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Trunk and pelvic alignment in relation to postural control in children with cerebral palsy

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Abstract.
BACKGROUND: Trunk-pelvic mal-alignment and postural control deficit are common problems facing children with cerebral palsy (CP).
OBJECTIVE: The aim of this study was to investigate the relation of trunk and pelvic alignment with postural control in children with diplegic CP.
METHODS: Seventy seven children with spastic diplegic CP, aged from 6 to 8 years with level II on Gross Motor Function Classification System, participated in this study. Trunk imbalance, lateral deviation of the spine and pelvic tilt were evaluated by using Formetric instrumentation system while postural control was assessed by using Pediatric Balance Scale.
RESULTS: The results showed that there was a moderate negative correlation of trunk imbalance, lateral deviation of the spine and pelvic tilt with postural control (-0.44, -0.59 and -0.57, respectively).
CONCLUSIONS: Increased trunk imbalance, lateral deviation of the spine and pelvic tilt may be associated with decreased postural control ability in children with diplegic CP.

Keywords: Cerebral palsy, diplegia, postural control, trunk and pelvic alignment

1. Introduction

Cerebral palsy (CP) is a group of disorders in movement and posture, which is caused by non-progressive lesion in the developing brain and leads to activity limitation [1]. The characteristics of motor disorders of CP include: contraction, spasticity and hyperreflexia as well as impairment of motor control, poor balance and muscle weakness [2]. One of the most clinical subtypes of CP is spastic diplegia. It nearly represents about one third of all spastic types [3]. In children with diplegic CP, motor impairment in lower limbs is more than upper limbs and weakness of the trunk muscles is one of their common features [4]. Diplegic children are not able to move their legs independently because they are unable to dissociate the movement between the parts of their bodies, e.g. legs from the pelvis and pelvis from the trunk [5].

Postural control is the ability to control the position of the body in space to maintain stability and postural orientation [6]. It is a complex process that results from the interaction of different systems (e.g. peripheral, visual and vestibular) and neuromuscular response [7,8]. The upright posture requires proper orientation of each body part and spinal segments with the adjacent part and with the trunk [9]. The primary injury of the brain in children with CP leads to deficits in postural, motor and perceptual networks. Perceptual network is influenced by the dysfunction in vestibular, proprioceptive, tactile and visual systems. The deficits in these

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networks cause postural instability [10]. Balance reactions and postural control are inadequate in children with CP. They utilize alternative patterns of muscle coordination which result from the interaction between brain damage and postural instability [11].

Children with CP often have an abnormal alignment of the spine in comparison to normal developing children. Spinal development and alignment may be influenced by primary impairment such as abnormal muscle tone and secondary impairment which includes skeletal anomalies in the lower extremities [12]. Standing and walking balance in children with CP might be affected by trunk imbalance and pelvic obliquity. It may also lead to sitting intolerance in wheelchair patients [13,14]. Several studies concentrated on postural control and balance in children with CP, such as the study conducted by Fahimi et al. [15], who studied reactive postural control in children with CP, and the study by Karabicak et al. [16], who investigated the effect of postural control and balance on femoral anteversion in children with CP. The studies that focus on the relation between trunk and pelvic alignment with postural control are still limited. Therefore, the main purpose of this work was to study the relation of trunk imbalance, lateral deviation of the spine and pelvic tilt with postural control in children with diplegia.

2. Materials and procedures

2.1. Subjects

Seventy seven children with diplegic CP of both sex between 6 to 8 years old participated in this study, as shown in Fig. 1. They were recruited from the Outpatient Clinic of the Faculty of Physical Therapy at Cairo University from May 2017 to September 2017. The children were diagnosed with diplegia, as could be read in their medical records, which was supported by radiological examination such as magnetic resonance images or computed tomographyscan. The degree of spasticity ranged from 1 to 1+ according to Modified Ashwarth Scale [17], with level II on the Gross Motor Function Classification System (GMFCS) [18]. Their average heights were one meter or more to meet the prerequisites for assessment on the Formetric system. Participants were excluded if they had visual or auditory problems, fixed deformity related to any joints of the lower extremities, and/or perceptual or cognitive disorders and other cardiovascular or neurologic deficits. At the beginning of the current study, parents

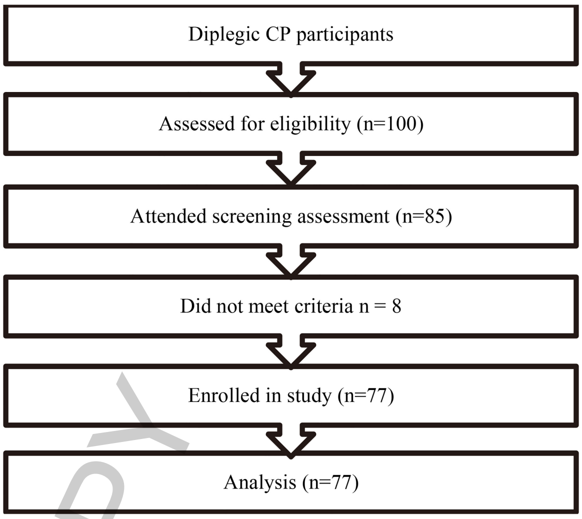

Fig. 1. Flow chart for patient selection.

signed consent forms concerning participation of their children in this work. The study was approved by the Ethical Committee of the Faculty of Physical Therapy at Cairo University (PT/REC/012/001585). It was hypothesized that there was no relation between trunk imbalance, lateral deviation of the spine and pelvic tilt with postural control in children with diplegia.

2.2. Study design

Correlational study design.

3. Materials of evaluation

3.1. Formetric instrumentation system

It is a valid and reliable method used for three-dimensional analysis of the spine with the advantage of no exposure to radiation [19]. Also it documents the spinal image of each patient and compares between recent and old data [20]. It consists of the following components: computer, scan system, laser printer and black ground screen. The back surface is plotted on the printer after its analysis as a graph. Each graph contains different parameters which are determined from specific anatomical land marks. There are several spinal and pelvic parameters that are measured through one capture, such as: trunk length, trunk imbalance, lateral deviation, surface rotation, pelvic tilt, pelvic torsion and trunk inclination [21].

3.2. *Pediatric balance scale*

Pediatric balance scale (PBS) was developed to assess daily functional activities of children between 5 to 15 years old with mild to moderate motor impairment. It is a reliable scale and can be applied easily. The scores of PBS are ranging from 0 to 56, better postural control meaning higher scores [22]. The PBS consists of 14 items which are related to everyday tasks. These items include: sitting to standing, standing to sitting, transfers, standing unsupported, sitting unsupported, standing with eyes closed, standing with feet together, standing with one foot in front, standing on one foot, turning 360 degrees, turning to look behind, retrieving object from floor, placing alternate foot on stool and reaching forward with outstretched arm [23]. Each item is based on 5 point scales (0, 1, 2, 3 or 4), with zero score meaning inability of the child to perform the activity without assistance and four score denoting the ability to do the activity independently. The score is based on the time for maintaining the position, the distance which the upper limb is reached to it in front of the body, and the time needed to complete the task [24].

4. Procedures of evaluation

4.1. *Trunk and pelvic alignment evaluation*

The steps of evaluation procedure were clarified for each child through verbal instructions. The software program was prepared before the child was positioned. Subsequently, the child's data of name, sex, height, weight and date of birth were entered to the system. Each child was asked to stand with bared trunk either on the ground or on the block (according to his/her height) at a distance of two meters away from the scan system and in front of the black ground screen. The inferior angles of scapulae should lie above the green horizontal line of scan system (which appears on the computer screen when the camera is ready for recording) to avoid overlooking the axillary points in which its overlooking will interfere with the recording of spinal image. The examiner asked each child to breathe normally to avoid the forced breathing because it will affect his balance then he/she was asked to hold on his breath during the capture for about 40 millisecond. A slightly forward bend position of the neck was preferable during the capture of the image to improve the presentation of the vertebral prominence, finally three-dimensional analysis of back surface was done, recorded and printed out for each participant of the study.

4.2. *Postural control evaluation*

The evaluation of postural control was carried out using PBS in a quiet and comfortable room. Visual and verbal instructions were provided to each child to ensure that he or she understood the tasks. Furthermore, each child was informed to maintain his balance during the performance of each task. Each item of PBS was scored based on the 0 to 4 scale and the total score for each child was determined by adding the scores of all items that the child achieved it. One trial was allowed for each item. A second trial was allowed when the child was unable to understand the directions with verbal and visual instructions were given to clarify the task. If the child achieved the maximum score of 4 on the first trial, no need for the second trail to be given.

5. Data analysis

Pearson Correlation Coefficient was conducted to determine the correlation between postural control and trunk and pelvic alignment. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through SPSS (statistical package for social sciences, version 19).

6. Sample size

The appropriate sample for the present study was determined based on an expected correlation coefficient that was calculated from analyzing the measures of postural control and pelvic tilt for the first seven children enrolled in the study. The analysis yielded a correlation coefficient equal 0.386, 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 50 children and we recruited up to 77 children.

7. Results

7.1. *Subject characteristics*

Table 1 shows the mean ± SD age, weight, and height of participants.

Table 1
Mean age, weight, and height of participants

	Mean ± SD	Minimum	Maximum
Age (years)	7.27 ± 0.6	6	8
Weight (kg)	16 ± 0.97	13	17
Height (cm)	122.98 ± 5.76	110	130

SD, standard deviation.

Table 2
Correlation between trunk imbalance, lateral deviation of the spine, pelvic tilt and postural control

		r value	p value
Postural control	Trunk imbalance (mm)	−0.44	0.0001**
	Lateral deviation of spine (mm)	−0.59	0.0001**
	Pelvic tilt (mm)	−0.57	0.0001**

r value, correlation coefficient value; p value, probability value; **significant.

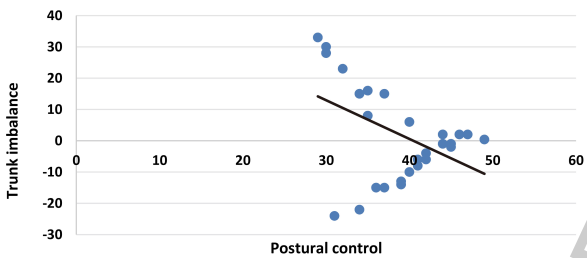

Fig. 2. Correlation between postural control and trunk imbalance.

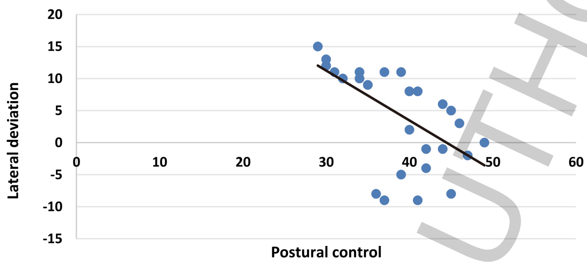

Fig. 3. Correlation between postural control and lateral deviation of the spine.

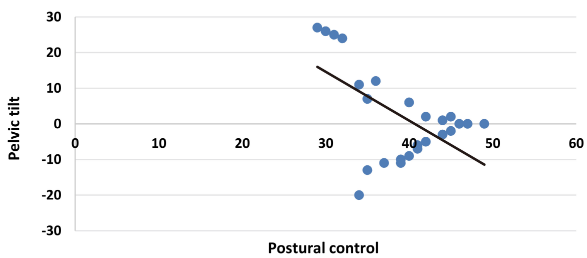

Fig. 4. Correlation between postural control and pelvic tilt.

7.2. *Correlation between trunk and pelvic alignment with postural control*

A moderate negative linear relationship was found between trunk imbalance, lateral deviation of the spine and pelvic tilt with postural control (Table 2, Figs 2 to 4).

8. Discussion

The purpose of the current study was to evaluate the relation of trunk and pelvic alignment with postural control in children with diplegic CP. The results showed that there was moderate negative correlation of trunk imbalance, lateral deviation of the spine and pelvic tilt with postural control.

The focus of the present study was on postural control and trunk-pelvic alignment because the participation of children with diplegia in daily activities is affected by postural control deficit and mal-alignment of trunk and pelvis. This is supported by Cook and Wollacott [25], who found that children with diplegia are prone to have neuromuscular deficits which hinder the postural control development. Children with diplegic CP suffer from poor balance and bad alignment of the trunk which interfere with their daily life activities [26].

Postural control process depends on neuromuscular subsystem through the motor process that includes three components; force generation, coordination and high level planning. Force generation process happens in motor neurons and muscles [27]. In children with CP, motor network is affected by spasticity, muscle weakness and decreased muscle recruitment and this can result in deficits of postural control and postural stability [10]. Chale'at-Valayer et al. [28], explained that the pathological alignment of trunk and pelvis in children with CP usually caused by hypertonia or weakness in the muscles of the trunk, pelvis and hip.

The deficit in the motor process in children with CP, which appears in the form of spasticity or muscle weakness, causes deficit in postural control. This may explain the current relation of our study as the motor deficit may be the main cause of abnormal alignment of spine and pelvis. In light of this study, the current relation between trunk imbalance and postural control may be due to weakness of trunk muscles which causes trunk imbalance and dysfunction in postural control. This is supported by Graham [26], who illustrated that in children with diplegic CP, trunk imbalance may be caused by weakness of trunk muscles and mal-alignment of trunk, pelvis and legs.

The alteration in pelvic alignment, e.g. pelvic tilt in children with CP, 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. This may explain the current relation between postural control and pelvic tilt.

The trunk has an essential role in keeping postural control, so any deficits in its alignment or control may lead to dysfunction of postural control mechanism. This is supported by Van der Heide et al. [30], who stated that trunk has an essential role in keeping the mechanism of postural control and organizing balance reaction. Gage [31], Quinby and Abraham [32], demonstrated that trunk control is important for stability and execution of functional activities for upper and lower limbs. In children with CP the control and stability of the trunk are affected which cause inadequate balance and postural control ability. Panibatla et al. [33], assessed the relation of trunk control with balance in children with CP by using trunk control measurement scale and PBS. They found high positive relation between trunk control and balance, meaning that children with CP with good trunk control will have a better balance ability. These findings may support our results because the trunk and pelvic alignment is affected by trunk control. On the other hand, the study conducted by Karabicak et al. [16], who evaluated the relation of balance and postural control with femoral anteversion (FA) in children with CP. They found a relation between FA and dynamic trunk activities but there was no relation between FA with balance, static sitting, and control of the trunk.

9. Limitation

The current study was limited by the length of time needed for each child to understand the evaluation procedure.

10. Conclusion

Based on the results of the current study, the postural control is negatively related with trunk imbalance, lateral deviation of the spine and pelvic tilt. Therefore, the mal-alignment of trunk and pelvis is related to postural control deficit. So it is important to all medical team members, and physical therapists in particular, to understand that mal-alignment of trunk and pelvis and postural control deficit need to be evaluated objectively and treated appropriately to improve the functional ability in children with diplegic CP. Further research is needed to study the relation of postural control with other parameters of spine and pelvis such as trunk inclination, surface rotation and pelvic torsion. Similar studies should also be conducted on other types of CP.

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Conflict of interest

None to report.

References

[1] Rosenbaum P, Paneth N, Leviton A, Goldstein M, Bax M, Damiano D, et al. A report: the definition and classification of cerebral palsy April 2006. Dev Med Child Neurol Suppl. 2007; 109: 8-14.
[2] Graham HK, Selber P. Musculoskeletal aspects of cerebral palsy. J Bone Joint Surg Br. 2003; 85(2): 157-166.
[3] Throgood C. Cerebral palsy: Introduction and diagnosis (part 1). J pediatric Health Care. 2012; 21(3): 146-152.
[4] Tong-Wai R, Wester R, Shevel M. A clinical and etiologic profile of spastic diplegia. Pediatr Neurol. 2006; 34(3): 212-218.
[5] Ratliffe K. Clinical pediatric physical therapy, 1st ed. London: Mosby; 1998, 178-191.
[6] Dewar R, Love S, Johnstonl M. Exercise interventions improve postural control in children with cerebral palsy: a systematic review. Dev Med Child Neurol. 2015; 57(6): 504-20.
[7] Rose J, Wolff DR, Jones VK, et al. Postural balance in children with cerebral palsy. Dev Med Child Neurol. 2002; 44(1): 58-63.
[8] Duarte NA, Grecco LA, Franco RC, et al. Correlation between Pediatric Balance Scale and functional test in children with cerebral palsy. J Phys Ther Sci. 2014; 26: 849-853.
[9] Otman A, Demirel H, Sade A. Basic Assessment Principles in Treatment Movements. Ankara: Hacettepe Yayınları, 1995, 1-12.
[10] Hadders-Algra M, Carlberg EB. Postural control: A key issue in developmental disorders. London: Mac Keith; 2008.
[11] Brogren E, Hadders-Algra M, Forssberg H. Postural control in sitting children with cerebral palsy. Neurosci Biobehav Rev. 1998; 22(4): 591-596.

[12] Song EW, Lenke LG, Schoenecker PL. Isolated thoracolumbar and lumbar hyperlordosis in patient with cerebral palsy. J Spinal Disord. 2000; 13(5): 455-460.
[13] Kalen V, Conklin MM, Sherman FC. Untreated scoliosis in severe cerebral palsy. J Pediatr Orthop. 1992; 12(3): 337-40.
[14] Comstock CP, Leach J, Wenger DR. Scoliosis in total-body-involvement cerebral palsy. Analysis of surgical treatment and patient and caregiver satisfaction. Spine. 1998; 23(12): 1412-24.
[15] Fahimi N, Hosseini S, Rassafiani M, Farzad M, Haghgoo HA. The Reactive Postural Control in Spastic Cerebral Palsy Children. Iranian Rehabilitation Journal. 2012; 10(15): 66-74.
[16] Karabicak G, Balcı N, Gulsen M, Ozturk B, Cetin N. The effect of postural control and balance on femoral anteversion in children with spastic cerebral palsy. J. Phys. Ther. Sci. 2016; 28: 1696-1700.
[17] Bohannon R, Smith MB. Inter-reliability of modified Ashwerth scale of muscle spasticity. Phys Ther. 1987; 67(2): 206-208.
[18] Palisano R, Rosenbaum P, Walter S, et al. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol. 1997; 39(4): 214-23.
[19] Diers H, Mooshake S, Heitmann KR. Dynamic 3D (4D) in objective classification of severe back deformities. Scoliosis Journal. 2009; 4(Suppl 2): 10-16.
[20] Drerup B, Hierholzer E. Back shape measurement using videoeastereography and three-dimensional reconstruction of the spinal shape. Clin Biomech. 1994; 9(1): 28-36.
[21] Hierholzer E. Formetric rastersterography 3-D back shape measurement and analysis, Formetric Manual 2001.
[22] Franjoine MR, Gunther JS, Taylor MJ. Pediatric balance scale: a modified version of the berg balance scale for the school-age child with mild to moderate motor impairment. Pediatr Phys Ther. 2003; 15(2): 114-28.
[23] Franjoine MR, Darr N, Held SL, Kott K, Young BL. The performance of children developing typically on the pediatric balance scale. Pediatr Phys Ther. 2010; 22(4): 350-359.
[24] Kembhavi G, Darrah J, Magill-Evans J, et al. Using the berg balance scale to distinguish balance abilities in children with cerebral palsy. Pediatr Phys Ther. 2002; 14(2): 92-99.
[25] Cook A, Wollacott M. Motor control. Theory & practical application. 2nd ed. Lippincott Williams and Wilkins 2001; Baltimore, 164-165, 169-270.
[26] Graham HK. The managements of spastic diplegia. Curr Orthop. 2003; 17(2): 88-104.
[27] Kandel ER, Schwartz JH, Jessell TM. Principles of neural science. 4th ed. McGraw-Hill, Health Professions Division; 2000, 816-32.
[28] Chale'at-Valayer E, Bernard J, Deceuninck J, Roussouly P. Pelvic-Spinal Analysis and the Impact of On abotulinum toxin A Injections on Spinal Balance in one Child with Cerebral Palsy. Child Neurology. 2016; 3: 1-5.
[29] Beverly D. Progressive casting and splinting for lower extremity deformities in children with neuromotor dysfunction. 1st ed. USA: Therapy Skill Builders; 1990.
[30] Van der Heide JC, Berger C, Fock JM, Otten B, Stremmelaar E, Van Eykern LA, et al. Postural control during reaching in preterm children with cerebral palsy. Dev Med Child Neurol. 2004; 46(4): 253-66.
[31] Gage JR. Gait analysis. An essential tool in the treatment of cerebral palsy. Clin Orthop Relat Res. 1993; (288): 126-134.
[32] Quinby JM, Abraham A. Musculoskeletal problems in cerebral palsy. Curr Paediatr. 2005; 15: 9-14.
[33] Panibatla S, Kumar V, Narayan A. Relationship between trunk control and balance in children with spastic cerebral palsy: cross-sectional study. Journal of Clinical and Diagnostic Research. 2017; 11(9): YC05-YC08.