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Lecture

Postural orientation and standing postural alignment in ambulant children with bilateral cerebral palsy

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ABSTRACT

Background: Standing postural alignment in children with cerebral palsy is usually altered by central postural control disorders. The primary aim of this study is to describe body alignment in a quiet standing position in ambulatory children with bilateral cerebral palsy compared with children with typical development.

Methods: Fifty-eight children with bilateral cerebral palsy (aged 7–13 years) and 45 age-matched children with typical development underwent a surface topography examination based on Moiré topography and were classified according to their sagittal postural profiles.

Findings: The following eight grouping variables were extracted using a data reduction technique: angle of trunk inclination, pelvic tilt, and lordosis, the difference between kyphosis and lordosis, angle of vertebral lateral curvature, shoulder inclination, and shoulder and pelvic rotation. According to the cluster analysis results, 25% of the participants were classified into Cluster 1, 9% into Cluster 2, 49% in Cluster 3, and 17% in Cluster 4.

Interpretation: Three different postural patterns emerged in accordance with the sagittal postural profiles in children with bilateral cerebral palsy and were defined as follows: 1) a lordotic postural pattern corresponding to forward-leaning posture; 2) a swayback postural pattern corresponding to backward-leaning posture; and 3) a balanced postural pattern corresponding to balanced posture.

1. Introduction

The term cerebral palsy (CP) encompasses a number of postural control and movement disorders caused by abnormal brain development or damage to the brain that occurs around the time of birth or during an early stage of life (Rosenbaum et al., 2007). The primary causes of posture control and postural adjustment disorders in children with CP include 1) impairment of reciprocal innervation of select muscle groups, 2) increased coactivation of agonists/antagonists, and 3) inappropriate muscle response sequencing (Colver et al., 2014).

Children with CP reach developmental milestones later than children with typical development (CTD). Therefore, these children develop compensatory mechanisms to achieve new activities as they attempt to overcome these primary deficits and over time develop secondary impairments, such as muscle imbalance across joints, poor alignment across joints, further muscle weakness and a contracture in the joints (Carlberg and Hadders-Algra, 2005). In CP, secondary musculoskeletal problems and disturbances in perception are commonly accompanied by primary standing postural control disorders. In recent decades, an increased number of publications have focused on postural deficits in children with CP. Current research evidence confirms that children with CP experience deficits and disturbances in postural control. However, postural dysfunction in CP is most commonly studied by evaluating postural stability while standing (Graaf-Peters et al., 2007; Woollacott and Shumway-Cook, 2005). There is evidence that children with CP tend to have poorer balance based on increased postural sway during standing compared to CTD (Graaf-Peters et al., 2007; Woollacott and Shumway-Cook, 2005). Standing postural control in children with CP has also been reported in terms of reactive postural control, which involves the coordination of movement strategies to stabilize the centre of the body mass following self-initiated or unexpected environmental changes (Rose et al., 2002; Donker et al., 2008). Children with CP show less complex movement strategies, activate all joints simultaneously with altered patterns, tolerate slower

Abbreviations: BCP, children with bilateral cerebral palsy; CTD, children with typical development; TT, angle of trunk inclination in the sagittal (A-P) plane; SHI, angle of shoulder line inclination in the coronal (M-L) plane; SHR, angle of shoulder rotation; PR, angle of pelvic rotation; PT, angle of pelvic tilt; LL, angle of lordosis; KL, the difference between angle of kyphosis and angle of lordosis; AAOS, acromial angle of shoulders; SAOS, superior angle of scapulae; IAOS, inferior angle of scapulae; PSIS, posterior superior iliac spine; K_{max}, maximum of kyphosis; L_{max}, maximum of lordosis

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speed before stepping, and require more time to recover from perturbations compared to CTD (Graaf-Peters et al., 2007). In studies investigating reactive postural control in response to perturbations, children with CP tend to have impaired coordination of movement, reduced between-limb synchronization (Graaf-Peters et al., 2007) inadequacies in the fine tuning of motor activity (Carlberg and Hadders-Algra, 2005), and a deficit in anticipatory adjustments to execute functional activities and react to unexpected perturbations of balance (Rose et al., 2002), which in turn can cause problems with maintaining an upright weight-bearing position (Donker et al., 2008).

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 limbs (Bartonek et al., 2011; Tomita et al., 2010). Although the foot and knee positions are frequently studied in the standing position (Bartonek et al., 2011; Lidbeck et al., 2014; Tomita et al., 2010) in children with CP, 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.

In our previous studies, the standing postural orientation and postural alignment in children with unilateral CP (UCP) were described, and the relationship between these variables was demonstrated (Domagalska et al., 2011). Additionally, we revealed two different abnormal postural patterns in children with UCP (Domagalska-Szopa and Szopa, 2013; Domagalska-Szopa and Szopa, 2014). The obtained results were promising and encouraged us to extend this analysis to investigate body posture in children with bilateral CP (BCP). The primary aim of this study was to investigate the characteristics of body alignment and postural orientation in a quiet standing position in ambulatory BCP. The second aim was to determine whether different atypical postural patterns were statistically recognized for these children with bilateral cerebral palsy (BCP). We hypothesized that 1) children with BCP would present altered postural alignments compared with CTD children and 2) the postural patterns in BCP would differ depending on the sagittal profile of the spine and the body position with respect to the base of support.

2. Methods

2.1. Patients and procedures

Our local Ethics Committee approved this study. The children were subjected to examination after parental informed written consent was obtained prior to the participant enrolment in the study. All work was performed in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Sixty ambulant children with BCP who were patients of local paediatric rehabilitation centres were recruited to the study. The inclusion criteria were a diagnosis of bilateral CP, age > 7 years (to minimize the incidence of unstable postural patterns), an ability to stand without assistive devices, and sufficient cooperation to enable accurate clinical body assessment. Children were excluded if they had spasticity management for 6 months prior to the evaluation, prior surgery within the past 12 months, medications for spasticity, uncontrolled seizures, intellectual or other developmental disabilities, or an inability to communicate verbally. Two participants were excluded because they refused to undress for the examination. The final study group consisted of 58 participants between 7 and 13 years of age with a mean age of 10.6 years (SD 2 years) including 25 females and 33 males. The patients were classified into Gross Motor Function Classification System (GMFCS) level I (n = 34) and II (n = 24) (Palisano et al., 1997). As reference values, we invited an age- and sex-matched sample of 45 children with typical development and no known history of neurological or orthopaedic diseases to participate (18 girls and 27 boys; mean age 10.2 years; SD 2 years).

Both groups of children (BCP and CTD) underwent a surface topography examination based on the Moiré phenomenon (*i.e.*, projection Moiré topography, MT). MT is a simple method for the analysis of spatial characteristics using a three-dimensional optical system to map the body surface. The Moiré phenomenon involves the illumination of the subject with a spotlight through a special screen to highlight the contoured body surfaces, which will appear as Moiré fringes that can be observed or photographed and documented as Moiré topograms (MTs). MT may be used to obtain a graphical representation of the body posture and mathematical measurements for a quantitative assessment of postural patterns; many other researchers (Patias et al., 2010) have effectively used this technique for both objectives.

A few studies assessed the accuracy of MT measurement in respect to other methods of body posture examination. A very high correlation between measurement of kyphosis and lordosis obtained by MT and RTG was reported by (Leroux et al., 2000), what is more (Ruggerone and Austin, 1986) proved that MT and radiography assessment of scoliosis are also highly correlated. The repeatability of MT examination was assessed based on the value of intra-observer error and inter-observer error in the study of Chowanska et al. (2012). They stated that CQ surface topography evaluation has a good repeatability and reproducibility.

All children were tested in a CQ Elektronik System of Projection Moiré topography analysis (Czernica, Poland) device. We used the same basic method described in our previous studies examining body alignment and postural orientation in a standing position in children with unilateral CP (UCP) (Domagalska-Szopa and Szopa, 2013; Domagalska-Szopa and Szopa, 2014). Each measurement was recorded three times by the same experienced physiotherapist.

Prior to MT examination, it was necessary to uncover the whole surface of the back and to mark the following anatomical landmarks: spinous process of C7, spinous process of S1, spinous processes from C7 through S1 (C7-S1); maximum of kyphosis (K_{max}), maximum of lordosis (L_{max}), and bilaterally: acromial angle of shoulders (AAOS), superior angle of scapulae (SAOS), inferior angle of scapulae (IAOS), posterior superior iliac spine (PSIS) (according to Society on Scoliosis Orthopaedic and Rehabilitation Treatment - SOSORT) recommendations (Grivas et al., 2007). During MT examination, participants were instructed to stand looking straight ahead, arms down in a relaxed position and back parallel to the screen. No attempt was made to position the upper trunk, except that participants were instructed to relax.

The MTs were automatically recorded with dedicated software (CQ-Plecy, Czernica, Poland). Many indices can be computed in each of the three planes based on the MTs (Domagalska et al., 2011). The following eleven MT indices were originally defined for each subject in the CTD and BCP groups:

Indices measured on the sagittal plane (Fig. 1A):

- trunk inclination index in the sagittal plane (TI) refers to the magnitude of the horizontal distance measured from the midline situated within the coronal plane and a line connecting the spinous processes from C7 through S1. If C7 is anterior to S1, RTT has the negative (−) value, and the positive (+) value in the opposite case (i.e., if C_7 is posterior to S_1).
- angle of trunk inclination in the sagittal (A-P) plane (TT) - the angle contained between two adjacent lines as follows: a line situated within the coronal plane and a line connecting the spinous processes from C7 through S1. If C7 is anterior to S1, the angle of trunk inclination (TT) value ranges from -180° to 0°; conversely, the TT value ranges from 180° to 0° in the opposite case (i.e., if C7 is posterior to S1).
- angle of pelvic tilt (PT) – the angle contained between two adjacent lines as follows: a line connecting C7 with S1 and a line connecting L_{max} with S1. If L_{max} is anterior to a line C7-S1, PT value ranges from -180° to 0°; conversely, the PT value ranges from 180° to 0° in the opposite case (i.e., if L_{max} is posterior to C7-S1).