8 (50%)	0	1	6 (37.5%)	7 (43.8%)	0.13	0.72	4 (25%)	6 (37.5%)	0.58	0.45
	YES	8 (50%)	8 (50%)			10 (62.5%)	9 (56.2%)			12 (75%)	10 (62.5%)		
T14	NO	9 (56.2%)	10 (62.5%)	0.1	0.72	7 (43.8%)	8 (50%)	0.13	0.72	4 (25%)	7 (43.8%)	1.25	0.26
	YES	7 (43.8%)	6 (37.5%)			9 (56.2%)	8 (50%)			12 (75%)	9 (56.2%)		
T15	NO	10 (62.5%)	12 (75%)	0.6	0.45	8 (50%)	10 (62.5%)	0.51	0.48	6 (37.5%)	10 (62.5%)	2	0.16
	YES	6 (37.5%)	4 (255)			8 (50%)	6 (37.5%)			10 (62.5%)	6 (37.5%)		

*Significant Difference, SD: Standard Deviation, p-value: Probability Value, T1-T15: 15 Items of Sit-to-Stand Movement.

Table 4. Comparison of PBS and Modified Borg Scale between the groups

		Study group (n=16)	Control group (n=16)	p-values		
Variable		Mean ± SD	Mean ± SD	Group	Group x time	Time
PBS	Baseline	46.25±4.05	47.13±3	0.312	<0.001*	<0.001*
	4 weeks	47.25±4.2	48.63±2.91			
	8 weeks	48.19±4.02	49.81±2.88			
Modified Borg Scale	Baseline	6.56±1.26	6.06±0.92	0.006*	<0.001*	<0.001*
	4 weeks	5.69±1.19	4.5±0.73			
	8 weeks	5±1.09	3.62±0.80			

*Significant Difference, 2×2 Repeated Measures ANOVA was Applied, SD: Standard Deviation; p-value: Probability Value, PBS: Pediatric Balance Scale.

Table 5. Comparison of PBS and Modified Borg Scale at different time intervals in study group

Variable	0 vs. 4 weeks	4 weeks vs. 8 weeks	0 weeks vs. 8 weeks
PBS	<0.001*	<0.001*	<0.001*
Modified Borg Scale	<0.001*	<0.001*	<0.001*

*Significant difference. PBS: Pediatric Balance Scale.

DISCUSSION

Children with CP have severely limited mobility and functional abilities, particularly in the STS and functional balance domains, due to movement and posture disorders. Inability to keep their bodies against gravity without losing balance while performing tasks like the PBS tests may have been caused by neuromotor deficits arising from their brain injuries (23). These children suffer earlier fatigue due to their increased energy needs. Pilates is an exercise programme that enhances the neuromuscular system to control and safeguard the core stability body or spine (24). This study sought to ascertain the effects of pilates on movement patterns, balance, and tiredness in children with spastic CP because the pilates strategy concentrates on core body activity. When completing STS movements, children with CP show higher postural oscillation, showing difficulty assuming the standing position.

After 8 weeks of pilates exercises, differences were observed in almost all of the items in the study group. Moreover, previous research has also suggested that the ability to start the lower limb joint motions required to attain the standing posture improves as a result of pilates exercise program (25). A significant improvement was found in PBS after pilates exercise program in the present study. However, conventional therapy, which included stretching, strengthening, and postural control exercises, also demonstrated positive changes in the balance outcomes in the control group. However, improvements observed in the pilates group were superior than control group. These findings can be explained by the fact that the body's kinematics improved resulting in more efficient motor function after structured pilates intervention. For the purpose of enhancing balance, increasing functional mobility, and controlling extremity movement, the trunk is crucial (26). Pilates exercises offer multitask intervention with improved kinaesthetic and proprioceptive awareness and movement coordination by requiring the practitioner to maintain a stable posture while focussing on the respiratory rhythm (27). Results of the present investigation were consistent with previous studies which also emphasized upon the fact that pilates exercise could help children with CP with their trunk, lower limb strength, and balance (28-31).

Findings of the present study suggested that an eight-weeks pilates training regimen can have a positive impact on fatigue in ambulant children with spastic CP. Children with spastic CP may find their level of exhaustion reduced by engaging in core exercises. These findings are consistent with the findings of Soysal Tomruk et al. (32), which showed that pilates training has the potential to reduce fatigue in patients with multiple sclerosis. Pilates was developed as a low-impact exercise to target and strengthen certain muscle groups without exhausting the entire body. It explains how to engage your back and stomach muscles without putting too much strain on your joints, as well as how to develop your mind-body connection by synchronising your breathing and movement. It is ideal for children with neurological disorders who easily get fatigued. Pilates is a low-impact exercise that enhances muscle balance and neuromuscular processes to achieve maximal strength. Pilates practice leads to an improvement in the ability to stabilize the body and in the ability to produce muscle contraction; as well as promotes increased strength, balance and flexibility. Thus, it seems reasonable to suggest that children with CP who can perform functional activities, such as walking and quiet standing, but need to enhance components required for a controlled movement, such as muscle strength, joint mobility, flexibility and postural control, could benefit from pilates practice (28).

Limitations

In the present study, there was no long-term follow-up assessment; therefore, more research is required to evaluate long-term effects of pilates exercise on children with spastic CP. The effect of plates on strength and flexibility was not evaluated which was another limitation. This study included only spastic diplegic children, therefore, additional research with varying GMFCS levels should be conducted on various CP subtypes. Though PBS is valid and reliable scale to assess balance, objective measures like biodex balance system could not be used in the study due to unavailability of the equipment.

CONCLUSION

The present study revealed that pilates exercises along with conventional exercises plays an important role in improving movement pattern, balance and decreasing fatigue which are important clinical parameters for children with spastic CP. Therefore, pilates exercises could be considered as an adjunct exercise program in children with spastic CP.

Ethics: Ethical clearance was obtained from Departmental Ethics Committee, Faculty of Physiotherapy, *Shree Guru Gobind Singh Tricentenary* University, Gurugram, before recruiting subjects (proposal ID: SGTU/FPHY/2022/421, approval date: 12 October 2022, meeting held on 8 October 2022).

Informed Consent: The subjects' parents were explained about the nature and procedures of the study and a written assent was obtained from them for participation of their ward into the study.

Sources of Support: None.

Conflict of Interest: The authors declare that there is no conflict of interest.

Author Contributions: Concept- AD; Design- AG; Supervision- AG; Resources and Financial Support- AG; Materials- AD; Data Collection and/or Processing- AD; Analysis and/or Interpretation- AG, PB, VC; Literature Search- AD; Writing Manuscript- AG; Critical Review- VC, PB.

Acknowledgements: The subjects and their parents who took part in the study and gave up their valuable time are all recipients of a sincere expression of gratitude from the authors.

REFERENCES

1. Levitt S, Addison A. Treatment of cerebral palsy and motor delay. John Wiley & Sons; 2018 Nov 28.
2. Vitrikas K, Dalton H, Breish D. Cerebral palsy: an overview. Am Fam Physician. 2020;101(4):213-20.
3. Da Costa CS, Rocha NA. Sit-to-stand movement in children: a longitudinal study based on kinematics data. Hum Mov Sci. 2013;32(4):836-46.
4. Suriyaamarit D, Boonyong S. Mechanical work, kinematics, and kinetics during sit-to-stand in children with and without spastic diplegic cerebral palsy. Gait Posture. 2019;67:85-90.
5. Pavão SL, Santos AN, Oliveira AB, Rocha NA. Postural control during sit-to-stand movement and its relationship with upright position in children with hemiplegic spastic cerebral palsy and in typically developing children. Braz J Phys Ther. 2015;19(1):18-25.
6. Gupta A, Sen S. The effect of pelvic control exercises on standing posture in children with spastic diplegic cerebral palsy: a pilot randomized controlled trial. Turk J Physiother Rehabil. 2025;36:20-40.
7. Balemans AC, van Wely L, Becher JG, Dallmeijer AJ. Longitudinal relationship among physical fitness, walking-related physical activity, and fatigue in children with cerebral palsy. Physical Therapy. 2015;95(7):996-1005.
8. Tarakci D, Ozdincler AR, Tarakci E, Tutuncuoglu F, Ozmen M. Wii-based balance therapy to improve balance function of children with cerebral palsy: a pilot study. J Phys Ther Sci. 2013;25(9):1123-7.
9. Lowes LP, Westcott SL, Palisano RJ, Effgen SK, Orlin MN. Muscle force and range of motion as predictors of standing balance in children with cerebral palsy. Phys Occup Ther Pediatr. 2004;24(1-2):57-77.
10. Hornsby E, Johnston LM. Effect of pilates intervention on physical function of children and youth: a systematic review. Arch Phys Med Rehabil. 2020;101(2):317-28.
11. O'Shea R, Siconolfi-Morris G. Complementary therapy approaches for children and youth with cerebral palsy. Cerebral Palsy. 2020:3069-81.
12. Dos Santos AN, Serikawa SS, Rocha NA. Pilates improves lower limbs strength and postural control during quite standing in a child with hemiparetic cerebral palsy: A case report study. Dev Neurorehabil. 2016;19(4):226-30.
13. Schmidt SA, Lo S, Hollestein LM. Research techniques made simple: sample size estimation and power calculation. J Invest Dermatol. 2018;138(8):1678-82.
14. Ghotbi N, Nakhostin Ansari N, Naghdi S, Hasson S. Measurement of lower-limb muscle spasticity: intrarater reliability of Modified Modified Ashworth Scale. J Rehabil Res Dev. 2011;48(1):83-8.
15. Palisano RJ, Avery L, Gorter JW, Galuppi B, McCoy SW. Stability of the Gross Motor Function Classification System, Manual Ability Classification System, and Communication Function Classification System. Dev Med Child Neurol. 2018;60(10):1026-32.
16. Yonetsu R, Nitta O, Surya J. "Patternizing" standards of sit-to-stand movements with support in cerebral palsy. NeuroRehabilitation. 2009;25(4):289-96.
17. Nuzik S, Lamb R, VanSant A, Hirt S. Sit-to-stand movement pattern. A kinematic study. Phys Ther. 1986;66(11):1708-13.
18. Park ES, Park CI, Lee HJ, Kim DY, Lee DS, Cho SR. The characteristics of sit-to-stand transfer in young children with spastic cerebral palsy based on kinematic and kinetic data. Gait Posture. 2003;17(1):43-9.
19. Chen CL, Shen IH, Chen CY, Wu CY, Liu WY, Chung CY. Validity, responsiveness, minimal detectable change, and minimal clinically important change of Pediatric Balance Scale in children with cerebral palsy. Res Dev Disabil. 2013;34(3):916-22.
20. Maltais D, Wilk B, Unnithan V, Bar-Or O. Responses of children with cerebral palsy to treadmill walking exercise in the heat. Med Sci Sports Exerc. 2004;36(10):1674-81.

21. Robert M, Ballaz L, Hart R, Lemay M. Exercise intensity levels in children with cerebral palsy while playing with an active video game console. Phys Ther. 2013;93(8):1084-91.

22. Gutner K. The Pilates essential repertoire. Art of motion, 19 edition. 2013:96-208.

23. Pavão SL, Dos Santos AN, de Oliveira AB, Rocha NA. Functionality level and its relation to postural control during sitting-to-stand movement in children with cerebral palsy. Res Dev Disabil. 2014;35(2):506-11.

24. Phrompaet S, Paungmali A, Pirunsan U, Sitilertpisan P. Effects of pilates training on lumbo-pelvic stability and flexibility. Asian J Sports Med. 2011;2(1):16-22.

25. Niaradi FDSL, Niaradi MFDSL, Gasparetto MERF. Effect of eutonia, holistic gymnastics, and pilates on body posture for pre-adolescent girls: randomized clinical trial. J Bodyw Mov Ther. 2022;30:226-36.

26. Panibatla S, Kumar V, Narayan A. Relationship between trunk control and balance in children with spastic cerebral palsy: a cross-sectional study. J Clin Diagn Res. 2017;11(9):YC05-8.

27. Suner-Keklik S, Numanoglu-Akbas A, Cobanoglu G, Kafa N, Guzel NA. An online pilates exercise program is effective on proprioception and core muscle endurance in a randomized controlled trial. Ir J Med Sci. 2022;191(5):2133-9.

28. Dos Santos AN, Serikawa SS, Rocha NA. Pilates improves lower limbs strength and postural control during quite standing in a child with hemiparetic cerebral palsy: A case report study. Dev Neurorehabil. 2016;19(4):226-30.

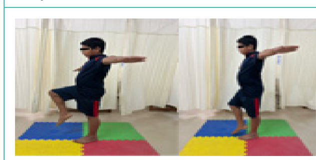
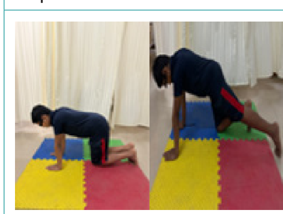
29. Adıguzel H, Elbasan B. Effects of modified pilates on trunk, postural control, gait and balance in children with cerebral palsy: a single-blinded randomized controlled study. Acta Neurol Bel. 2022;122(4):903-14.

30. Abd-Elfattah HM, Galal DOSM, Aly MIE, Aly SM, Elnegamy TE. Effect of pilates exercises on standing, walking, and balance in children with diplegic cerebral palsy. Ann Rehabil Med. 2022;46(1):45-52.

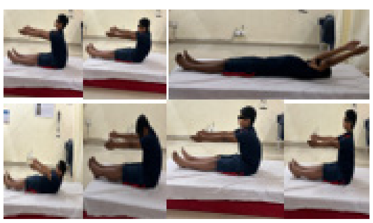
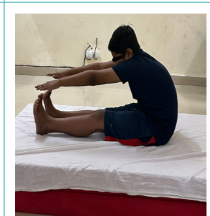
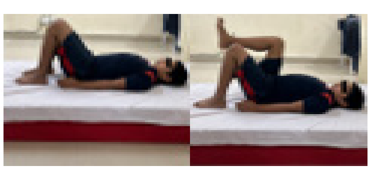
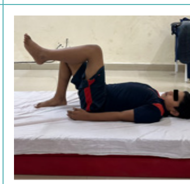
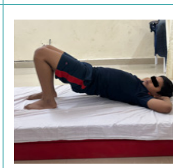
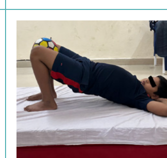
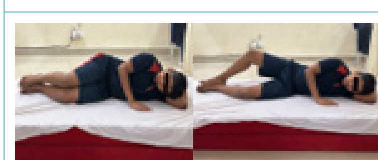
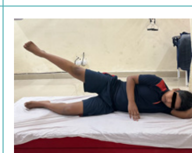
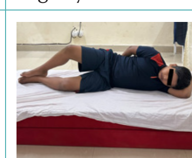
31. Değer Ü, Mutlu A. An investigation of relationship between trunk and lower extremity muscle strength and functional activity in children with spastic cerebral palsy. Turk J Physiother Rehabil. 2020;31(3):225-32.

32. Soysal Tomruk M, Uz MZ, Kara B, İdiman E. Effects of pilates exercises on sensory interaction, postural control and fatigue in patients with multiple sclerosis. Mult Scler Relat Disord. 2016;7:70-3.

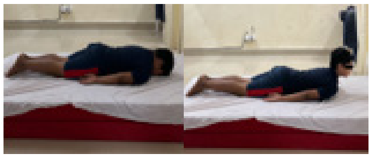
Appendix 1. Pilates programme

	0-4 weeks	4-6 weeks	6-8 weeks
Bow and arrow	In standing, outstretched the arms in front at chest height. Allow the right scapula to slightly protract as you extend your right arm forward. The scapula protraction starts the thoracic rotation. Exhale and continue segmentally rotating the left side of the thoracic spine while bending the left elbow back diagonally. Repeat the exercise 5 times each side.	High kneeling can be used to perform the exercise.	The exercise can be done while seated.
			
Knee lift and aeroplane	In standing, outstretched the arms in front at chest height. The heel is raised off the ground. Raise the knee. The pelvis is dynamically stabilised. The spine is neutral and long. Toes should just barely contact the ground when you bring the unsupported leg down. Repeat the exercise 5 times each side.	For a few breaths, continue to lift the unsupported leg.	The supported leg should bend and extend.
			
Arm and leg lift	In quadruped position, one of the leg is extended back. The floor is softly touched by the toes. Lift the leg until the hip joint is fully stretched. In a neutral position, the lumbar spine and pelvis are stabilised. Bring that leg down. Repeat the exercise 5 times each side.	Lift one arm while maintaining shoulder blade stability.	Lift the right leg off the ground while sliding it backward until the hip joint is stretched. Lift the left arm at the same time.
			

Appendix 1. Continued

	0-4 weeks	4-6 weeks	6-8 weeks
Shoulder separation	The arms are elevated in front of the body at chest height. The hands are stacked one on top of the other, left hand in front of right. Raise the right arm diagonally up while bringing the left arm down. Five times on each side, repeat the exercise.	The arms should be raised and lowered vertically.	Include swinging your arms in a semicircle.
			
Roll up	At chest height, the front arms are outstretched. Segmentally flex the spine beginning at the lower lumbar spine, engage the centre, and tilt the pelvis back. Roll each vertebra down one at a time untill the shoulders and head are on the floor. Reach the arms overhead while maintaining the front ribs in place. Lift the head and shoulders off the floor while circling the arms in front of you. Roll up while peeling each vertebra off the mat one at a time in a segmental motion. Turn your legs over and stretch your spine forward. Thoracic spine extension should be done in segments until neutral alignment is restored.	Knees should be bent while you sit. Roll down while leaving the heels in place to allow the legs to expand freely.	Dorsiflexion is added when you roll into leg stretch.
			
Leg float	In supine lying, lift one leg such that it forms a 90° angle at the hip and knee. Lower the leg and roll the foot down. 5-6 times on each side, alternating sides or only right, then left, repeat the exercise.	Alternating leg float	A simple leg floating with a ball
			
Pelvic curl	In supine lying, bend your knees and lift your buttocks off the plinth. Five to ten times should be enough to complete the exercise.	With arms behind head, pelvis curl	Knee squeezes and pelvic curl
			
Clam	In sidelying, knees are 90 degrees bent; lift the top knee and rotate the hip joint to the side. The large toes remain joined. Leg is lowered. 10 times total should be repeated.	Keep your upper thigh in line and straighten your knee.	With one hand on the sacrum, stabilise the pelvis and tilt the pelvis in the transversal plane slightly to the front.
			

Appendix 1. Continued

	0-4 weeks	4-6 weeks	6-8 weeks
Dart	Lift the head and shoulders up while lying prone and keep the palms facing up. Maintain a relaxed or slightly raised arm position.	With the palms down, rotate the arms laterally. Inhale With the palms facing up, rotate the arms medially.	Raise your arms and extend the small fingers.
			
Alternate arm and leg lift	Raise the left leg and right arm while lying prone. On each side, perform the exercise 5 to 6 times.	When lifting, rotate your upper arm laterally. The thumb is pointing up.	simultaneously raise your arms and legs off the ground.