

RELATIONSHIP BETWEEN BALANCE AND PELVIC CONTROL IN CHILDREN WITH SPASTIC DIPLEGIC CEREBRAL PALSY: A CROSS-SECTIONAL STUDY

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Abstract

Children with spastic diplegic cerebral palsy (CP) frequently have pelvic instability. It restricts the patient's capacity to maintain balance. The aim of the study was to investigate the relationship between pelvic control and balance in children with spastic diplegic CP. Thirty-seven subjects of age group 5-14 years with gross motor classification system (GMFCS) scale I-II of CP were recruited in the study. The Participants' postural angles for pelvic control were evaluated using the photographic method, while balance was assessed using timed up and go (TUG) scale. The values of postural angles were correlated to TUG scores by the Pearson's correlation coefficient. There was a statistically significant relation ($p < 0.01$) between TUG and pelvic control. Lumbar angle (LA) and lumbar curve (LC) angles had a moderately significant inverse correlation with the TUG score. Pelvic tilt (PT) and horizontal alignment of anterior superior iliac spine (HAASIS) had a moderately significant positive correlation with the TUG score. The findings of this study indicated a substantial link between pelvic control and balance among diplegic CP children.

Keywords: Balance, Diplegia, Pelvis, Spasticity

Introduction

CP is the term for a group of chronic abnormalities of posture and motor development that restrict an individual's activities and is associated with non-progressive disruptions in the growing foetal or infant brain (Rosenbaum *et al.*, 2007). Multiple factors contribute to the motor impairment associated with CP, including dystonia, spasticity, muscle contractures, bone abnormalities, coordination issues, loss of selective motor control, and muscle weakening (Dar *et al.*, 2023). A more common

clinical subtype of CP is spastic diplegia. It almost perfectly captures 35% of all spastic children (Patel *et al.*, 2020). One of the common characteristics of children with diplegic CP is weakness of the trunk muscles, and compared to the upper limbs, the lower limbs have more motor dysfunction (Özal *et al.*, 2023). Children with diplegia are unable to move their legs independently due to their inability to distinguish between movement of different body segments, such as the pelvis and the legs leading to

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impaired walking ability and balance control (Ratliffe, 1998).

Balance control is needed for optimal performance of most functional activities. The capacity to regulate one's body's position in space in order to preserve stability and postural orientation is known as postural control (Dewar *et al.*, 2015). The intricate process arises from the interplay of various systems, including peripheral, ocular, and vestibular, as well as neuromuscular response (Rose *et al.*, 2002; Duarte *et al.*, 2014). To maintain an upright posture, each body part and spinal segment must be oriented correctly with respect to the trunk and its neighbouring parts (Szopa *et al.*, 2020). Children with CP have abnormalities in their postural, motor, and perceptual networks as a result of their initial brain injury. Dysfunction in the vestibular, proprioceptive, tactile, and visual systems affects the perception network. Postural instability is brought on by deficiencies in these networks (Hadders-Algra and Carlberg, 2008). Children with CP have insufficient balance reflexes and postural control. They make use of different muscular coordination patterns that arise from the combination of postural instability and brain injury (Brogren *et al.*, 1998).

The crucial bone that connects the lower extremities to the spine is the pelvis. The pelvis must be horizontal in the coronal plane and somewhat anteriorly tilted in the sagittal plane, more when standing and less when sitting, in order to permit a normal spinal form (Hasler *et al.*, 2020). Pelvic control refers to the ability of coordinated activity between the lower trunk and proximal hip muscles. As hip movements are limited in children with spastic CP, pathologic motion of the pelvis occurs either with excessive motion or asymmetric motion affecting the pelvic alignment (Miller, 2020). This alignment can be measured by pelvic spinal analysis (Chal  at-Valayer *et al.*, 2016) i.e., by measuring angles like PT, LC, LA, HAASIS. LA, LC, and PT may be impacted by weak hip-extensors, abductors, and abdominal muscles whereas changes in HAASIS are correlated with pelvic asymmetry in the transverse plane in patients with asymmetrical types of diplegic CP (factors linked with pelvic asymmetry). Altered pelvic alignment resulting from poor pelvic control shall positively influence the functional performance and balance. A variety of clinical problems are brought on by variations in pelvic position. There is a gap in the literature with limited research on the connection between pelvic control and balance. Research is therefore required to determine the relationship between variations in postural angles and balance. The purpose of this study was to investigate the relationship between

pelvic control and balance in children with diplegic CP.

Material and Methods

The Khushboo Welfare Society, SGT Medical College Hospital and Research Institute in Gurugram, Haryana and Wisdom special school, Delhi, India conducted this study from August to November 2023.

Study Design

The cross-sectional correlational study design was used for the current study. The University's ethics committee gave the study approval (SGTU/FPHY/2022/438). Each participant's parents were informed of the study's objectives and procedures, and their written informed consent was obtained.

Sample Size

The appropriate sample for the present study was determined based on correlation coefficient calculated from analyzing the measures of balance and pelvic tilt in a pilot study on five spastic diplegic CP children (Bhati *et al.*, 2019; El-Nabie and Saleh, 2019). The analysis yielded a correlation coefficient equal 0.20, the probability for rejecting the null hypothesis ($\alpha = 0.05$), and a power ($1 - \beta = 0.80$). These assumptions created a sample size of at least 34 children (using the G Power programme version 3.1) and we recruited up to 37 children considering 10% attrition rate.

Thirty-seven children with spastic diplegic CP (28 boys and 9 girls), referred by pediatric neurologists were recruited in the study using simple random sampling method. The inclusion criteria included having a diagnosis of spastic diplegic CP, both gender with age 5-14 years, motor function levels "I and II" as per the GMFCS, spasticity ranging from grade 1, 1+, and grade 2 according to modified Ashworth scale, and comprehending all spoken instructions. The exclusion criteria included receiving surgical treatment during the past six months, spine surgery, and botulinum toxin (BoNT), behavioural problems, as well as neurological or orthopedic disorders unrelated to CP (Kim and Seo, 2015).

Postural Evaluation

The postural angles were measured using photographic analysis. We adhered to the methods used by Pau  i   *et al.* (2010). The landmarks were placed on the ground to make sure that each subject faced the camera (Nikon DSLR 7100) in the same

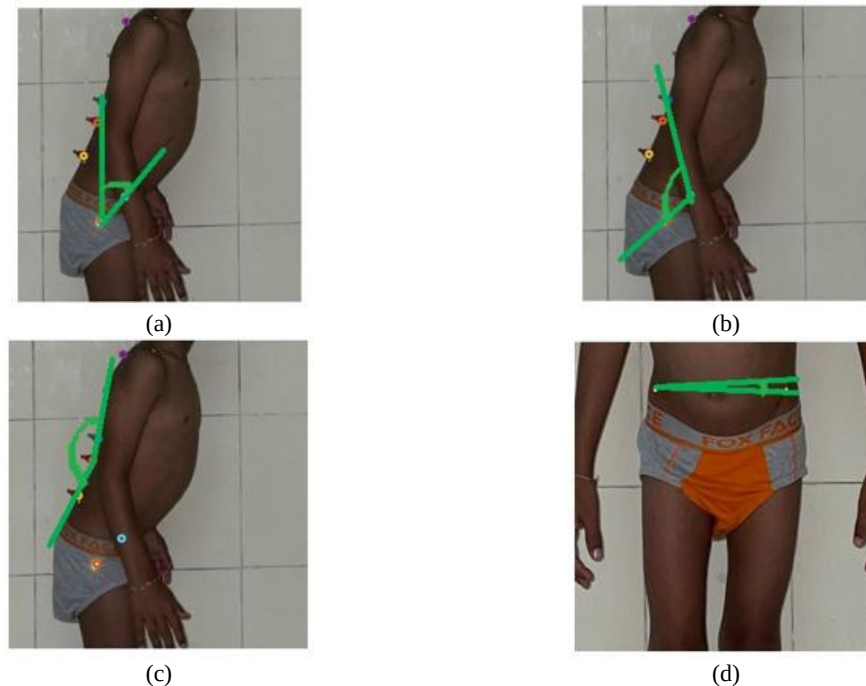


Figure1. Postural Angles; (a) Pelvic Tilt (b) Lumbar Angle (c) Lumbar Curve and (d) Horizontal Alignment

direction. The digital Nikon DSLR 7100 cameras were used. The cameras were positioned 200 cm apart from the line indicating the subject's location using two tripods-one in front of the subject and the other on its right. They were levelled on the stand using a spirit level to keep them parallel to the ground. By varying the tripod's height, the centre of the Nikon 20 mm wide-angle lens was positioned at the child's eye level. Prior to taking pictures, the researcher marked the subject's body parts at given anatomical locations using reflective markers that had a 16mm diameter: anterior superior iliac spine (ASIS), greater trochanter, spinous process of T12, L3, S2. After the markers were installed, the individual was instructed to face forward, pick a comfortable standing posture, and position themselves as to face the front camera (Paušić *et al.*, 2010). Every child was photographed twice by the researchers, once from the front and once from the right, while they had their feet planted firmly on the ground (Gupta *et al.*, 2023).

We computed the following postural angles for pelvic control with photogrammetry:

1. Pelvic tilt (PT)

It is the vertical line measured from the vertical above intersect and traced from the greater trochanter to ASIS (Claeys *et al.*, 2016) (Figure 1(a)).

2. Lumbar angle (LA)

The lumbar angle is formed by a line that passes through T12, ASIS, and the greater trochanter (Claeys *et al.*, 2016) (Figure 1(b)).

3. Lumbar curve (LC)

The lumbar curve is formed by two lines: one drawn from L3 and S2, and the other from T12 and L3 (Claeys *et al.*, 2016) (Figure 1(c)).

4. Horizontal alignment of ASIS (HAASIS)

It represents the angle formed by the two ASIS with a horizontal line (Ferreira *et al.*, 2011) (Figure 1(d)).

Each participant's photo was put into the Kinovea software 0.2.5. The software has excellent inter-rater and intrarater reliability (ICC<0.80) (Sharifnezhad, 2021). The software's cross marker, line, and angle tools were used to examine postural angles. To make the points in the image easier to see, the bony landmarks were highlighted using the cross-marker tool with bright contrast colour and angles were calculated.

Balance Evaluation

As TUG test can distinguish between children at levels I–III of the Gross Motor Function Classification System (GMFCS) and with different

subtypes of CP, it has been used to assess balance in ambulatory children with CP (Williams *et al.*, 2005 ; Gan *et al.*, 2008). For GMFCS levels I and II, the TUG has MCIDs of 0.36 and 0.87 (i.e., a large effect size) and excellent test-retest reliability (ICC = 0.91-0.98) (Williams *et al.*, 2005). There is a significant negative association (Spearman $\rho = -0.88$, $p < 0.01$) between the TUG and the berg balance scale (BBS) overall score (Carey *et al.*, 2016). The test entailed getting up, walking ten feet, turning at a certain location on the floor, returning to the chair, and finally sitting down. After the instruction “ready, go,” the participants moved to stand, and the test concluded when they sat down in the chair and stopped moving.

Data Analysis

The software programme SPSS 20.00 was used for the statistical analysis. Frequency and percentage analysis was performed for demographic data, while Karl Pearson's correlation test was utilised to determine the relationship between postural angles and balance. The interpretation of either positive or negative values of correlation coefficient (r-value)

is classified as follows: $r < 0.20$, very low; 0.20-0.39, low; 0.40-0.59, moderate; 0.60-0.79, high; and 0.80-1.00, very high. A p value < 0.05 was considered as statistically significant, and a p value of < 0.001 as highly statistically significant (Karthikbabu *et al.*, 2017). To illustrate the substantial correlations between the variables, scatterplot diagrams were created.

Results

Thirty-seven children with spastic diplegic CP participated in this study. The distribution of children was 28 boys and 9 girls, with a mean age $\pm$ SD of 8.78 ± 3.44 years, 34.17 ± 13.70 kg weight, and 1.22 ± 0.24 m height respectively. The GMFCS distribution showed that there were 15 cases in grade I (40.54%) and 22 cases in grade II (59.46%). The distribution of spasticity grades showed that there were 13 participants in grade 1 (35.14%), 13 participants in grade 1+ (35.14%), and 11 participants in grade 2 (29.72%). Table 1 displays a participant attribute.

Table 2 shows the mean values of postural angles and balance of these children.

Table 1. General characteristics of spastic diplegic CP children in the study

Gender distribution		
Boys	28	75.68%
Girls	9	24.32%
GMFCS distribution		
Grade I	15	40.54%
Grade II	22	59.46%
Spasticity grade distribution		
Grade 1	13	35.14%
Grade 1+	13	35.14%
Grade 2	11	29.72%

Table 2. Mean values of postural angles and balance of spastic diplegic CP children

Measurement	Mean $\pm$ SD	Minimum	Maximum
PT (degrees)	48.64 ± 7.79	33.60	68.90
LC (degrees)	118.57 ± 12.92	100.40	165.40
LA (degrees)	115.56 ± 11.53	101.70	129.40
HAASIS (degrees)	4.16 ± 1.55	2.30	7.30
TUG	14.14 ± 1.87	9	18

PT: pelvic tilt; LA: lumbar angle; LC: lumbar curve; HAASIS: horizontal alignment of anterior superior iliac spine; TUG: timed up and go scale

Table 3. Correlation between TUG and postural angles in children with diplegic spastic CP

		PT	LA	LC	HAASIS
TUG	r value	0.496	-0.520	-0.447	0.469
	p value	0.002**	0.001**	0.006**	0.003**

TUG: timed up and go scale; PT: pelvic tilt; LA: lumbar angle; LC: lumbar curve; HAASIS: horizontal alignment of anterior superior iliac spine
r value: Pearson correlation coefficient; p value: Probability value

*=Significant at 0.05 level

**=Significant at 0.01 level

Table 3 and Figure 2 show the relationships between TUG and postural angles in children with spastic diplegic CP.

TUG and PT

When standing, the pelvic alignment was not normal in the sagittal plane showing an anterior pelvic tilt of 48.64° (7.79°) and statistically significant positive correlations were detected between TUG and PT ($r = 0.496$, $p = 0.002$) indicating that increase in the pelvic tilt of children with spastic CP leads to increase in TUG score and worsening of balance.

TUG and LA

Sagittal abnormalities acting on the lumbar spine contributed to reduction in LA of 115.56° (11.53°) and statistically significant inverse correlations were observed between TUG and LA ($r = -0.520$, $p = 0.001$) showing that reduction in LA increases the TUG score and deterioration of balance.

TUG and LC

Similarly, sagittal abnormalities acting on the lumbar spine contributed to reduction in LC of 118.57° (12.92°) and statistically significant inverse correlations were observed between TUG and LC

($r = -0.447$, $p = 0.006$) showing that reduction in LC increases the TUG score and worsening of balance.

TUG and HAASIS

Pelvic obliquity in the coronal plane increases the angulation of HAASIS of 4.16° (1.55°) and significant positive correlations were observed between TUG and HAASIS ($r = 0.469$, $p = 0.003$) showing that increase in HAASIS increases the TUG score and worsening of balance.

Discussion

This study looked at how pelvic control is associated with balance in children with spastic diplegic CP. We found that these children's balance is greatly impacted by pelvic control, as determined by postural angles such as PT, LC, LA and HAASIS. The findings of our investigation demonstrated a highly substantial relationship between TUG and postural angles.

The pelvis, which is a part of the lower trunk, is said to provide dynamic postural stability during lateral and anterior weight transfers, according to biomechanics. To achieve lateral flexion and rotation of the trunk movements, a person needs higher dynamic stability of the lower trunk and

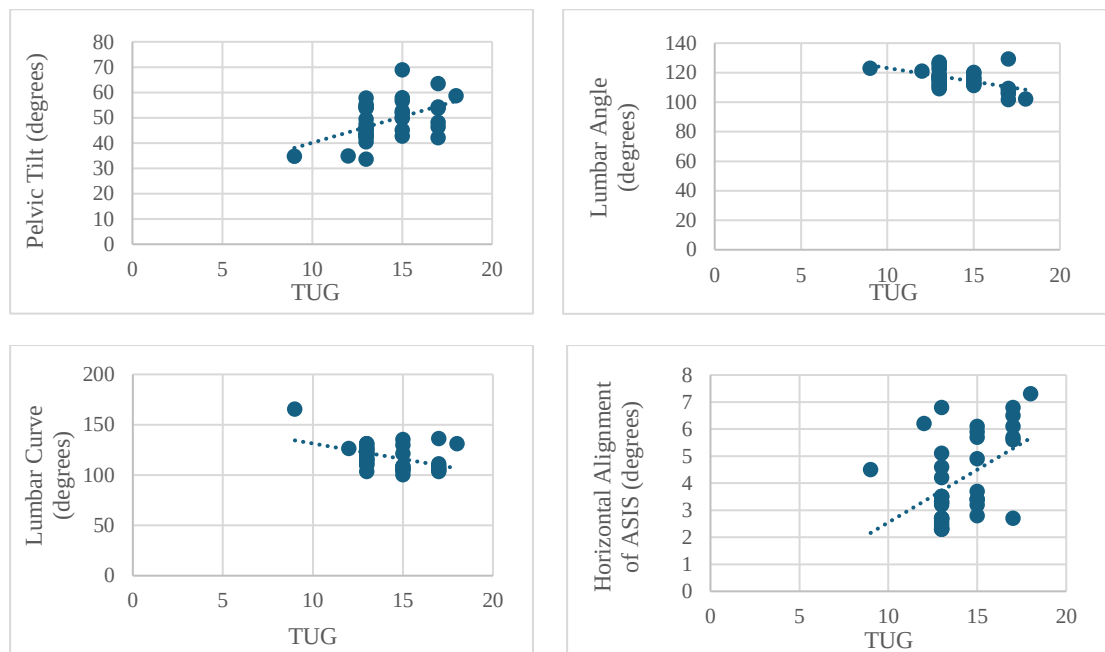


Figure2. Scattergram showing the relationship between postural angles and balance in children with spastic diplegic cerebral palsy

pelvis (El-Meniawy and Thabet, 2012). Children with CP may have impaired pelvic mobility and excessive pelvic motion due to increased tone, which stiffens the hip joint and limits hip motion (Miller, 2020). The current study's findings indicate that children with spastic CP who have improved pelvic control have more functional balance. Children suffering from spastic diplegia showed difficulty executing lateral trunk displacements, which could have led to low scores of balance (El-Meniawy and Thabet, 2012). The present findings are in accordance with findings of El-Nabie *et al.* who provided evidence in favour of this, showing that in children with diplegic CP, increased trunk imbalance, lateral spinal deviation, and pelvic tilt may be linked to a lower capacity for postural regulation (El-Nabie and Saleh, 2019). Any improper pelvic position undermines the person's ability to manage their equilibrium and necessitates spinal correction (Hasler *et al.*, 2020). Said *et al.* designed a pelvic stability program for children with spastic CP and found significant improvement in balance. It leads to the speculation that balance and pelvic control are correlated in these children (Said *et al.*, 2020). This correlation was further favoured by Sharma *et al.*'s conclusion that proprioceptive neuromuscular facilitation (PNF), a type of pelvic training exercise, aids in improving pelvic control, which is crucial for preserving trunk control, gait, and balance (Sharma and Kaur, 2017). In stroke patients, pelvic displacement was found to be correlated with balance capacity by Kong *et al.* He said that pelvic displacement limits social engagement, makes it harder to maintain balance and a regular gait, and that pelvic displacement control is a prerequisite for functional training for stroke patients (Kong *et al.*, 2015).

Also, looking at the Pearson correlation coefficient values that fall within the moderate range of correlation (i.e., 0.4-0.5) the authors conclude that balance is associated with pelvic control in children with spastic diplegic CP.

Limitations

Future research is needed to determine the relationships between balance, gait, and other functional tasks impacted by pelvic displacement. Similar studies should also be conducted on children with motor function levels more than II as per the GMFCS and other types of CP.

Conclusions

The current study confirmed the relationships between pelvic control and balance in children with spastic diplegic CP (motor function levels "I and II" as per the GMFCS). Pelvic evaluation provides additional information required to develop a personalised therapy programs for individuals with CP.

Conflicts of Interest

There are no conflicts of interest that could impede the results of this investigation.

Acknowledgement

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