A Study to Determine the Efficacy of Multifaceted Exercise Program on Balance and Trunk Control in Children with Spastic Diplegic Cerebral Palsy: A Pilot Study

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Abstract: ***Background**: Spastic Diplegia, often leads to impaired Balance and Trunk control resulting in deterioration of walking efficiency Traditional physiotherapy has been a cornerstone but with emerging time there is a need of holistic and comprehensive structured intervention. Therefore, this study aimed to determine the efficacy of Multifaceted Exercise Program (EXECP) on Balance and Trunk control in children with Spastic Diplegia. **Methods**: Twenty Children (aged 4-12 years) pre-diagnosed with Spastic Diplegia were distributed randomly into two equal groups; Group A (Experimental) and Group B (Control). Group A received EXECP program while Group B received traditional physiotherapy; 4 days/week for 9 weeks (60 minutes/session). Children were assessed for Balance and Trunk Control using Paediatric Balance Scale (PBS) and Trunk Control Measurement Scale (TCMS) respectively and pre-post readings were taken at baseline and 9th week. **Results**: Statistical analysis revealed statistically significant gains in Group A across all the domains (p<0.001) indicating marked improvement in balance capability, walking efficiency, trunk control and gait functions. **Conclusion**: Conclusively, EXECP program for Cerebral palsy (EXECP) demonstrated positive outcomes in enhancing the Balance and trunk control of SDCP children. The results support the integration of holistic goal-oriented rehabilitation interventions in routine clinical practice for children with spastic diplegia.***

Keywords: Balance, EXECP, Spastic Diplegia, Trunk Control

1. Introduction

Growth; a continuous process that commences at the moment of conception and lasts until a child becomes fully developed adult, Child's ability to grow is a crucial aspect of their life that sets them apart from adults.[1] Intrauterine life period is as vital as the early years of growth because the master organ 'BRAIN' starts developing after a period of 2 weeks of conception & it continues into young adulthood 20 years later.[2]

In spite of being under the genetic control, other factors also influence the developmental growth of the brain like, supply of nutrition (folic acid), presence of toxins (e.g.- Toxins).[2] Therefore presence of any deviational factor in the development of master organ during intrauterine and even postnatally period of growth can lead to various neuromuscular impairments and disabilities. One of the most common physical disability of childhood occurring due to the former cause is known as the 'CEREBRAL PALSY'.

1.1 Cerebral Palsy

"*Cerebral palsy (CP) describes a group of disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing foetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, cognition, communication, perception, and/or behaviour, and/or by a seizure disorder*."[3] It is a group of motor disorders stemming from the episode of brain insult during antenatal or postnatal period [4] that has a devastating effect on individual's mobility, postural stability and Body equilibrium.[5] these symptoms are often associated with other comorbidities.[4] Cerebral palsy is the most prevailing etiological factor for causing disability among children globally.[5] According to research studies conducted worldwide, there are 1.5-4 cases of cerebral palsy for every 1000 live births.[5,6]

According to **Hirtz et al.(2007)** the total prevalence estimate for live births in the United States is 2.4 per 1000.[5,7] While in India, According to National Family Health Survey (NFHS) 2015- 2016 conducted in Punjab ,24.6% mothers delivered their child through caesarean section while in 2020-2021 survey of NFHS the count escalates to 38.5%.[8] Deliveries through C-section approach is one of the perinatal risk factor.[9,10] for Cerebral palsy and that s increased with a spike in Punjab region. Global burden disease study report a total of 16.8 million people reported with cerebral palsy in India in 2019.[11]

As per the Swedish classification (1989)[12], Cerebral palsy is divided into four major categories i.e. spastic (hemiplegic, tetraplegic, and diplegic), dyskinetic (dystonic and athetotic), ataxic and unclassified/mixed. Among all, the Spastic type is one of the most prevalent forms of Cerebral palsy.[13] that occurs in 70-80% of all cases. As per the survey Report[14] of 248 children with CP of age group 3-13 years that was done in Jalandhar district of Punjab, the Spastic type of CP was the most common (83.46%) in all ages with 43.5% of diplegics, 13% hemiplegics, 9.2% triplegics and 34.3% quadriplegics followed by dyskinetic (16.93%), mixed (2.82%) and ataxic (2.01%). The most common subtype of Spastic Cerebral palsy across the globe is the Spastic diplegia.[15] In addition to functional difficulties brought on by spasticity or altered muscle tone, children with cerebral palsy (CP) also struggle with posture control, sensory processing, and motor coordination.[16] Activities like sitting, standing, reaching, and walking become challenging due to these deficits, which impair both static and dynamic balance. Impaired balance in CP can be due to various neural factors including hyperactive stretch reflexes, abnormal muscle tone, co-activation of muscles and weakness.[17] Moreover, contracture, abnormal timing, decreased isometric force output, and lower amplitude of muscle recruitment are among the abnormalities that influence efferent balance control networks as a result of the primary brain lesion in cerebral palsy (CP). [16] These abnormalities in Balance further compromises the ambulatory skills in lower extremities and hand functions in upper limb of the child. [16]

Fundamental elements of movement, including balance and upright postural control, are crucial for keeping the body in equilibrium in a particular sensory environment through automatic and anticipatory postural modifications. [18] An important aspect of postural stability is the smooth communication between the central and peripheral nervous systems. These interactions are disrupted in children with cerebral palsy (CP) due to brain injury, which causes structural musculoskeletal problems, abnormal muscle timing, stiffness, and inadequate muscle recruitment.[13] Studies [13,19,20] reveal that as compared to peers who are usually developing, children with spastic diplegic CP (SDCP) exhibit significantly impaired postural control. Impairment of postural control is also caused by a lack of selective control over muscle activity and a lack of regulation of muscle group activity in response to body motions and postural changes. Stabilization and targeted trunk motions are part of trunk control, which serves as the foundation for postural control.[13] The head and extremities cannot move freely or selectively without this stability. [13,21] A major contributing factor to the motor dysfunction of children with cerebral palsy is postural control issues, which comprises trunk control impairments. [13,22] Children with SDCP functioning at different gross motor levels presents with different trunk control deficits, a study by ***L. Heyrman et al.***[23] investigated trunk impairment in children with cerebral palsy (CP), in which various motor participation levels, classified by GMFCS levels were included. Trunk control, a crucial component of functional capacities in children with cerebral palsy, differed across levels I and II, with level I children demonstrating superior performance. while level II and III children were compared, it was shown that level III children showed higher trunk control deficiencies, especially while engaging in dynamic trunk movement exercises like crossed reaching and lateral reaching. According to these findings, children with inadequate capacity for walking have particularly poorer static and dynamic control of the upper and lower trunk, or the pelvic region. They also suggest that therapeutic exercises aimed at trunk control may help children walk more easily. For proper posture regulation and balance both the motor and sensory systems must be integrated.[23] The vestibular, proprioceptive, and visual systems work together to provide normal motor responses, balance, and mobility. Recognizing joint mobility, joint position sense (JPS) plays a crucial part in postural regulation and gait. Lesions to the central nervous system, which affect proprioceptive inputs from muscle spindles, Golgi tendon organs, and sensory innervations of joints and skin to the brain, are most likely the cause of proprioception impairments in cerebral palsy.[24]

More impairments related to the visual, tactile, proprioceptive, vestibular, and other perceptual systems exacerbate the compromising of balance responses.[16] Deficits in reactive and anticipatory postural changes, as well as in the sensory and musculoskeletal aspects of postural control, can be observed in children with cerebral palsy. They might lack smoother distal-to-proximal muscular activation sequence than children who are usually developing, as well as enhanced antagonistic muscle co-activation and co-contractions of both proximal and distal muscles.[16,25] All above factors play a causative role in declining balance in CP children. Furthermore, deterioration in balance function is one of the major causative factor for declining the ambulatory function of CP patients. [16,26] Evidently, level IV and level V CP patients are supposed to have impaired trunk control which is one of the central controlling factor to maintain upright posture, due to which they usually try to maintain the stability by either using upper extremities or external support, even on perturbations, an irregular and abnormal muscular activation is notable in them.[16] As a part of postural control, functional balance aids child in doing every day, social, and recreational tasks on their own at home, at school, and in the community.[18,27] Children with cerebral palsy have inadequate postural control mechanisms, which impairs their functional balance.[18] According to earlier research on balance, children with CP exhibited disturbed static and dynamic balance reactions than children with usual development. These balance issues made falls more likely, which further hampered the mobility, involvement, and activities of daily living (ADL) of children with CP. [18] Secondly, various other musculoskeletal derangements may further contribute to development of balance dysfunction; Due to these impairments, patients with cerebral palsy are often seen with scared and worried attitudes, consequently leading to decline in balance dysfunction.[16,18]

Physical rehabilitation plays a vital role in the care of cerebral palsy, by promoting functional activities and improvisation in limited mobility. Using different approaches and treatment interventions, therapist aims to restore and maintain the physical as well as psychosocial wellbeing of individual with cerebral palsy. [28,29]

Several therapies and interventions are available to treat sensorimotor dysfunction of CP such as Vojta therapy, Roods approach, sensory integration and other occupational therapies. Commonly applied interventions include Passive movements, gradual stretching, weight bearing exercises, proprioceptive training and many more. [29] The literature also states the lower limb muscle strength as a key factor for walking in children with CP.[30] The therapist or Rehabilitation team members should look and plan out according to deficits and frame to enhance the clinical manifestations. The rehab should include strengthening and stretching's as the primary treatment interventions. Strength training is one of the most applied intervention in physical therapy. But lately, a conflict developed in relation to strengthening exercises that application of these exercises may lead to increase in the muscle tone and abnormal motor behaviour[31], various studies were conducted in the past; some of it made negative infrences[32,33,34], However, some studies [35] haven't discovered any alteration in spasticity during or after training, nevertheless which validates the widespread opinion that strength training is safe for people with spasticity. As Cerebral Palsy presents with multiple manifestations, there is a need to work on specific motor deficits with multidimensional approach rather than working with general approach. For instance, correcting the tightness alone will not help in achieving independent walking until or unless the posture mechanisms, balance reactions and specific movement control is not strengthened. Therefore, the Motor learning-based rehabilitation with Multifaceted approach can bring fruitful Gains in children with Cerebral Palsy. In this context, This study aimed to find the efficacy of EXECP program on the Balance and trunk control in SDCP children.

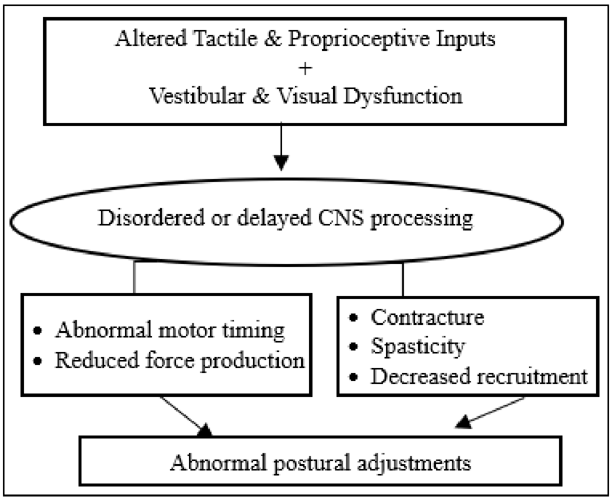


Figure 1: Effect of disturbed CNS input and output on balance and postural mechanism[16]

2. Methods

The approval for present study has been taken from the institutional ethical committee. This pilot study with pre-test post-test experimental design was carried out for a duration of one and a half year in department of Neurology physiotherapy in DAV Institute of physiotherapy and Rehabilitation, Jalandhar. Convenient sampling technique was used. After the screening using WHO Ten question screening instrument, The study commences with the proper demonstration of our study to the guardians as well as children and informed consent was obtained. A total of 20 children were assessed and recruited as per the inclusion and exclusion criteria. The general characteristics of children are shown in Table1.

Inclusion criteria-

- Children between 4-12 years of age group.
- Both genders were included.
- Children Pre-diagnosed with Spastic Diplegic Cerebral Palsy were included.
- Children falling in the Category of Level I to Level III as per the Gross Motor Classification System (GMFCS) were included.
- Children having ability to walk for more than 2 minutes with or without hand-held mobility aid.
- Children undergoing Rehab.
- Children having Grade 1, 1+ and 2 for Bilateral Hip Flexors and extensors, Hip Abductors and Adductors, Knee Flexors and Extensors, Ankle Plantar flexors and Dorsiflexors according to Modified Ashworth Scale were included.
- Children who are Able to follow simple commands.

Exclusion Criterion:

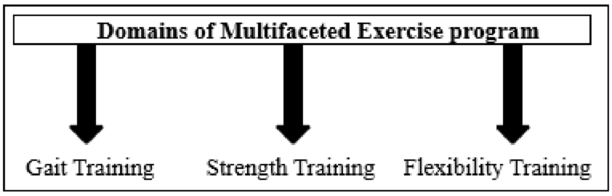
- Children with intellectual disabilities like Moderate and severe Mental Retardation & behavioural, attentional defects such as Autism and ADHD were excluded.
- Children with Ataxic, Athetoid and Mixed Cerebral palsy.
- Children having visual defects such as Strabismus.
- Children with the history of Epilepsy and Seizures.
- Children with the history of Surgical Orthopaedic interventions including rhizotomy, muscle lengthening operations or botulinum toxin injections in the last 3-6 months or intrathecal baclofen.
- Children with Lower limb fixed Contractures and Deformities.

Table 1: General Characteristics of the children

Variables	Experimental Group (Group A)	Control Group (Group B)
Age	6.60±2.514	6.20±1.619
Gender-		
Female	5	2
Male	5	8
GMFCS-		
Level I	2	1
Level II	5	6
Level III	3	3

Later on, Children were divided into two groups, i.e. Group "A" (Experimental group) who received the EXECP program exercises that included three domains; Gait training, Strength training and flexibility training and Group "B" (Control group) that underwent traditional physiotherapy. Each group contained 10 children.

The treatment was given for a period of 9 weeks; 4 days per week with total duration of minimum 60 minutes per day for Group A and Group B respectively. The total sessions for both groups were 36. Both the groups were assessed for Parameters of Balance, walking capacity, Trunk control and Spatial gait parameters using Paediatric Balance Scale (PBS) and Trunk Control Measurement Scale (TCMS) respectively. Fig. 2 shows the process of our study.



Gait Training:

A motorized treadmill with adjustable inclination of 3%-12% was used for gait training. In the initial training program, Children were instructed to walk at a comfortable speed with 6% inclination for 5-10 minutes for first 5 weeks and they were instructed to avoid toe walking and try their best to achieve heel strike. Further progression in the incline was made up to 9% for 5 -10 minutes in next 4 weeks. To prevent falling, Children was instructed to hold the handrail in front or parallel bars of the treadmill on their sides, moreover pelvic support and verbal feedback was given by the therapist to improve the walking pattern of the child.

Figure 2: Inclined treadmill gait training

Strength Training:

A total of five to seven strengthening exercises per session, comprising five single- joint and five multi-joint exercises, was included as a part of two weekly training programs. (as Session A and Session B on alternate days; ABAB/BABA). The program was divided in three blocks of 3 weeks. Weekly adjustments were made to the training load. Description of Strengthening domain is shown in Table 2 and Table 3.

Table 2: Description of Strengthening Training Protocol [32]

Session A	Session B
1) Seated calf raises 2) Seated Dorsiflexion 3) Standing calf Raise 4) Hip flexion 5) Seated horizontal Leg press 6) Trunk Extension 7) Squat	1) Seated machine knee flexion 2) Seated machine knee extension 3) Hip flexion 4) Standing calf Raise 5) Seated horizontal Leg press 6) Isometric Hollow Rocks 7) Squat

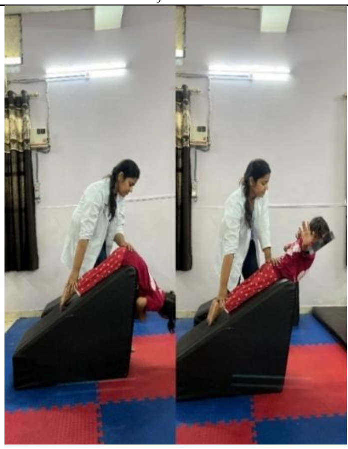
Table 3: Strengthening Exercise Sessions[32,36]

Week	Volume	Load	Movement Duration (s)	Rest (s)
1-3 week	3 sets of 8 repetitions	8 RM	2 Concentric 3 Eccentric	60
4-6 week	3 sets of 8 repetitions	8 RM	1 Concentric 3 Eccentric	90
7-9 week	4 sets of 6 repetitions	6 RM	1 Concentric 2 Eccentric	90

Table 4: Strengthening Exercise Sessions[32,36]

Exercise	Targeted muscle	Procedure	Kinesiological detail
Seated Calf Raise		In sitting, with 90o of knee flexion, keeping forefoot on a 10 cm step with ankle In maximal attainable dorsiflexion and the therapist provided weight over the distal thigh of the training leg.	Unilateral or Bilateral Plantarflexion
Standing Calf Raise		In standing, with hips & knees at 0o, keeping forefoot on a 10 cm step with ankle in maximal attainable dorsiflexion and asked to hold the parallel bars for balance.	

	Soleus & Gastrocnemius 		
Seated Dorsiflexion	 TibialisAnterior	In siting, with 70-90o of hip flexion knee at 0-20o of flexion and ankle in full plantarflexion. They were asked to perform the dorsiflexion against the resistance of TheraBand or manual Resistance placed on forefoot.	Unilateral or Bilateral Dorsiflexion
Seated Machine Knee Extension	 Quadriceps Femoris and Hamstrings	In sitting, with 80-90o of hip flexion knee at 115o of flexion and machine's lever arm was positioned at distal shank then they were asked to perform the exercise	Unilateral or Bilateral Knee Extension
Seated Machine Knee Flexion		In sitting, with 80-90o of hip flexion knee at 0-5o of flexion and machine's lever arm was positioned at distal shank then they were asked to perform the exercise	Unilateral or Bilateral Knee Flexion
Seated Horizontal Leg press	 Gluteus maximus, Quadriceps femoris, Hamstrings, Triceps Surae	Keeping hips at 90-110o of flexion & 0-20 o of hip external rotation, knees at 80-100o of flexion and feet & knees at hip width. The therapist kept a foam ball between the child knees to prevent hip adduction. The child was instructed to press against the Swiss ball.	Unilateral or Bilateral Hip & knee extension and ankle Plantarflexion

Squats	 Gluteus maximus, Quadriceps femoris, Hamstrings, Triceps Surae	In Standing, with hips and knees at 0o holding bar with both hands, feet and knees positioned at hip width and then by keeping hips in 0-20o of external rotation, squats were performed.	Bilateral Hip and Knee Extension & Ankle Plantarflexion
Hip Flexion	 Iliopsoas, rectus femoris, sartorius, tensor fasciae latae, tibialis anterior	In supine, keeping arms on side and both legs touching the mat, therapist applied resistance either with hand or TheraBand over the forefoot and asked the child to flex the training limb against the resistance.	Unilateral or Bilateral Hip Flexion & Isometric Ankle Dorsiflexion
Trunk Extension	 Erector spinae, multifidus	The child was positioned on padded inclined board (30o -45o), in prone lying with trunk in flexion outside the board. The pelvis and foot were stabilized with manual assistance by keeping knees at 0o against the padded board. After that, child was instructed to come up and do trunk extension	Isometric Trunk & Hip Extension
Hollow Rock	 Trunk flexors, Hip Flexors, Transverse abdominis	In Supine , keeping hips and knees at 0o, with arms by side and legs touching on the mat. The child was instructed to lift the legs slightly above the floor. (i.e. hip & trunk flexion, knee extension)	Isometric Trunk & Hip Flexion, Isometric Knee Extension

Flexibility Training:
4 sets of 45s manual Passive-static stretching at pain threshold were performed for each muscle group diagnosed short in the pre-assessment. Stretching procedures are as follows-

- **One & Two Joint Hip Flexors**

Children were positioned in Modified Thomas test position in supine lying with holding one leg in full hip flexion, while the other leg hanged outside the table. After this, the therapist applied the hip extension torque at the distal thigh with the knee joint positioned in full flexion to impart stretching force on two joint hip flexors, whereas to stretch one joint hip flexors one knee was kept relaxed.

- **Hip Adductors:**

The position was sitting with back well supported on a wall, hips in external rotation and knees in flexion while the soles of the feet were in contact therefore by achieving butterfly stretch position, the therapist used his knees to keep the child feet in position while pressing down the thighs causing hip abduction.

Figure 3: Stretching Hip Flexors

Figure 4: Stretching Hip Adductors

- **Knee Flexors:**

In supine lying, one leg was stabilized and kept flat against the plinth of the couch while the hip of another leg was flexed approximately to 90 degrees and then the therapist applied knee extension torque at the posterior aspect of the shank.

Figure 5: Stretching Knee Flexors

- **Ankle Plantarflexors:**

With child in supine lying, the therapist grasped the Heel with one hand and place the forearm along the plantar surface of the foot, and with another hand the anterior aspect of tibia was stabilised, Afterwards, the knee was maintained either in extension (Gastrocnemius) or flexion (soleus).

Figure 6: Stretching Ankle Plantar flexors

The Group B children underwent the traditional physiotherapy [29,37-44]

3. Results

20 subjects with Spastic Diplegic CP were enrolled, as per criteria. Group A had 5 males and 5 females; Group B had 8 males and 2 females. Based on GMFCS levels:

- Level I: 2 (20%) in Group A, 1 (10%) in Group B
- Level II: 5 (50%) in Group A, 6 (60%) in Group B
- Level III: 3 (30%) in both groups

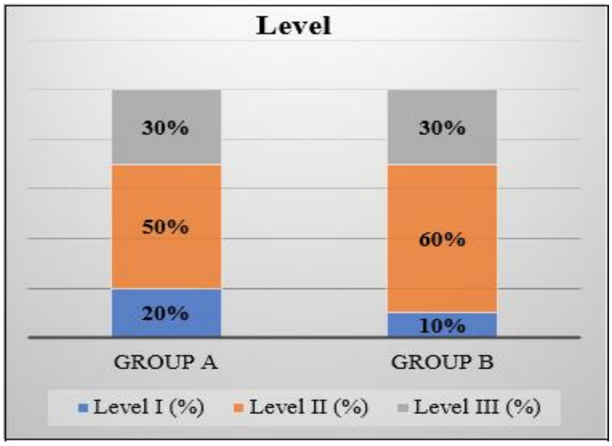


Figure 7: Shows levels according to GMFCS in Group A and Group B

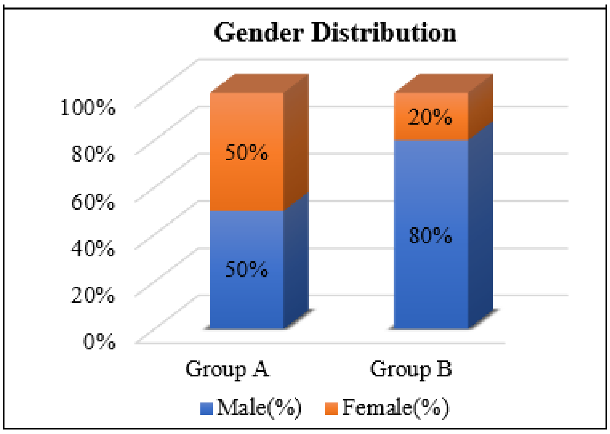


Figure 8: Shows gender distribution of subjects for Group A and Group B

On analysis using Paired T-test for PBS score for Group A, the mean and standard deviation was found to be 19.70 ± 6.165 at baseline and 31.80 ± 6.339 at the 9th week, respectively. The PBS scores showed a mean improvement from 19.70 to 31.80, with a mean difference of 12.10. The Paired T-test value was 10.190 and the p-value was <0.001, which was found to be significant. Similarly, on analysis using Paired T-test for PBS score for Group B, the mean and standard deviation was found to be 20.30 ± 10.361 at baseline and 24.10 ± 9.655 at the 9th week, respectively. The PBS scores showed a mean improvement from 20.30 to 24.10, with a mean difference of 3.80. The Paired T-test value was 5.879 and the p-value was 0.0002, which was found to be significant, showing an increase in postural balance in Group B, although the improvement was smaller as compared to Group A. In addition to improvements in postural balance, analysis using Paired T-test for TCMS demonstrated significant gains in trunk control. For Group A, the mean and standard deviation was 22.60 ± 6.620 at baseline and 34.10 ± 8.089 at the 9th week, respectively, with a mean improvement from 22.60 to 34.10 and a mean difference of 11.50. The Paired T-test value was 9.338 and the p-value was <0.001, indicating significant improvement over the 9 weeks.

Likewise, Group B showed improvement in trunk control, with mean TCMS scores increasing from 23.20 ± 9.426 at baseline to 25.70 ± 9.129 at the 9th week. The mean difference was 2.50, with a Paired T-test value of 8.135 and a p-value of <0.001, indicating a significant but smaller improvement in trunk control compared to Group A over the 9 weeks. Overall, both groups demonstrated statistically significant improvements in postural balance and trunk control over the 9-week period. However, **Group A showed a notably greater improvement** in both PBS and TCMS scores, suggesting that the intervention applied to Group A was more effective in enhancing these functional outcomes.

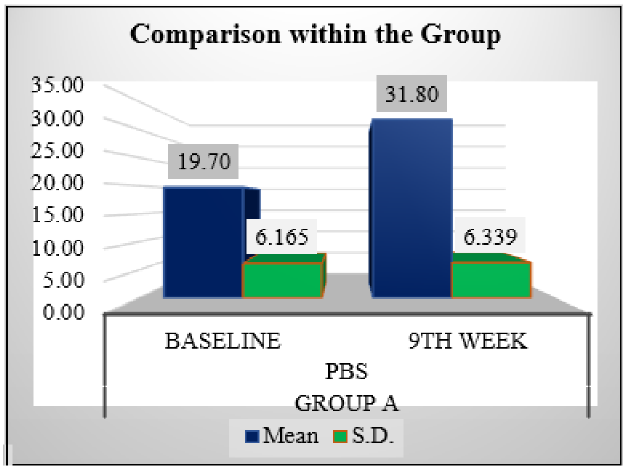


Figure 9: Within the group difference for Paediatric balance scale (PBS) for group A at baseline and at 9th week.

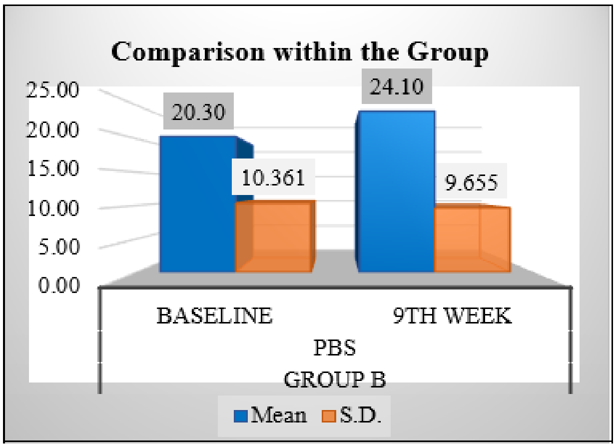


Figure 10: Within the group difference for Paediatric balance scale (PBS) for Group B at baseline and at 9 weeks

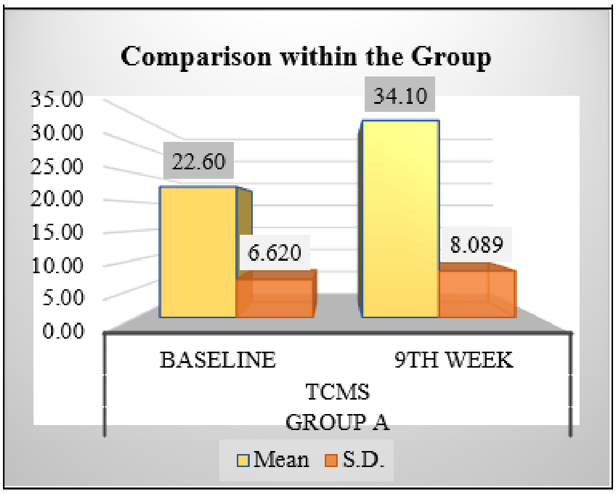


Figure 11: Within the group difference for Trunk control measurement scale (TCMS) for Group A at baseline and at 9 weeks.

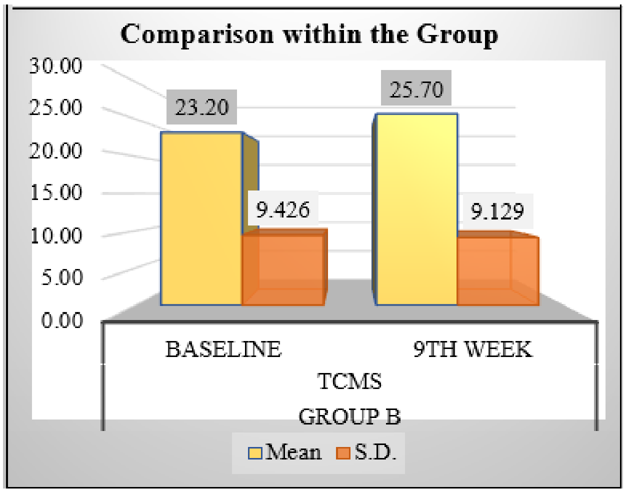


Figure 12: Within the group difference for Trunk control measurement scale (TCMS) for Group B at baseline and at 9 weeks

4. Discussion

The aim of the present study was to determine the efficacy of Multifaceted Exercise Program (EXECP) on Balance and Trunk Control in Children with Spastic Diplegic Cerebral Palsy. The variables of the current study were Scores of PBS scale and Scores of TCMS scale. The objectives of the study were to determine the efficacy of Multifaceted Exercise Program on Balance and trunk control in children with Spastic Diplegic Cerebral Palsy. The subjects were divided into two groups that is Group A and Group B. Group A was Experimental Group and Group B was a Control Group with a total of 10 children in both the groups with Spastic Diplegic CP. Both the groups received the treatment for 9 weeks;4 days per week with a total minimum duration of 60 minutes per day. The total sessions for both groups were 36. The patients were assessed at baseline and post intervention 9 weeks for balance and trunk control with PBS scale and TCMS scale respectively.

The analysis was obtained using the SPSS software version 18.0 Level of significance 0.05 was used to determine the statistical significance. Unpaired t test and paired t test were used as a statical tools in this study. Both within group and between the group analysis was done to analyse the dependent variables; scores of Paediatric Balance Scale (PBS) and scores of Trunk Control Measurement Scale (TCMS).

It was hypothesized that there would have been statistically significant differences among Balance, and trunk control. The demographic details for the age of the children were found to be 6.60±2.514 and for the group B were 6.20±1.619 for Group A and Group B respectively. The demographic data for the gender showed 5 males and 5 females in Group A while Group B included 8 males and 2 females. The subjects falling in level I of GMFCS were 2 (20%) and 1(10%) for Group A and for Group B respectively. For Level II of GMFCS were 5(50%) and 6 (60%) for Group A and B respectively, Lastly the Subjects falling in the category of Level III of GMFCS were 3(30%) and 3(30%) in Group A and B respectively.

Effect of EXECP Program on Balance

In Group A, within group analysis of PBS; results showed significant difference from baseline to 9th week .The mean PBS scores increased from 19.70 to 31.80 and a larger mean difference of 12.10. It is further supported by the Paired T-Test value of 10.190, which was higher than the critical value of 2.26 at the 0.05 significant level. Current findings demonstrated highly significant improvement with p-value of <0.001, indicating that the intervention significantly improved the Scores of Paediatric balance Scale in Group A with.

While, within the group analysis of Group B, also exhibited statistically significant improvement in PBS scores with mean improvement from 20.30 to 24.10, and a Mean Difference of 3.80. The associated p-value was 0.0002 which showed statistically significant change in PBS scores.

Both comprehensive and conventional protocols led to an within group improvement in Balance. Nonetheless, the comprehensive protocol led to mean increase of 12.10 on PBS scale, whereas conventional training led to a 3.80. These findings unveiled children recruited in Group A had significant improvement in Balance of CP following the multifaceted intervention. The possible mechanisms behind the improved balance includes the activation of CPG's i.e. central pattern generators which facilitates the motor patterns resulting in the improvisation of balance and posture control as reported in findings of **Mattern-Baxter K.(2010)**[45] in 2010; who explained that treadmill training enhances the rhythmic reciprocation and smooth balance reactions. As **Gage JR(2014)**[46] highlighted that standing and walking are disrupted due to abnormal pelvic and trunk alignment in children with SDCP because of ankle equinus and increased knee flexion or extension, which may even cause positional lever arm dysfunction resulting from the muscle weakness and altered muscle tone. Therefore, correction of lower limb alignment following treadmill training enhances the stabilization of the pelvis and trunk and diminishes the postural sway which may also contribute in the enhancement of balance control in BSCP children; Furthermore; the findings of **ÖZAL C 2023**[47] proposed that treadmill training enhances motor learning and thereby enhancing the capabilities of CP child. In light of this, the findings of current study have been supported by following literature; A study conducted by **El Shemy SA.(2018)**[48] which reported treadmill training with eyes open and closed as effective for improvisation in knee proprioception, functional balance and enhancing mobility in children with spastic diplegia. **Tedla JS. (2014)**[49] conducted a study on Spastic diplegic subjects with purpose to examine the efficacy of strength training on muscle strength, balance and motor functions in 5-14 years old subjects over a period of 6 weeks. They concluded that strengthening exercises targeting trunk and lower limb are beneficial for the improvisation in balance, muscle strength and function of subjects with spastic diplegia. **Merino-Andres J (2022)**[50] did a meta-analysis to explore the efficacy of muscle strength training in children and adolescents with cerebral palsy, they concluded after analysing twenty seven studies that for children and adolescents with cerebral palsy in Gross Motor Function Classification System levels I, II, and III, a strength training program has beneficial functional and activity effects on muscle strength, balance, gait speed, or gross motor function without increasing spasticity when the right dosage and principles are applied. Similar results were found in the study conducted by **Grecco LA (2012)**[51] who concluded that treadmill training had positive gains on functional balance and mediolateral oscillation relative to overground gait training.

Effect of EXECP Program on Trunk control

Trunk control and balance are the fundamental needs to attain the functionality in CP children.[18] Because it immediately affects movement quality and the capacity to carry out tasks demanding strength and coordination, trunk stability must be incorporated into functional training regimens. Reflecting on this, our study after the within-group analysis, it showed improvement in TCMS scores of Group A from baseline to 9th week with larger mean change as compared to Group B; the mean difference for the TCMS for Group a from baseline to 9th week is 11.50 while for Group B the mean difference come out to be 2.50 from baseline to 9th week. The observations and results of our study closely mirrors to those of **ÖZAL C 2023.**[47] who investigated the effect of unsupported treadmill training on postural control and balance in SDCP children functioning at GMFCS level I and II. They suggested to add treadmill locomotor training in rehabilitation of CP children to escalate their functionality as it improves the postural control, stability, weight shifting and sensory organization during static as well as dynamic part of daily activities. Furthermore **Kim CH.(2024)**[52] conducted a single subject design to investigate the effect of high intensity muscle strength training and stretching exercises in adolescents with SSDCP; after a intervention period of 16 weeks, they observed improvisation in strength, postural alignment without increased spasticity. Their results suggested that Hi-intensity strengthening and stretching exercise can be beneficial for enhancing muscle strength, body alignment; due to lengthening of hamstrings and increased power of quadriceps. The similar outcomes were seen by **Merino-Andres J (2022)**[50] who observed that children and adolescents with cerebral palsy in Gross Motor Function Classification System levels I, II, and III, when given a strength training program, it has beneficial outcomes on muscle strength, balance, walking speed, or gross motor functions. All things considered, this pilot study provides valuable insights into the efficacy of a multifaceted exercise program in improving balance, walking capacity, trunk control, and spatial gait parameters in children with spastic diplegic cerebral palsy. The significant improvements observed across all these domains underscore the potential of this program as an effective rehabilitation strategy. Although the findings are promising, further research with larger sample sizes and long-term follow-up is necessary to validate these results and explore the program's sustainability. Nonetheless, this study contributes to the growing body of evidence supporting the use of holistic, multifaceted interventions in the management of cerebral palsy, and it offers a foundation for future clinical applications and studies aimed at enhancing mobility and quality of life for children with cerebral palsy.

5. Conclusion

This study investigated the 9 weeks pre-tailored comprehensive Multifaceted Exercise Program (EXECP) comprising gait training, strength and stretching domain targeting the children with Spastic diplegic CP with an aim to improve the Balance, trunk control, walking capacity and spatial gait parameters of children to maximise functional capabilities in their daily living. The findings of our study suggests that implementation of the multimodal intervention over 9 weeks led to considerable positive gains in all the selected parameters as compared to conventional physiotherapy. Notably, children in experimental group showed enhanced balance and trunk control with better walking capacity and improvements in spatial gait parameters. These results reinforce the possible advantages of incorporating the multifaceted exercise intervention into clinical aspects of Cerebral palsy rehabilitation. However, keeping the limitations of our study in view; such as, small sample size, simple gait analysis method, should be kept in consideration while these observations are interpreted. Although this is a pilot study, providing preliminary data and supports the viability of the intervention, but further large-scale longitudinal studies with advanced and sophisticated gait analysis methods are advised to validate and expand the current outcomes. At last, it can be concluded that Multifaceted exercise program emerges as a promising intervention program in optimising functional mobility and quality of life in children with Spastic Diplegic Cerebral Palsy, offering a focused direction for clinical practice and research.

6. Limitations and Future Scope

This study had a few limitations, including the absence of a follow-up protocol and a small sample size, which limits the generalisability of the results. Findings are based on children with mild spasticity and may not apply to those with more severe forms. Additionally, due to resource constraints, advanced gait analysis tools were not used, which may have limited the precision of gait assessments.

Future studies should involve larger, multicentre trials and incorporate advanced gait analysis technologies for more accurate data. Long-term follow-up is needed to assess the lasting effects of the intervention. Including caregiver-reported outcomes could provide further insight into daily functional improvements, and extending the study to other types of cerebral palsy may help validate its broader clinical use.

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References

[1] Ghai OP, Gupta P, editors. Essential Paediatrics. New Delhi, India: CBS Publishers & Distributors; 2007:1.

[2] Tierney AL, Nelson III CA. Brain development and the role of experience in the early years. Zero to three. 2009 Nov 11;30(2):9.
[3] Rosenbaum P. Proposed definition and classification of cerebral palsy, April 2005. Dev Med Child Neurol. 2005; 47:571-6.
[4] Gulati S, Sondhi V. Cerebral palsy: an overview. The Indian Journal of Pediatrics. 2018 Nov; 85:1006-16.
[5] Chauhan, A., Singh, M., Jaiswal, N., Agarwal, A., Sahu, J. K., & Singh, M. Prevalence of Cerebral Palsy in Indian Children: A Systematic Review and Meta-Analysis. Indian journal of pediatrics, 2019 Mar 86 (12), 1124–1130.
[6] Paneth N, Hong T, Korzeniewski S. The descriptive epidemiology of cerebral palsy. Clinics in perinatology. 2006 Jun 1;33(2):251-67.
[7] Hirtz D, Thurman DJ, Gwinn-Hardy K, Mohamed M, Chaudhuri AR, Zalutsky R. How common are the "common" neurologic disorders? Neurology. 2007 Jan 30;68(5):326-37.
[8] Ministry of Health and Family Welfare (India). National Family Health Survey (NFHS-5), 2019–21: India Report – Phase II [Internet]. New Delhi: Ministry of Health and Family Welfare; 2021 [cited 2025 Apr 22]. Available from: https://main.mohfw.gov.in/sites/default/files/NFHS-5_Phase-II_0.pdf
[9] Sadowska M, Sarecka-Hujar B, Kopyta I. Cerebral palsy: current opinions on definition, epidemiology, risk factors, classification and treatment options. Neuropsychiatric disease and treatment. 2020 Jun 12:1505-18.
[10] Kułak W, Sobaniec W, Okurowska-Zawada B, Sienkiewicz D, Paszko-Patej G. Antenatal, intrapartum and neonatal risk factors for cerebral palsy in children in Podlaskie Province. Neurol Dziec. 2009;18(36):19-24.
[11] Singh G, Sharma M, Kumar GA, Rao NG, Prasad K, Mathur P, Pandian JD, Steinmetz JD, Biswas A, Pal PK, Prakash S. The burden of neurological disorders across the states of India: The Global Burden of Disease Study 1990– 2019. The Lancet Global Health. 2021 Aug 1;9(8): e1129-44.
[12] Ogoke CC. Clinical classification of cerebral palsy. Cerebral Palsy-Clinical and Therapeutic Aspects. 2018 Nov 5.
[13] Kallem Seyyar G, Aras B, Aras O. Trunk control and functionality in children with spastic cerebral palsy. Developmental neurorehabilitation. 2019 Feb 17; 22(2):120-5.
[14] Sharma R, Sinha AG. Physical profile of children with cerebral palsy in Jalandhar district of Punjab India. Indian Journal of Cerebral Palsy. 2015;1(1).
[15] Huntsman R, Lemire E, Norton J, Dzus A, Blakley P, Hasal S. The differential diagnosis of spastic diplegia. Archives of disease in childhood. 2014 Nov 18: archdischild-2014.
[16] Day BL, Lord SR. PRUE MORGAN1* AND JENNIFER L. MCGINLEY 2 1 Physiotherapy Department, School of Primary and Allied Health Care, Monash University, Frankston, VIC, Australia. Balance, Gait, and Falls. 2018 Nov 24:323.
[17] Woollacott MH, Burtner P, Jensen J, Jasiewicz J, Roncesvalles N, Sveistrup H. Development of postural responses during standing in healthy children and children with spastic diplegia. Neuroscience & Biobehavioural Reviews. 1998 Mar 4;22(4):583-9.
[18] Panibatla S, Kumar V, Narayan A. Relationship between trunk control and balance in children with spastic cerebral palsy: a cross-sectional study. Journal of clinical and diagnostic research: JCDR. 2017 Sep;11(9): YC05.
[19] Brogren E, Hadders-Algraa M, Forssberg H. Postural control in sitting children with cerebral palsy. Neuroscience & Biobehavioural Reviews. 1998 Mar 4;22(4):591-6.
[20] Liu WY, Zaino CA, McCoy SW. Anticipatory postural adjustments in children with cerebral palsy and children with typical development. paediatric Physical Therapy. 2007 Oct 1;19(3):188-95.
[21] Verheyden G, Vereeck L, Truijen S, Troch M, Herregodts I, Lafosse C, Nieuwboer A, De Weerdt W. Trunk performance after stroke and the relationship with balance, gait and functional ability. Clinical rehabilitation. 2006 May;20(5):451-8.
[22] Dasoju V, Kovela RK, Tedla JS, Sangadala DR, Reddy RS. Psychometric properties of trunk impairment scale in children with spastic diplegia. Scientific Reports. 2021 Sep 17;11(1):18529.
[23] Heyrman L, Desloovere K, Molenaers G, Verheyden G, Klingels K, Monbaliu E, Feys H. Clinical characteristics of impaired trunk control in children with spastic cerebral palsy. Research in developmental disabilities. 2013 Jan 1;34(1):327-34.
[24] El Shemy SA. Effect of treadmill training with eyes open and closed on knee proprioception, functional balance and mobility in children with spastic diplegia. Annals of Rehabilitation Medicine. 2018 Dec 28;42(6):854-62.
[25] Nashner LM, Shumway-Cook A, Marin O. Stance posture control in select groups of children with cerebral palsy: deficits in sensory organization and muscular coordination. Experimental brain research. 1983 Mar;49(3):393-409.
[26] Jahnsen R, Villien L, Egeland T, Stanghelle JK. Locomotion skills in adults with cerebral palsy. Clinical rehabilitation. 2004 May;18(3):309-16.
[27] 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. Research in developmental disabilities. 2013 Mar 1;34(3):916-22.
[28] Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public health reports. 1985 Mar;100(2):126.
[29] Gunel M. Rehabilitation of children with cerebral palsy from a physiotherapist's perspective. Acta orthopaedica et traumatologica turcica. 2009 Mar 1;43(2):173-80.
[30] Dallmeijer AJ, Rameckers EA, Houdijk H, de Groot S, Scholtes VA, Becher JG. Isometric muscle strength and mobility capacity in children with cerebral palsy.

Disability and rehabilitation. 2017 Jan 16;39(2):135-42.
[31] Verschuren O, Peterson MD, Balemans AC, Hurvitz EA. Exercise and physical activity recommendations for people with cerebral palsy. Developmental Medicine & Child Neurology. 2016 Aug;58(8):798-808.
[32] Valadão P, Piitulainen H, Haapala EA, Parviainen T, Avela J, Finni T. Exercise intervention protocol in children and young adults with cerebral palsy: the effects of strength, flexibility and gait training on physical performance, neuromuscular mechanisms and cardiometabolic risk factors (EXECP). BMC Sports Science, Medicine and Rehabilitation. 2021 Dec;13(1):1-9.
[33] Kirk H, Geertsen SS, Lorentzen J, Krarup KB, Bandholm T, Nielsen JB. Explosive resistance training increases rate of force development in ankle dorsiflexors and gait function in adults with cerebral palsy. The Journal of Strength & Conditioning Research. 2016 Oct 1;30(10):2749-60.
[34] Taylor NF, Dodd KJ, Baker RJ, Willoughby K, Thomason P, Graham HK. Progressive resistance training and mobility-related function in young people with cerebral palsy: a randomized controlled trial. Developmental Medicine & Child Neurology. 2013 Sep;55(9):806-12.
[35] Damiano DL, Vaughan CL, Abel ME. Muscle response to heavy resistance exercise in children with spastic cerebral palsy. Developmental Medicine & Child Neurology. 1995 Aug;37(8):731-9.
[36] Valadão P, Cenni F, Piitulainen H, Avela J, Finni T. Effects of the EXECP intervention on motor function, muscle strength, and Joint Flexibility in individuals with cerebral palsy. Medicine and Science in Sports and Exercise. 2023 Aug 7;56(1):1.
[37] Ameer MA, Fayez ES, Elkholy HH. Improving spatiotemporal gait parameters in spastic diplegic children using treadmill gait training. Journal of bodywork and movement therapies. 2019 Oct 1;23(4):937-42
[38] Kisner C, Lynn Allen Colby. Therapeutic exercise: foundations and techniques. Philadelphia, Pa: F.A. Davis Co., Publishers; 2002.
[39] Harjpal P, Raipure A, Kovela RK, Kovela Sr RK. The effect of neuro-physiotherapy on gross motor function in a male child with spastic diplegic cerebral palsy: a case report. Cureus. 2022 Sep 19;14(9).
[40] Bandy WD, Irion JM. The effect of time on static stretch on the flexibility of the hamstring muscles. Physical therapy. 1994 Sep 1;74(9):845-50.
[41] Liao HF, Liu YC, Liu WY, Lin YT. Effectiveness of loaded sit-to-stand resistance exercise for children with mild spastic diplegia: a randomized clinical trial. Archives of physical medicine and rehabilitation. 2007 Jan 1;88(1):25-31.
[42] Levitt S, Addison A. Treatment of cerebral palsy and motor delay. Hoboken, Nj: Wiley-Blackwell; 2019.
[43] Prakash S, Singh JN. Effect of Neuro-Development Treatment with Roods Approach on Posture Control and Balance in Cerebral Palsy Children. International Journal of Convergence in Healthcare. 2024 Jan 31;4(1):40-54.
[44] Cho HJ, Lee BH. Effect of functional progressive resistance exercise on lower extremity structure, muscle tone, dynamic balance and functional ability in children with spastic cerebral palsy. Children. 2020 Jul 31;7(8):85.
[45] Mattern-Baxter K. Locomotor treadmill training for children with cerebral palsy. Orthopaedic Nursing. 2010 May 1;29(3):169-73.
[46] Gage JR, Schwartz MH, Koop SE. The identification and treatment of gait problems in cerebral palsy. London: Mac Keith Press; 2014.
[47] ÖZAL C, AKSOY S, Gune M. The effects of treadmill training on postural control and balance in children with spastic diplegic cerebral palsy: A cross-over controlled study. Neurology Asia. 2023;28(2).
[48] El Shemy SA. Effect of treadmill training with eyes open and closed on knee proprioception, functional balance and mobility in children with spastic diplegia. Annals of Rehabilitation Medicine. 2018 Dec 28;42(6):854-62.
[49] Tedla JS. Strength training effects on balance in spastic diplegia subjects: A randomized controlled trial. Journal of Pediatric Neurology. 2014 Mar;12(01):015-28
[50] Merino-Andres J, Garcia de Mateos-Lopez A, Damiano DL, Sanchez-Sierra A. Effect of muscle strength training in children and adolescents with spastic cerebral palsy: A systematic review and meta-analysis. Clinical rehabilitation. 2022 Jan;36(1):4-14.
[51] Grecco LA, Tomita SM, Christovão TC, Pasini H, Sampaio LM, Oliveira CS. Effect of treadmill gait training on static and functional balance in children with cerebral palsy: a randomized controlled trial. Brazilian journal of physical therapy. 2013;17:17-23.
[52] Kim CH. Effects of High-Intensity Muscle Strength Training and Stretching Exercises on Strength, Spasticity, Postural Alignment, and Participation in an Adolescent with Spastic Diplegic Cerebral Palsy: A Single-Subject Design. Journal of the Korean Society of Physical Medicine. 2024;19(3):1-1.

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