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Original article

# Head stability during whole body movements in spastic diplegia

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**Abstract**

Head angular stability is essential for postural control in whole body movement. Using the opto-electronic ELITE system, we have studied head orientation during the movements of squatting from the standing position and straightening-up from the squatting position in 12 children with spastic diplegia and 12 age-matched controls. Although no instruction was given regarding the head, diplegic children consistently performed excessive neck flexion in the squatting movement and excessive hyperextension in the straightening-up movement, whereas normal children maintained the initial orientation throughout both movements. We discuss pathophysiological implications. © 2000 Elsevier Science B.V. All rights reserved.

*Keywords:* Visual-perceptual; Head stability; Spastic diplegia; Visual referential

## 1. Introduction

Cerebral palsy is a clinical syndrome characterized by abnormal movement and posture secondary to non-progressive pathological processes affecting the immature brain. The most prevalent type of cerebral palsy, spastic diplegia, is characterized by predominance of the motor syndrome (mainly pyramidal) in the lower limbs, which becomes obvious gradually during infancy. It is commonly due to perinatal hypoxic–ischaemic insult in premature neonates resulting in lesions in the white matter adjacent to the cerebral ventricles, or periventricular leukomalacia. One of the earliest signs of spastic diplegia is delayed acquisition of the righting function of the head [1], which ensures control of head posture and movement along and around the body axis [1,2]. Head stability is of utmost importance for vision, as it fosters gaze stability and therefore image stability on the retina, facilitating the processing of visual information [3]. In the present work, we studied the orientation of the Frankfort plane [4], during rapid squatting and straightening-up in 12 children with spastic diplegia and 12 normal age-matched controls.

## 2. Material and methods

### 2.1. Patients

Twelve children with spastic diplegia aged between 3 and 12 years (mean 6.3 ± 2.6) participated in the study. All were born premature with gestational ages ranging from 27 to 36 weeks (mean 30.7 ± 3.1). Motor milestones were attained late in all children: absence of head lag when pulled to sitting from 7 to 21 months (mean 11.9 ± 3.3); independent sitting from 8 to 19 months (mean 12.8 ± 4.2); independent walking from 21 to 40 months (mean 31.2 ± 5.1). Mean normalized global Gross Motor Function Measure scores were 0.78 ± 0.28, corresponding to partial completion of the tasks, with 0.76 ± 0.34 for the items specifically concerning the lower limbs (kneeling, standing, walking and climbing). All patients have Bobath-type physiotherapy (one to three times per week, started in the first year of life in all but one patient). No systematic ophthalmological data could be obtained at this stage. All patients had magnetic resonance imaging (MRI) between three months and six years of age (mean 2.3 ± 1.5 years). The scans showed features of periventricular leukomalacia in all patients, with cystic lesions in the anterior periventricular white matter in two patients, associated left temporal lobe atrophy in one patient and vermian atrophy in another one. Eight patients had lesions involving the optic radiations bilaterally, showing marked asymmetry in two patients. No patients had lesions in the visual cortex.

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### 2.2. Normal controls

The control group consisted of 12 age-matched children with normal development and no disabilities. Gestational ages at birth ranged from 33 to 41 weeks (mean 38.2 ± 2.4). The child born at 33 weeks gestation had a normal cerebral ultrasound in the neonatal period.

### 2.3. Considered movements

Two movements were studied: (1) rapid squatting from the standing position with the arms extended forward, following a paradigm used previously in adults [5] and (2) rapid standing up from a stable squatting position with the arms extended forward, following a paradigm used previously in adults [6].

### 2.4. Movement recording and analysis

Ten trials of each movement were recorded for each subject using the opto-electronic ELITE system [7], which consists of two infrared light-emitting digital cameras that detect reflective markers at a sampling rate of 100 Hz with an accuracy of 0.67 mm. The markers were adhesive plastic spheres (∅ 15 mm) placed on the child's skin overlying the lateral aspect of the nose at the height of the infra-orbital edge and the ear tragus, forming a line (FP) which approximates the Frankfort plane. Recorded marker images were processed for real time shape recognition. Image centroids were reconstructed in three dimensions. The angular position of FP was calculated with respect to the horizontal. Analysis of variance between sets of data (ANOVA) was computed using the Statistica Software (Softcom).

## 3. Results

### 3.1. Head orientation

Before the onset of the squatting movement, the mean angle of FP with respect to the horizontal was 39.4° (standard deviation 8.8°) in diplegic children and 32.3° (standard deviation 4.2°) in normal children. This relative neck hyperextension in diplegic children did not differ significantly from the control's FP orientation. Before the straightening-up movement, the mean FP angle was 26.2° (standard deviation 12.1°) in diplegic children and 29.0° (standard deviation 7.4°) in controls, with no significant difference between groups. The mean differential angle between the Frankfort plane at the onset and at the end of the squatting was −24.8° (standard deviation 22.5°) in diplegic patients

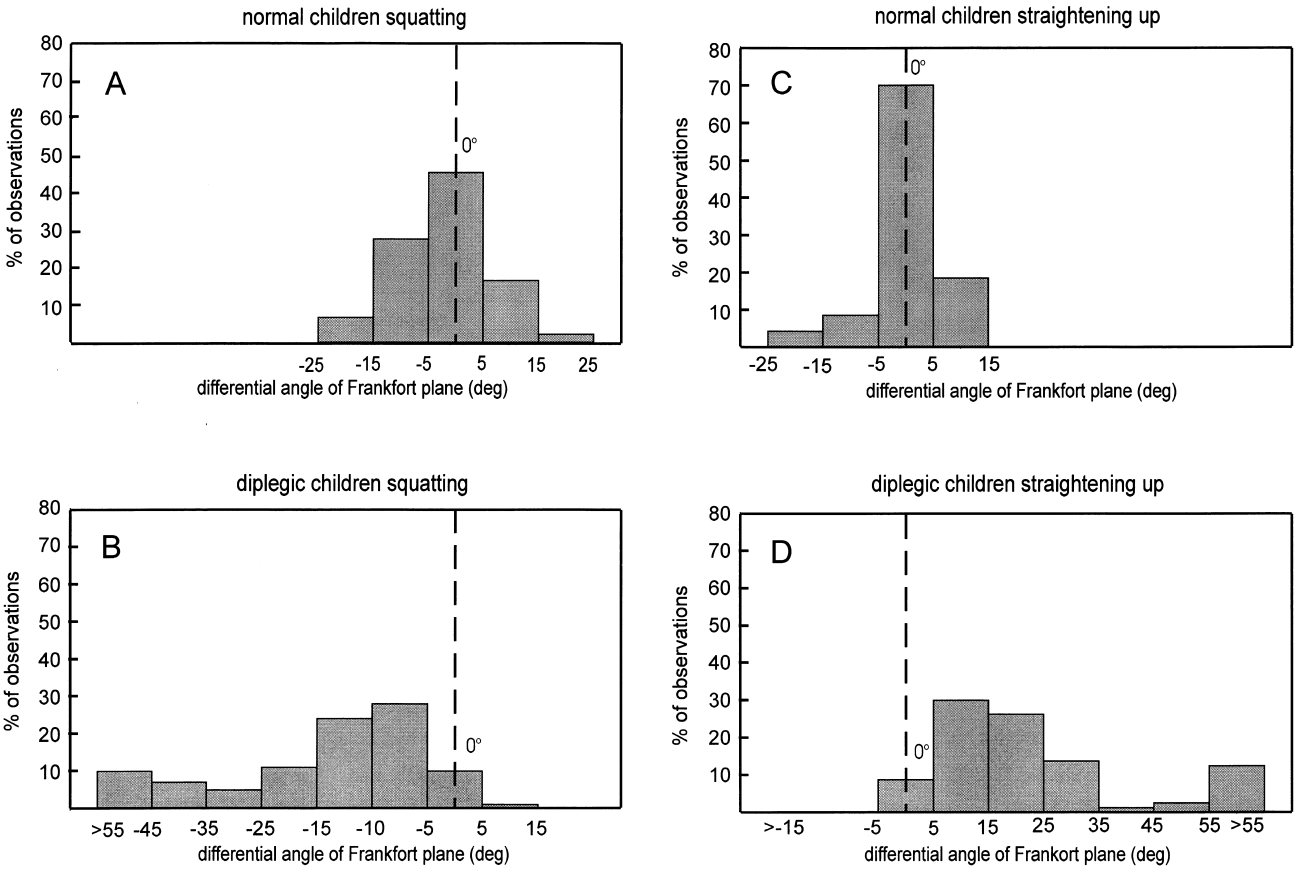


Fig. 1. Distribution of the difference between the angular position of the head at the onset and at the end of the movement of (A) squatting in normal children (B) squatting in diplegic children (C) straightening-up in normal children and (D) straightening-up in diplegic children.

and −1.9° (standard deviation 8.5°) in normal children, showing a highly significant difference between the two groups ($F_{(1,238)} = 119.64$; $P < 0.001$). The dispersion of the observed values are shown in Fig. 1A,B. For the straightening-up movement, it was 26.0° (standard deviation 26.2°) in diplegic children and 0.7° (standard deviation 6.5°) in controls, showing a similarly significant difference between the two groups ($F_{(1,239)} = 92.27$; $P < 0.001$). The dispersions of the observed values are shown in Fig. 1C,D. There were no clear age-related trends.

## 4. Discussion

Head angular stability has been demonstrated to be essential for effective dynamic postural control in whole body movements [3,7]. It provides the central nervous system with visual and vestibular references, and serves as a basis for inertial guidance for postural and motor control [8].

Although no instruction regarding the head was given for either motor task in this study, normal children consistently maintained the initial head orientation throughout the movement whereas diplegic children did not. The deficit in head angular stability reflects dysfunction of the brainstem reflexes normally involved in head control: tonic neck reflex, opto–cervical reflex and vestibulo–cervical reflex. Our patients have no documented brainstem lesions. However, efferent pathways, which are under hemispheric control, are impaired. Excessive flexion associated with squatting and extension with straightening up are not an inertial effect of the movements. Indeed, although the distance between the centre of gravity of the head and the rotation axis located in the cervical column is reduced in both situations, resulting in reduced moment of inertia, the articular moments depending on inertial coupling of the head with the rest of the body should favour neck extension for squatting and extension for straightening up. The observed excessive angular shifts therefore represent an active process. Head flexion during lower limb flexion and head extension during lower limb extension correspond to ontogenetic global motor synergies which develop at the end of the foetal life and in the first six months of life, respectively [9]. Motor organization in cerebral palsy is largely determined by the persistence of these archaic patterns [10]. According to the concept of adaptive motor strategies, the motor patterns developed by children with cerebral palsy represent their solution for the underlying cerebral problem, reflecting priority management by the central nervous system [11]. Stability of head orientation appears to be an important priority for normal children but not for children with spastic diplegia.

The evolution of the axial righting function follows a rostro–caudal course [2]. In the normal new-born and young infant, it facilitates early voluntary visual contacts. Thereafter, the righting function gradually enables the child to free his/her upper limbs by 3–4 months, when it reaches the shoulder girdle, then to achieve the sitting posture by 6–8 months, and eventually the standing posture around the end of the first year of life. One of the presumed important early effects of the axial righting function is the establishment of referentials which rely on head stability, such as the visual referential, which contribute to programming as well as modulation of movement [8]. We speculate that the abnormally late and often incomplete development of the axial righting function in spastic diplegia precludes the establishment of these referentials. In turn, this may have a role in the visual-perceptual deficits which are commonly associated with spastic diplegia [12]. This may warrant a larger scale study of the relationship between head orientation and visual perception in patients with spastic diplegia, with possible implications for management concentrating on head stability and early visual experience.

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## References

[1] Lacey JL, Henderson-Smart DJ, Edwards DA, Storey B. The early development of head control in preterm infants. Early Hum. Dev. 1985;11:199–212.
[2] Hadders-Algra M, Brogren E, Forssberg H. Ontogeny of postural adjustments during sitting in infancy: variation, selection and modulation. J. Physiol. 1996;493:273–288.
[3] Pozzo T, Berthoz A, Lefort L. Head stabilization during various locomotor tasks in humans. I. Normal subjects. Exp. Brain Res. 1990;82:97–106.
[4] DeBeer GR. How animals hold their heads. Proc. Linn. Soc. Lond. 1947;159:125–159.
[5] Cheron G, Bengoetxea A, Pozzo T, Bourgeois M, Draye JP. Evidence of a preprogrammed deactivation of the hamstring muscles for triggering rapid changes of posture in humans. Electroencephalogr. Clin. Neurophysiol. 1997;105:58–71.
[6] Cheron G, Bengoetxea A, Dan B, Draye JP. Multi-joint co-ordination strategies for straightening up movements in humans. Neurosci. Lett. 1998;242:135–138.
[7] Pozzo T, Levik Y, Berthoz A. Head and trunk movements in the frontal plane during complex dynamic equilibrium tasks in humans. Exp. Brain Res. 1995;106:327–338.
[8] Batista AP, Buneo CA, Snyder LH, Andersen RA. Reach plans in eye-centered co-ordinates. Science 1999;288:257–260.
[9] Brown JK, Omar T, O'Regan M. Brain development and the development of the tone and movements. In: Connoly KJ, Forssberg H, eds. Neurophysiology and Neuropsychology of Motor Development, Cambridge: MacKeith Press, 1997. pp. 1–41.
[10] Bobath K. The Motor Deficit in Patients with Cerebral Palsy. Clinics in Developmental Medicine no. 23, London: Spastics International Medical Publications, 1966.
[11] Dan B, Bouillot E, Bengoetxea A, Noël P, Kahn A, Cheron G. Adaptive motor strategies for squatting in spastic diplegia. Eur. J. Paediatr. Neurol. 1999;3:159–165.
[12] Cioni G, Fazzi B, Coluccini M, Bartalena L, Boldrini A, van Hof-van Duin J. Cerebral visual impairment in preterm infants with periventricular leukomalacia. Pediatr. Neurol. 1997;17:331–338.