Influence of Pelvic Inclination on Dynamic Balance in Children With Spastic Diplegia

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ABSTRACT

Background: Children with cerebral palsy suffer from deficits in balance and abnormal body alignment. Pelvic movements are essential in daily living activities. **Purpose**: This study aimed to investigate the relation between pelvic inclination (anterior and posterior pelvic tilt) and dynamic standing balance in children with diplegia. **Subjects and Methods**: Thirty children with spastic diplegic cerebral palsy of both sexes, aged from 5 to 14 years participated in this study. Their degree of spasticity ranged from 1 to 1+ according to the Modified Ashworth' Scale and they were level I or II on the Gross Motor Function Classification System. Pelvic inclination angle was measured by using the Formetric instrumentation system during standing position, while dynamic standing balance was assessed by the Biodex balance system. **Results**: The results showed a moderate positive significant correlation between pelvic inclination and the overall, anteroposterior, and mediolateral stability indices of dynamic standing balance ($P < 0.05$). **Conclusion**: Abnormal pelvic alignment affects dynamic balance abilities in children with spastic diplegia.

Key words: Cerebral palsy; Diplegia; Dynamic balance; Pelvic inclination.

INTRODUCTION

Cerebral palsy (CP) is an umbrella term that describes a group of conditions affecting an individual's movement and posture **[1].** Children with CP also experience higher incidence of pain, epilepsy, cognitive impairment, and sleep, communication, and eating difficulties, as well as difficult behaviors than people in the general population **[2].** Cerebral palsy is caused by non-progressive damage to the developing brain before 2 years of age. However, the complex casual pathway leading to the brain injury is often unclear. Several risk factors for CP have been identified, such as preterm birth, low birthweight for gestational age, and multiple births. Genomics likely plays a role for a subset of people with CP. For most, it will be a combination of factors that form a causal pathway to CP **[3].** Spastic diplegia is characterized by increased muscle tone and spasticity in the lower extremities more than upper extremities **[4].** It is the most common type of CP that gives rise to difficulties in posture, balance, and gait control **[5].** Impaired trunk control, pelvic asymmetry, balance, and gait asymmetry are some of the common impairments in spastic diplegia **[6].**

Some studies have suggested that children with CP present problems with the positioning of the body in space and standing postural misalignments, which result from alterations due to skeletal deformities that are mostly a result of muscle spasticity in the lower extremities **[7].** Although the foot and knee positions are frequently studied in the standing position in children with CP **[8],** little is known about the alignment of other body segments, such as the trunk, spine, and pelvis. Moreover, how the misorientation of body segments influences the standing posture has not been described **[9].** Children with CP may have malalignments related to their spine and pelvis. Spinal deformities are very common in children with CP and since the spine ends at the pelvis, deformities which involve the pelvis are also very common. In addition, problems of the pelvis fall between the hips and the spine which means that pelvic malalignments could have suprapelvic or infrapelvic etiologies or even sometimes both **[10].**

Posture refers to the relationship between the different body parts, and between the body and a reference frame **[11].** Control of posture is required to obtain balance (the act of maintaining or restoring the center of mass relative to the base of support). Balance is achieved by the complex integration of multiple body systems, including vestibular, visual, auditive, proprioceptive and higher-level premotor systems **[12].** Static and dynamic balance reactions of children with CP are poorer when compared with those of typically developing children **[13],** they demonstrate increased co-contractions of distal and proximal muscles and do not have a smooth distal-to-proximal pattern of muscle activity **[14].** They have more difficulty recovering balance efficiently when exposed to a balance threat due to various neuromuscular constraints **[15].** As balance skills are an integral part of gross motor abilities, poor balance causes difficulties with functional tasks involved in activities of daily living **[16].**

Although, numerous studies analyzed the effects of spine malalignments on balance in CP, there is limited research area analyzing the effect of pelvic malalignments on balance. Therefore, the purpose of the current study was to investigate the relation between pelvic inclination and dynamic balance in children with spastic diplegic CP.

Materials and Procedures

Study design

Correlational study design.

Participants

Thirty children with spastic diplegia of both sexes participated in this study. They were recruited from the Outpatient Clinic of the Faculty of Physical Therapy at Cairo University. Their age ranged from 5 to 14 years, they were level I or II on the Gross Motor Function Classification System (GMFCS) **[17].** Their degree of spasticity ranged from 1 to 1+ according to Modified Ashworth' Scale (MAS) **[18].** They met the inclusion criteria of 1) standing without assistive devices for 30 seconds and 2) following the instructions to complete the assessments. The children were excluded if they had one of the following: 1) visual or auditory impairment, 2) fixed deformities of the lower extremities, or 3) botulinum toxin injections in the last 6 months. This study was approved by the Ethical Committee of the Faculty of Physical Therapy at Cairo University (P.T.REC/012/003257).

Materials of evaluation

I. Formetric instrumentation system

This system serves for the determination of the geometry of the spine of the human being based on non-contact three-dimensional scan and spatial reconstruction of the spine derived from it by means of a specific mathematical model. It showed an overall excellent intra- and interrater reliability and good validity**[19].** The Formetric instrument system contains the following major subassemblies

- The scan system: It is (optical column) with base plate contains a raster projector and a video camera mounted into a profile tube. A telescopic drive provides motorized vertical adjustment of the entire system.

- The computer: It is visual spine software which provides 3D-reconstruction of the spine based on measurement data

of the system Formetric and allows individual image analysis of the carried-out examinations.

- The black background screen: It is black to allow absorption of any light rays fall away of the patient body and prevents any reflection of the rays again to the recording camera to allow clear and accurate recording of the patient's back.

- The laser printer: Provides high-quality result presentation.

The results of shape analysis were plotted on the laser printer as graphic protocol. Each graphic protocol contains some anatomical parameters which are calculated from the anatomical landmarks. The anatomical landmarks are denoted as follows:

VP: Vertebra prominence,

SP: Sacrum point,

DL: Left dimple,

DR: Right dimple, and

DM: Midpoint between both dimples, and, derived from it, a spatial reconstruction of the spine by means of a specific mathematical model **[20].**

II. The Biodex Balance System

This system is used to assess a patient's neuromuscular control in a closed chain, multi-plane test by quantifying the ability of the patient to maintain dynamic unilateral or bilateral postural stability on an unstable surface. It showed good reliability and validity for evaluating dynamic postural balance **[21].** The primary components and adjustment mechanisms of the Biodex system include:

- Foot platform: This platform allows approximately 20° inclination in a 360° range.

- Wheels -
Joy-stick port

- Support handle: Swing away from platform if desired.

- Support handle release pin

- Printer: Cannon Bubble-Jet Printer, 80 column, centronics parallel interface

- PC port

- Display module

- Display height locking knob: Display height adjustable from 51" to 68" above the platform **[22].**

Evaluation Procedures

I. Evaluation of Pelvic alignment

All parents had been informed of all study procedures and objectives for their children with the absence of any risk. After signing a written consent form, instructions about evaluative procedures were explained for each child before the testing session to make sure that all children understood the steps of evaluation and familiar with the device. Evaluation for each child was conducted in a warm and quite room using Formetric instrument system to measure pelvic inclination as follows:

Child data were entered in his/her file on the computer including date of birth, name, sex, height, and weight .Each child was asked to stand facing the black background screen at a distance of 2 m away from the scan system either on the ground or on the blocks (according to his/her height). The horizontal line of scan system should lie below the inferior angles of scapulae. It is important that the child’s back (including buttocks) was completely bare to avoid disturbed image structures. Each child was asked to assume the usual natural standing attitude with chin in to improve the presentation of the vertebral prominence. The child was also asked to keep his/ her both upper extremities freely extended beside the body as much as possible. Height adjustment of the optical column was done before capturing to obtain the suitable image. When the camera was ready for image recording, a green horizontal line appeared on the computer screen and the projector lamp was automatically switched. During capture, the child was asked to hold on breath for a period of 40 ms. Full back shape three-dimensional analysis was recorded and printed out for each child. Through one capture, pelvic inclination angle was recorded for each child which represents the mean torsion of the surface normals of the right and left dimples **[20].**

II. Evaluation of dynamic balance

The aim of the evaluation was explained to every child before the start of the study. Each child was instructed to remove his or her shoes and step onto the foot platform. All children were given an explanatory session before the evaluative procedure to be aware of the different test steps. Each child was asked to stand on the center of the locked platform with two legs stance. The display was adjusted so that the child can look straight at it. The following data were introduced to the device; child's height, chronological age, and platform firmness (stability level). All children were tested on the stability level 5 for 30 seconds test duration **[23].** Children centering steps were performed to position the center of gravity (COG) over the point of the vertical ground reaction force and instructions were given to the child to maintain his feet position till stabilizing the platform, then the feet angles and heels coordinate from the platform were recorded. At the end of each test trial, a printout report was obtained. This report included the following measured variables:

- The overall stability index (OASI) represents the variance of the foot platform displacement in degrees, from level, in all motions during the test.

- The mediolateral stability index (MLSI) represents the variance of the foot platform displacement in degrees, from level, for motion in the frontal plane.

- The anteroposterior stability index (APSI) represents the variance of the foot platform displacement in degrees, from level, for motion in the sagittal plane **[24]**.

Data analysis

Data management and statistical analysis were done using SPSS version 28 (IBM, Armonk, New York, United States). Quantitative data were assessed for normality using the Shapiro-Wilk test and direct data visualization methods. Quantitative data were summarized as means and standard deviations. Categorical data were summarized as numbers and percentages. Correlation analyses were done using Pearson's correlation. All statistical tests were two-sided. P values less than 0.05 were considered significant.

Results

General characteristics

Thirty children with diplegic CP (22 boys & 8 girls) participated in the current study. The mean of their age was 8.47 ± 2.42 years. The mean weight and height were 26.45 ± 5.85 kg and 124.75 ±11.41 cm, respectively, as shown in **(Table 1).** According to MAS, 17 children had a grade (1) of spasticity, while 13 children had a grade (1^+). According to GMFCS, 14 children were on Level 1 while 16 children were on Level II of motor function, as shown in **(Table 2).**

Table 1. General characteristics of the studied children (n=30):

	Mean ±SD	Minimum	Maximum
Age (years)	8.47 ± 2.42	5.0	14.0
Weight (kg)	26.45 ± 5.85	20.0	40.0
Height (cm)	124.75 ± 11.41	106.0	148.0

Data were expressed as mean ±SD

Table 2. Frequency distribution of gender, MAS, and GMFCS among studied children:

	No. (%)
Gender	
Boys	22 (73.3 %)
Girls	8 (27.6 %)
MAS degree	
Grade 1	17 (56.6 %)
Grade 1^+	13 (43.3 %)
GMFCS level	
Level I	14 (46.6 %)
Level II	16 (53.3 %)

Data were expressed as numbers and percentages.

Descriptive statistics of pelvic inclination and dynamic balance in studied children:

The mean value of pelvic inclination was 19.30 ±9.91. However, the mean values of OASI, APSI, and MLSI were 2.16 ±0.56, 1.57 ± 0.46, and 1.63 ± 0.48, respectively, as shown in **(Table 3).**

Table 3. Descriptive statistics of pelvic inclination and dynamic balance in studied children:

Measurement	Mean ±SD	Minimum	Maximum
Pelvic inclination (degrees)	19.30 ± 9.91	1.40	40.80
OASI	2.16 ± 0.56	1.30	4.10
APSI	1.57 ± 0.46	0.90	2.90
MLSI	1.63 ± 0.48	1.10	3.70

Data were expressed as mean ±SD

Correlation between pelvic inclination and dynamic balance in studied children:

There was a moderate positive significant correlation between pelvic inclination and OASI (r = 0.540, P = 0.007), APSI (r = 0.429, P = 0.003) and MLSI (r = 0.302, P = 0.004) as shown in **(Table 4, Figure 1).**

Table 4. Correlation between dynamic balance and pelvic inclination in studied children.

	Pelvic inclination (degree)	
	r value	**p value**
OASI	0.540*	0.007
APSI	0.429*	0.003
MLSI	0.302*	0.004

r value: Pearson correlation coefficient; p value: Probability value * Significant; **OASI**: Overall stability index; **APSI**: Anteroposterior stability index, **MLSI**: Mediolateral stability index.

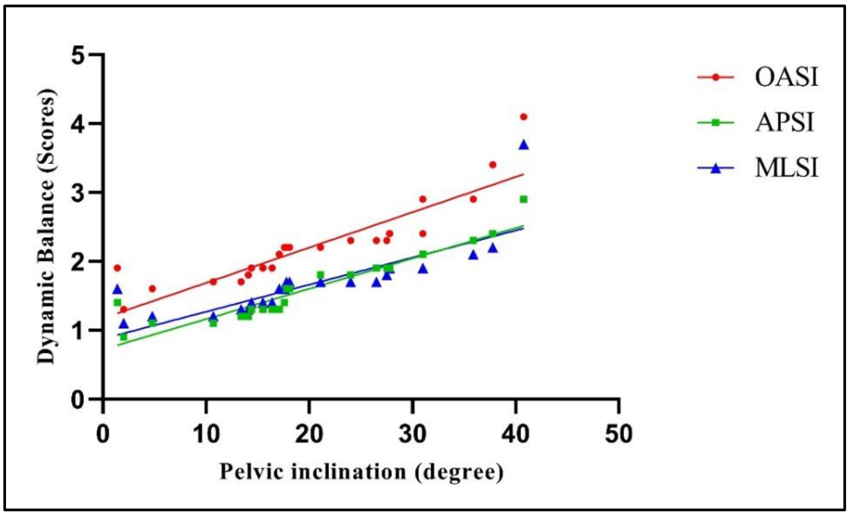

Figure 1. Correlation between dynamic balance and pelvic inclination in studied children.

Discussion

The purpose of the current study was to find the relation between pelvic inclination and dynamic balance in children with diplegic CP. Thirty children with diplegia, aged from 6 to 10 years, were evaluated by using the Formetric system to assess pelvic inclination angle, and the Biodex system to assess dynamic balance. The current results showed that, there is a positive significant correlation between pelvic inclination and dynamic standing balance ($P < 0.05$).

Pelvic alignment is the cornerstone of overall body alignment [25]. It allows efficient movements' performance and effective muscle recruitment. Control of the pelvic motion is important in maintaining whole body balance in different planes [26].

The current result regarding the correlation between pelvic inclination and dynamic balance may be due to the improper alignment of the pelvis that causes weakness of trunk and pelvic muscles leading to abnormal or reduced force generation which affects the dynamic balance ability. This comes in agreement with Shah et al. [27] who stated that, inadequate force generation in the trunk muscles resulting from the abnormal pelvic position leads to inadequate length-tension relationship. Also, due to inadequate alignment of the pelvis, trunk muscles cannot be adequately recruited resulting in a craniocaudal recruitment pattern.

The positive correlation between pelvic inclination and dynamic balance could be also due to the presence of hamstring tightness that causes pelvic tilt. This is supported by Shah et al. [27] who reported that, in children with spastic diplegia, hamstrings muscle tightness was related to increased posterior pelvic tilt and consequently impacting muscle recruitment and reduced functional balance.

Our results were also supported by El-Nabie et al. [28] who investigated the relation between pelvic alignment and postural control in children with spastic diplegia. They used the Formetric system to assess pelvic tilt, while postural control was assessed by using the Pediatric Balance Scale (PBS) (higher scores of the PBS indicated better postural control). Their results showed that there was a moderate negative correlation of pelvic tilt with postural control. This relation was explained by the alteration in pelvic alignment, e.g., pelvic tilt in children with CP, which is a common problem caused by tightness of iliopsoas muscle and weakness of hip extensors and trunk flexors [29]. Therefore, the tightness and weakness in the previously mentioned muscles that lead to pelvic tilt may cause disturbance in the motor network and indirectly lowering the postural control ability.

Posture and balance adjustment provide the basis for all motions. During ordinary life, many tasks require the adjustment of posture and balance, which are maintained by the center of gravity within the base of support (BOS). Kim et al. [30] found that more anterior pelvic tilt is associated with balance dysfunction and weight-bearing asymmetry in chronic stroke patients which come in consistent with the results of our study.

The current study was limited to thirty children with spastic diplegia aged from 6 to 10 years with level I or II on GMFCS. So, it is recommended that further study include different types of CP with different GMFCS level. In conclusion, our study showed that, there is a significant positive correlation between pelvic inclination and dynamic balance in children with CP indicating that pelvic malalignment is related to deficits in dynamic balance in children with spastic diplegia. So, rehabilitation programs to improve functional abilities of children with diplegia through improving their balance abilities must be targeted to correct malalignments of the pelvis. **Conclusion**

Addition of manual rib cage compression technique to traditional chest physiotherapy show positive clinical effects on PaO2 in mechanically ventilated patients but has no effect on PaCO2.

Disclosure statement

No author has any financial interest or received any financial benefits from this research.

Conflict of interest

The authors state no conflict of interest

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