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Effect of Postural Stability Exercises on Gait Parameters in Children with Spastic Diplegia Cerebral Palsy: An Experimental Trial

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Abstract

Postural stability helps maintain the position of the body within the support area to maintain control, but this postural stability is affected in children with cerebral palsy during static or dynamic activities. However, the practical application of postural stability exercises combined with muscle strengthening has not been studied in spastic diplegia cerebral palsy children with gait difficulties.

Purpose. To study the effect of postural stability exercises on the gait and posture of children with spastic diplegia cerebral palsy.

Material & Methods. 23 subjects with spastic diplegia cerebral palsy within the age group of 8 to 15 years, both male and female were randomly allocated into two groups Group A (Experimental) n=12 and Group B (Control) n=11, voluntarily participated and EVGS and DGI were used to assess the posture, gait, and functional capacity as outcome measures. Pre-test and post-test values were used for the interpretation of data.

Results. The mean difference of 3.25 with a t-value of 8.74 at a significance of 0.000 ($p<0.005$) was calculated which shows a statistically significant difference between the pre and post-values of Group A and the mean difference of 1.63 with a t-value of 8.05 at a significance of 0.000 was calculated, which is statistically significant.

Conclusion. Combined effect of postural stability exercises along with muscle strengthening exercises have a significant effect on the gait functions in children with spastic diplegia CP of GMFCS level II and III.

Keywords: Cerebral Palsy, Edinburg Visual Gait Score, Gait parameters, Postural Stability, Postural Stability Exercises, Spastic Diplegia CP.

Introduction

Cerebral Palsy (CP) is a Non-Progressive Neurological disorder occurring due to a lesion in the developing brain, which provokes clinical manifestations. These manifestations include motor disorders, accompanied by disorders of cognition, perception, and communication and leading to activity limitation (Filho et al., 2014) (Capucho et al., 2012). There has been a significant rise in the birth prevalence of cerebral palsy to 2.0 (Range=1.5 to 4) per 1000 live births over the last 40 years approximately worldwide according to the recent census by the Centers for Disease Control and Prevention (CDC). As per the ICF – Disability and Health of WHO – Geneva, the clinical manifestations of CP children restrict them

from performing their ADLs and confine them to play their role in society as an individual. National Sample Survey Office's (NSSO) 2011 census in India, approximately 2.68 cr. (2.21%) the population is 'disabled' from a total population of 121 cr. mostly suffering from locomotor (gait) disability including cerebral palsy.

Traditionally it has been classified based on clinical motor disorders and topographical lesions in the brain. Anatomically cerebral palsy is generally classified as diplegia, monoplegia, hemiplegic, and quadriplegic but clinical and topographical classification has been widely used, irrespective of function (Filho et al., 2014).Secondary alterations in the cerebrum result in disorders related to movement and musculoskeletal disorders which leads to impairment in the child's functional performance, posture, balance, and gait deficits (Rosenbaum et al., 2008). Loss of postural control, other musculoskeletal complications with more pronounced contractures, and weakness of the muscles, which is due to alteration in the neural mechanism and changes in the muscle tissues are the possible factors affecting the normal pattern of gait in children with CP (Eek et al., 2008). It has been found that there is a reduction of 6-59% of muscle strength in the lower limb in individuals with CP depending on the muscle group when compared with typically developing peers (Shin et al., 2016).

The ability of the body to control it in a position of stability about space is known as postural control while stability could be defined as the achieving and maintaining the center of body mass (COM) support during static and dynamic activities, within the base of support. (Pavão et al., 2013). Gait disorders in CP are suggested to be the major component due to postural control deficits. Thus, impaired postural balance contributed enormously to the gait abnormalities in children with diplegia CP (Rose et al., 2002).

The Gross Motor Function Classification System (GMFCS) has provided a means for categorizing children with CP into the level of functioning, but it also varies among children with the same level. The GMFCS classifies the functional levels into five levels based on the gross motor function and is simple, reliable, and easily reproducible. The classification is done based on the patient's motor performance, the nature of movement indoors and outdoors, and the need for any sort of assistive technologies to place them into different levels (Filho et al., 2014). The Can Child Center of Canada has provided a scale for specifying the children with CP according to GMFCS levels as per their functional abilities. Level I: Optimal trunk control and independent gait; Level II: Good trunk control and gait limitations; Level III: Good trunk control and gait dependent on locomotion auxiliary devices; Level IV: Poor trunk control and gait dependent of auxiliary devices and supervision with possible use of powered wheelchair; Level V: Limited trunk control and locomotion with wheelchair. This scale can be used for individuals aged up to eighteen years for the assessment, but for premature children, the corrected age should be considered. As the GMFCS classification is ordinal, it does not have any intention to keep the distance between levels equal, or that the CP children can be distributed equally, within five levels WHO, (Capucho et al., 2012).

Among the different types of CP, Spastic Cerebral Palsy is the commonest form of CP (approximately 70-80%) and about 50% of these are diplegias (Kalirathinam & Arumugam, 2012) in spastic diplegia CP, there is severe involvement of the lower extremities, but the upper extremities are seldom, usually with normal intelligence and with epilepsy not being so common. In children with CP spasticity, contractures, muscle imbalance, minimal voluntary control, and muscular weakness are some common disorders. Amongst the major motor complications is muscle weakness which is more involvement of distal muscles like the extensors of hip, knee, and ankle dorsiflexors and the flexors being the weaker ones (Kalirathinam & Arumugam, 2012).

Individuals with spastic diplegia typically face difficulty in ascending and descending stairs, running, and are slow walkers. The most common gait patterns in children with spastic diplegia CP have peculiar characteristics of excessive flexion at the hip and knee which implicates weak hip and knee extensors and ankle plantar flexors. Individuals with spastic diplegia cerebral palsy demonstrate crouched gait. Most parents of children with GMFCS level I, II, and III have major concerns about their child's ability to walk, and improve or maintain this ability using therapeutic interventions to address the motor difficulties becomes the primary focus in children with spastic diplegia. The cost of energy required to walk is increased in a crouch gait and leads to joint degeneration and pain. Nearly all children in GMFCS level II and III are eventually an ambulatory with varying levels of difficulty (Peungsuwan et al., 2017).

Crouch's gait typically worsens over time, if timely intervention is not provided. A host of possible factors including muscle tightness, weakness, spasticity, skeletal deformities, muscle imbalances, and motor control deficits are associated with the development of crouch gait. Varying success has been seen in treatments to improve crouch gait. However, identifying the root cause of the progression of this gait pattern and the desired treatment for correction of the crouch gait is difficult as the unstated movement is created by muscle forces. The complex multi-joint linkage

through which the muscles can cause movement at the joints that they do not cross by dynamic coupling. The non-intuitive function of bi-articular muscles is a result of coupling. Several clinical implications have been noted between crouch gait and the ability of muscles for hip and knee extension. So, the need for maintaining this crouch posture will significantly minimize the ability of the muscle for hip or knee extension (Read et al., 2003).

Minimal reduction of the distance variables of the gait cycle on the ipsilateral extremity is noted in these children as gait deviations with reduced stride length and joint excursion and acceleration in comparison with the contralateral extremity and the magnitude of these deficits are directly related to the degree of severity at the neurological level. Hemiplegic CP children have shown reduced strength values in children in the same age group, but these values are generally at peak for children with diplegia CP (Peungsuwan et al., 2017; Read et al., 2003). Multiple studies demonstrating various techniques of muscular strength training provide evidence to improve muscle strength in children with diplegia CP. The increase in Gross Motor Functional Measure score has been reported in walking ability by strength training (Eek et al., 2008).

Therefore, implementing appropriate training programs can be beneficial to develop specific motor abilities. Exercise training programs should be closely related to the functional activities of daily living such as balance training, postural stability, and strengthening exercises. Because many of our ADLs demand muscle strength and cardiovascular endurance, strength training combined with an intensive functional exercise program can be a better way to improve physical function for CP children (Rosenbaum et al., 2008).

It is important to understand how exercise training combined with strength and endurance exercises in participants with CP affects muscle functions that relate to routine activity; however, none of the studies to date have studied the effects of a functionally related combined strength and postural stability exercise program on gait parameters in participants with CP (Rosenbaum et al., 2008). These exercises can make children with CP stronger, as well as they can also increase strength at a rate similar to persons with weakness without any brain damage (Peungsuwan et al., 2017). In literature quantifying the gait performance by use of visual analysis of gait has been described in disabled children using video recordings to prevent fatigue but challenging reliability has been noted (Emara, 2015).

The use of highly advanced 3-D gait analyzers is a crucial investigation for the assessment of patients with cerebral palsy and demonstrates the complexity of movement analysis laboratory. However, accessibility to these facilities is not universally available although a simplified visual score such as the Edinburgh Visual Gait Score (EVGS) may permit a quantitative assessment of gait when no clinical tool to assess gait is available. EVGS is a visual scoring system that is easy to use, reliable, and well-correlated with recordings obtained during instrumented gait analysis (Emara, 2015).

The children with spastic diplegia especially GMFCS level II, III experience difficulty in ambulation due to muscle imbalances and lack of postural stability due to muscular weakness and the crouch gait. Parents of children with CP usually are concerned about their child's ability to walk so gait becomes an important aspect of rehabilitation in terms of independence and functional abilities. Although some studies have shown significant improvement in gait functions after functional strength training, it is still controversial, but none have opted for a combination of postural stability and strength training. The lack of literature identifying the effect of postural stability exercises on postural control and gait parameters in children with spastic diplegia CP makes this study important to be done for contributing towards the profession as a Physiotherapist.

Material and methods of research

Participants

A Randomized controlled trial of an experimental type of study was conducted and a sample size of 23 children with spastic diplegia (n=12 group A, n=11 group B) was selected by Simple Random sampling for an intervention period of 12 weeks. The subjects were recruited from different centers of Physiotherapy.

Children with spastic diplegia CP with GMFCS level II and III, both males and females aged between 8-15 years who participated voluntarily were included in the study and a duly signed consent form was obtained from the parents before the initiation phase of the study. While the patient who received BOTOX or surgical procedures within the last 3 months before the intervention, children other than spastic diplegia type of cerebral palsy and children with severe cognitive disability/ Perceptual and Cognitive Dysfunction were excluded from the study. Institutional ethical clearance was obtained initially. The pre-intervention data was obtained using the outcome measures for all the subjects along with the detailed assessment of the subjects after taking informed consent from the parents of the subjects.

Procedures

The Edinburg Visual Gait Score, Dynamic Gait Index, and Posture Screen mobile phone appli-

cation were used as outcome measures in this study. After the assessment and baseline (pre-intervention data) values were noted, the subjects were randomly allocated into two groups, Group A (Experimental) n=12 and Group B (Control) n=11 by lottery method. Later, Group A (Experimental) was given postural stability exercises including heel-to-toe walking, foot waves, calf raises, toe curls, single leg standing, standing, and steps up and down along with muscle strengthening exercises for quadriceps and calf muscles along with their respective regular physiotherapy program. Group B (Control) received only muscle strengthening exercises for the quadriceps and calf muscles using progressive resistance using free weights, bands, and weight cuffs according to the strength of the child. Both groups performed all the exercises for 60 minutes, 5 times a week for 12 weeks.

Statistical Analysis

Post-intervention data were collected after 3 months (12 weeks) of an intervention program prescribed to each group. The treatment was monitored by researchers through their physiotherapist and parents. The data availed was tabulated using Microsoft Excel (MS Excel). The demographic data like the age and sex of the subjects in both groups were tabulated to know about the distribution of the sample. Later, the significance test was done. The analysis of data was done by using Statistical Package for Social Sciences, Version-20 (SPSS-20). A paired t-test was used to know the difference within the group and an independent t-test for between-group comparisons.

Results

Table 1 depicts the pre and post-values within Group A and Group B by paired t-test analysis for EVGS. The mean difference of 3.25 with a t-value of 8.74 at a significance of 0.000 ($p<0.005$) was calculated which shows the statistically significant difference between the pre and post-values of Group A while the pre and post-values within Group B by paired t-test for EVGS, the mean difference of 1.63 with a t-value of 8.05 at a significance of 0.000 was calculated, which is statistically significant and shows that both the groups improved statistically for the EVGS.

Table 2 depicts the pre and post-values within Group A and Group B by paired t-test analysis for DGI. The mean difference of 3.08 with a t-value of 8.14 at the significance of 0.000 ($p<0.005$) was calculated which is statistically significant while the pre and post-values within Group B by paired t-test for DGI, the mean difference of 1.27 with t value of 4.66 at the significance of 0.001 ($p<0.005$) was calculated which is statistically significant. On comparison, the data shows that both groups showed improvement statistically for DGI.

After 12 weeks of intervention, the outcome measures improved significantly in Experimental Group A for both EVGS and DGI, but the outcome scores did not change much in Control Group B when compared with the baseline scores. Thus, it can be said that postural stability as well as a combination of muscle strengthening exercises has an effect in improving the gait parameters in children with spastic diplegia CP.

Table 1. **Paired t-test analysis of group A and group B for EVGS between pre- and post-intervention values**

Group A (experimental)	N	Mean ± SD	Mean Diff.	t-value	p-value
Pre	12	18.00±4.28	3.25	8.74	.000
Post	12	14.75±3.16			
Group B (control)	**N**	**Mean ± SD**	**Mean Diff.**	**t-value**	**p-value**
Pre	11	17.27±3.82	1.63	8.05	.000
Post	11	15.63±4.20			

EVGS – Edinburg Visual Gait Score

Table 2. **Paired t-test analysis of group A and group B for DGI between pre and post-intervention values**

Group A (experimental)	N	Mean± SD	Mean Diff.	t-value	p-value
Pre	12	11.08±5.59	*3.08*	8.14	0.000
Post	12	14.16±4.60			
Group B (control)	**N**	**Mean ± SD**	**Mean Diff.**	**t-value**	**p-value**
Pre	11	12.09±4.72	*1.27*	4.66	0.001
Post	11	13.36±4.47			

DGI – Dynamic Gait Index

Table 3. Independent t-test analysis of pre- and post-intervention values between group A and group B for EVGS

EVGS	Group	N	Mean ±SD	Mean Diff	t- value	p-value
PRE	Group A	12	18.00±4.28	0.63	0.42	0.56
	Group B	11	17.27±3.82			
POST	Group A	12	14.75±3.16	0.88	0.56	0.18
	Group B	11	15.63±4.20			

EVGS – Edinburg Visual Gait Score

Table 4. Independent t-test analysis of pre- and post-intervention values between group A and group B for DGI

DGI	Group	N	Mean ± SD	Mean Diff	t- value	p-value
PRE	Group A	12	11.08±5.59	1.01	0.46	0.41
	Group B	11	12.09±4.72			
POST	Group A	12	14.16±4.60	0.80	0.42	0.77
	Group B	11	13.36±4.47			

DGI – Dynamic Gait Index

Table 3 displays an independent t-test analysis between the Groups that shows no significant difference (P>0.005) between the pre-intervention values of EVGS between Group A and B at baseline and after the intervention with a mean difference of 0.63 for pre- and 0.88 for post-intervention values for EVGS and Table 4 displays independent t-test analysis between the Groups that shows no significant difference (P>0.005) between the pre-intervention values of DGI between the Group A and B at baseline and after the intervention with a mean difference of 1.01 for pre and 0.80 for post-intervention values for DGI.

Discussion

The purpose of this study was to find out whether the postural stability exercises have some effect on the gait parameters along with muscle strengthening exercises for the lower limbs in children with spastic diplegia cerebral palsy with GMFCS levels II and III. There was a 69% (n=16) percentage of male subjects and 31% (n=7) of female subjects who participated in the study. Of these 23 subjects with spastic diplegia CP 10 subjects were from GMFCS level III while the other remaining 13 subjects were from GMFCS level II. Most of the children in the study were between 8 to 11 years (n=20) of age while only 3 subjects were aged between 12 to 15 years (n=3). Group A received postural stability exercises including heel too toe walking, foot waves, calf raises, toe curls, single-leg standing, sit-to-stand, step up and down, calf muscle strengthening, and quadriceps strengthening exercises which resulted in improvement in scores of EVGS and DGI scores which were used as outcome measures in this study. A similar improvement was also seen in Group B which only received strengthening exercises for calf and quadriceps muscles.

There was a significant difference noted between the pre and post-intervention values of the experimental group for both EVGS and DGI used as an outcome measure. It was found during the study that the application of DGI in assessing the children with spastic diplegic CP was difficult as the children were not able to control the body while performing a few items in DGI. These items included change in speed, stepping over, and stepping around obstacles. The post values for DGI were less statistically significant as compared to the post values for EVGS in both groups. This study regarding the effect of postural stability exercises on gait parameters assessed by EVGS and DGI shows a significance of 0.000 in Group A for both outcome measures.

In the study on Gait Training in Spastic Diplegia Children (Kalirathinam & Arumugam, 2012) also discussed the limitations of function in people with cerebral palsy which can be multifactorial such as increased tone, contractures, and fixed skeletal deformities for which muscular strength training can be seen as a part of comprehensive management rather than a stand-alone therapy. One of the exercises given to the experimental group was sit-to-stand. In a few studies, sitting-to-stand ability is a key factor in determining functional independence as performing sit-to-stand results in a change in physiologically stable position to a position of less stability of small base of support and higher center of mass of the body. Therefore, targeting walking abilities with training helps in gaining independence and increased active participation in daily life.

The concept of rehabilitation of CP has changed over the years. Rather than focusing on single aspects of ADLs, combined effects with the

use of various treatment and management approaches are being used extensively to promote improvement and independence.

The posture screen mobile application which used an outcome measure to assess the postural deviation in these subjects' showed improvements in the number of shifts and tilts in the body at different levels in anterior-posterior and lateral views after placing marks on anatomical levels on the body. This is necessary to improve because postural control abnormalities are one of the major limitations to motor development in children with CP. Most of the deviations were noted at the hip and knee level, the mean backward shift of 3.75" at the hip and forward shift of 2.25" was noted at the knees in Lateral view were noted. Similarly mean shift of 1.2" and a mean tilt of 4.62° were noted at the hips in the AP view. The forward shift at the knee in most of the cases was significantly correlating as mostly the children demonstrated a similar pattern to crouch gait.

Additionally, a gait practicing program was also implemented in the protocol for both groups after 3 weeks of the intervention period, in which the subjects were told to walk at least 3 meters of distance daily after the exercise protocol, which added benefits to the patients in improving the gait functions. The intervention group also showed improvements in the increased AROM from the baseline values although it did not have any effect on the tone of the lower extremity when compared to the baseline values.

In the study on the Effects of Combined Exercise Training on Functional Performance (Peungsuwan et al., 2017) emphasized appropriate training programs that play a role in developing specific motor abilities. He suggested that exercise training programs should be closely related to the routine functional activities of an individual. For observational gait analysis using EVGS, anatomical landmarking was done before the recordings were taken for each subject the scoring was done thrice to avoid observational errors and the final score was recorded. The scores were noted according to the deviations noted from the normal at six anatomical levels and in three planes and were scored accordingly. Although in literature, controversies regarding the effect of muscle strengthening on gait function are known this study also supports the prescription of muscle strengthening exercises for lower extremities in children with spastic diplegia CP aged between 8 to 15 years belonging to GMFCS level II and II.

However, the results of the intervention group showed that statistically significant differences between the mean scores of the EVGS and DGI were obvious, and the postural deviation of the lower limbs and hip also reduced as recorded by the posture screen mobile application. This greater level of improvement in Group A is a combined effect of postural stability and muscle strengthening of lower limbs which resulted in improvement in gait functions and parameters for spastic diplegia. Through this, the importance of muscle strengthening is evident for children with spastic diplegia and similarly, it was concluded by (Peungsuwan et al., 2017) in a study on the effect of combined exercises on functional performance.

Limitations and recommendations

Along with the limitations the study had some strengths which included the use of the digitalized tool for postural evaluation, from this study all the subjects benefited from the regime given to them, no harm was noted and the administration of EVGS was useful for clinical settings where no other alternative tool is available for gait evaluation.

The limitation of a smaller sample size, small duration of intervention, self-administration, and daily follow-up of the cases was not possible as subjects were recruited from different rehabilitation centers. From the outcome measures performing few tasks in DGI was difficult to administer in such a population. The results were only studied for GMFCS levels II and III; the results cannot be applied to other GMFCS levels.

Recommendation for including a larger sample size in future studies with long-term exercise regimes should be implemented because, in the case of spastic diplegia in children, proper time and practice are required for the adaption of muscle to perform efficiently. The use of 3-D Gait analysis can be done for future studies for more accurate and specific targeted muscles.

Conclusion

This study concluded that the postural stability exercises combined with muscle strengthening exercises have a significant positive effect on gait parameters in children with spastic diplegia cerebral palsy on using EVGS and DGI as outcome measures along with a digitalized mobile application which can measure postural deviations in an individual on basis of tilts and shifts occurring in the body.

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