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ORIGINAL RESEARCH ARTICLE

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Association between pelvic inclination and balance in children with spastic diplegia

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Abstract

Background: Children with spastic diplegia experience gait abnormalities and problems caused by deficits in balance, motor control, and spasticity. Abnormal pelvic inclination is common in patients with diplegia which may result in poor pelvic balance.

Purpose: This study was conducted to investigate the relation between pelvic inclination and *standing balance* in children with spastic diplegia.

Subjects and methods: Thirty children with spastic diplegic cerebral palsy from both sexes, aged from 5 to 14 years participated in this study. Their degree of spasticity ranged from 1 to 1+ according to Modified Ashworth Scale and they were on level I or II on Gross Motor Function Classification System. Pelvic inclination angle was measured by using the formetric instrumentation system during standing position while standing balance was assessed by the Biodex Balance System.

Results: There was a statistically significant relation between pelvic inclination and the overall, anteroposterior, and mediolateral stability indices of standing balance ($P < 0.05$).

Conclusion: The obtained results suggested that there was significant correlation between balance and pelvic inclination in children with diplegic cerebral palsy.

Keywords: Cerebral palsy, Diplegia, Balance, Pelvic inclination

Background

Cerebral palsy (CP) is as a disorder of movement and posture that appears during infancy or early childhood. It is caused by non-progressive damage to the brain during the prenatal, perinatal, or postnatal periods [1]. CP is not a single disease, but a name given to a wide variety of static neuromotor impairment syndromes occurring secondary to a lesion in the developing brain. The brain damage is permanent and cannot be cured but the consequences can be minimized. Progressive musculoskeletal pathology occurs in most affected children; intellectual, sensory, and behavioral difficulties may accompany CP, and are especially common in patients with spastic quadriplegia and severe motor disability [2]. Major risk factors for developing CP include consanguinity, assisted and home delivery, infections, and lack of antenatal care [3].

Spastic diplegia is the most common type of CP, presenting with symmetric involvement of both lower limbs. It constitutes 35% of all CP cases [3]. Children with spastic diplegia experience gait abnormalities and problems caused by deficits in balance, motor control, and spasticity [4]. Maintaining balance in an upright posture is strenuous for children with spastic diplegia [5]. They have spasticity and weakness in trunk muscles affecting their trunk control leading to lack of coordinated activation of trunk flexors and extensors that favors for well-balanced posture [6]. The quality of standing posture is also diminished by the presence of abnormal back geometry, poor postural reflexes, and poor alignment of the trunk which affects their quality of life and accomplishment of daily living activities [7].

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Although foot and knee positions are frequently studied in 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 disorientation of body segments influences 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 both [10].

Posture refers to the relationship between different body parts, and between the body and a reference frame [11]. Control of posture is required to achieve balance (the act of maintaining or restoring the center of mass relative to the base of support). Balance is achieved by complex integration of multiple body systems which include the vestibular, visual, 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]. Balance deficits lead to difficulties in functional activities because balance skills are an integral part of gross motor abilities [16].

Recent studies have investigated the relation between pelvic asymmetry and postural control in children with CP, such as the study conducted by El-Nabie et al. [17], who investigated the relationship of postural control with trunk and pelvic alignment in children with CP and the results demonstrated a significant correlation between lateral deviation of the spine and pelvic tilt with postural control. No studies, however, have investigated the possible effects of pelvic inclination on different balance measures. Therefore, the aim of the current study was to investigate the relation between pelvic inclination and 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 (Fig. 1). They were recruited from the Outpatient Clinic of Faculty of Physical Therapy at Cairo University. They met the inclusion criteria of (1) their age ranged from 5 to 14 years, (2) they were level I or II on the Gross Motor Function Classification System (GMFCS) [18], (3) their degree of spasticity ranged from 1 to 1+ according to Modified Ashworth Scale (MAS) [19], (4) they were able to stand without assistive devices, (5) children were able to understand orders, and (6) their height was not less than 1 m to meet the assessment requirements by the Biodex and formetric systems. Children were excluded if they had any of the following: (1) severe visual or hearing impairment, (2) fixed deformities of 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).

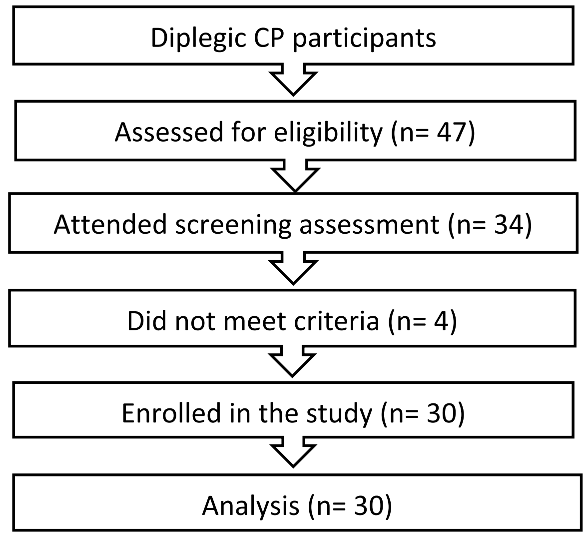

Fig. 1 Flow chart for patient selection

Materials of evaluation

Formetric instrumentation system

This system serves for the determination of the geometry of the spine of 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 [20]. The formetric system contains the following major subassemblies, a scan system (an optical column with base plate that contains a raster projector and a video camera mounted into a profile tube), computer (a 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, black background screen (it is black to allow absorption of any light rays that 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, laser printer (provides high-quality result presentation). The results of shape analysis are 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 include VP (vertebra prominence), SP (sacrum point), DL (left dimple), DR (right dimple), and DM (midpoint between both dimples), then a spatial reconstruction of the spine is derived by means of a specific mathematical model [21].

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. Cachupe et al. [22] reported that in a study of 20 subjects, the Biodex Balance System showed a reliable stability index. The primary components and adjustment mechanisms of the Biodex System include foot platform (it allows approximately 20° inclination in a 360° range), wheels, joy-stick port, support handles, printer, PC port, display module, and display height locking knob (adjustable from 51″ to 68″ above the platform) [23].

Evaluation procedures

Evaluation of pelvic alignment

All parents were 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.

Child's data was entered in his/her file on the computer which included 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 blocks (according to his/her height). 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 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. 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 represented the mean torsion of the surface normals of the right and left lumbar dimples [21].

Evaluation of balance

All children were given an explanatory session before the evaluative procedure to be aware of the different test steps. Each child was instructed to remove his/her shoes and step onto the foot platform. Each child was then 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 stability level 5 for 30 s test duration [24]. Children centering steps were performed to position the center of gravity (COG) over the center of the base of support (BOS) and instructions were given to each 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 the test trial, a printout report was obtained. This report included the following measured variables:

- The overall stability index (OASI) (it represented the variance of the foot platform displacement in degrees, from level, in all motions during the test).
- The mediolateral stability index (MLSI) (it represented the variance of the foot platform displacement in degrees, from level, for motion in the frontal plane).
- The anteroposterior stability index (APSI) (it represented the variance of the foot platform displacement in degrees, from level, for motion in the sagittal plane) [25].

Data analysis

Data management and statistical analysis were done using SPSS version 28 (IBM, Armonk, NY, USA). 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.

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

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 %)

Table 3 Descriptive statistics of pelvic inclination and standing 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

Results

General characteristics

Thirty children with diplegic CP (22 boys and 8 girls) participated in the current study. Their general characteristics are demonstrated in Table 1. The frequency distribution of gender, MAS, and GMFCS is shown in Table 2.

Data were expressed as mean ± SD

Data were expressed as numbers and percentages

-Descriptive statistics of pelvic inclination and standing balance in studied children are shown in Table 3.

Data were expressed as mean ± SD

-Correlation between pelvic inclination and standing balance in studied children:

There was a moderate positive significant correlation between pelvic inclination and OASI, APSI, and MLSI as shown in Table 4 (Fig. 2).

Table 4 Correlation between standing 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, *OASI* overall stability index, *APSI* anteroposterior stability index, *MLSI* mediolateral stability index

*Significant

Discussion

The purpose of the current study was to investigate the relation between pelvic inclination and balance in children with diplegic CP. Thirty children with diplegia, aged from 5 to 14 years, were evaluated by using the formetric system to assess pelvic inclination angle and the Biodex System to assess standing balance.

The current results showed a significant positive correlation between pelvic inclination and OASI ($r = 0.540$, $P = 0.007$), APSI ($r = 0.429$, $P = 0.003$), and MLSI ($r = 0.302$, $P = 0.004$).

Pelvic alignment is the cornerstone of overall body alignment. It allows efficient performance of movements 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 balance may be due to the improper alignment of the pelvis which leads to sustaining an incorrect posture for a long time that triggers inappropriate tension in the adjacent muscles and joints. Consequently, flexibility decreases, and the patient experiences restricted movement and balance ability. This comes in agreement with Shah et al. [27] who mentioned that, inadequate force generation in the trunk muscles results from the abnormal pelvic position which leads to inadequate length-tension relationship and the trunk muscles cannot be adequately recruited if there is inadequate alignment of the pelvis which results in a cranio-caudal recruitment pattern of the muscles.

The current correlation between pelvic inclination and balance could also be due to the presence of hamstring tightness that causes pelvic tilt. This is supported by Shah et al. [27] who reported that hamstrings muscle tightness in children with spastic diplegia 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. [17] who investigated the relation between pelvic tilt and

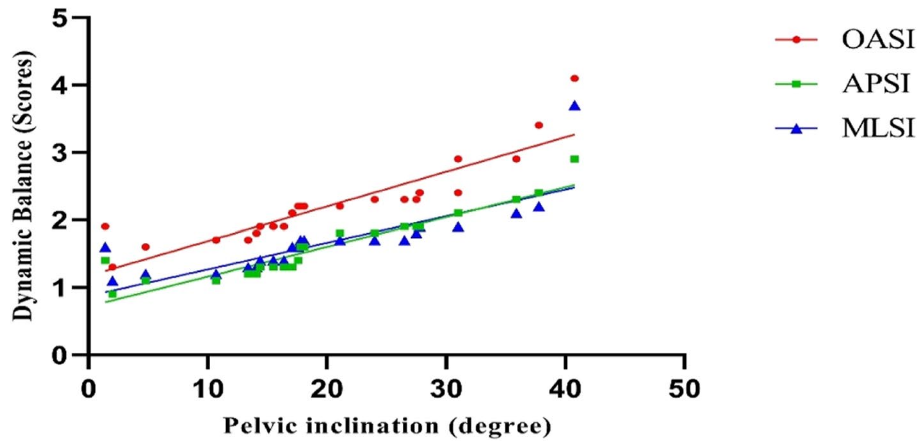

Fig. 2 Correlation between standing balance and pelvic inclination in studied children

postural control in children with spastic diplegia. The authors used the formetric system to assess pelvic tilt and the Pediatric Balance Scale (PBS) to assess postural control. Their results showed that there was a moderate negative correlation of pelvic tilt with postural control (increased pelvic tilt was associated with decreased postural control ability in children with diplegic CP as higher scores of the PBS indicate better postural control ability while higher scores on Biodex indicate less balance 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 COG within the BOS. The alteration in pelvic alignment may cause disturbance in the motor network and indirectly lowering the postural control ability in children with spastic diplegic CP [17].

The current study was limited to 30 children with spastic diplegia aged from 5 to 14 years with level I or II on GMFCS. It is recommended that further studies include different types of CP with different GMFCS levels using a larger sample size and using different objective evaluation methods of pelvic alignment to study its effects on balance and motor control in children with CP. In conclusion, our study showed a significant correlation between pelvic inclination and balance in children with diplegic CP indicating that pelvic malalignment may be related to deficits in balance in children with spastic diplegia.

Conclusion

Based on our findings, there was significant correlation between balance and pelvic inclination in children with diplegic cerebral palsy. It could be concluded that pelvic inclination may affect balance ability in children with spastic diplegia. Therefore, rehabilitation programs for children with CP should focus on restoring the normal alignment of the pelvis to improve overall balance and functional abilities among children with CP.

Acknowledgements

Not applicable.

Authors' contributions

NE performed evaluations for the study group using the formetric and the Biodex System and wrote down the manuscript. WA revised the work. HM revised the work. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The current study was conducted after approval by the local Ethical Committee at the Faculty of Physical Therapy, Cairo University (P.T.REC/012/003257) and ethical principles of the Declarations of Helsinki were followed.

Consent for publication

Signed informed consent was obtained from each child's parent regarding the participation of their children in the current study.

Competing interests

The authors declare that they have no competing interests.

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