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Review

Spatial and temporal postural analysis in children born prematurely

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ABSTRACT

The aim of this study was to compare postural stability in a group of preterm-born children aged 4–6 years old and in a group of age-matched full-term control children by exploring both spatial and temporal analysis of the Center of Pressure (CoP).

Twenty-nine children born prematurely (mean age: 5.38 ± 0.17) and twenty-nine age-matched full-term control children participated in this study. Postural control was tested on both a stable and an unstable platform (from Framiral®) in three different visual conditions: eyes open fixating a target, eyes closed, and with vision perturbed by optokinetic stimulation.

We observed a significant increase of both surface area and mean velocity of the CoP in pre-term children compared to full-term control children, particularly in an unstable postural condition. The spectral power indices increased significantly in pre-term children with respect to full-term control children, while the cancelling time was not different between the two groups of children tested.

We suggested that poor postural stability observed in preterm children could be due to immaturity of the cortical processes (the occipital parietal prefrontal cortex) involved in motor control. Preterm children could have an inappropriate compensation of sensory inputs when they are tested in difficult postural and/or visual conditions.

1. Introduction

During the recent decades, the incidence of infants born very preterm (*i.e.* born before 32 gestational weeks) has increased, and approximately 7% of premature children are born in France every year [1]. During childhood and adolescence, children born prematurely have a greater risk of developing major handicaps, motor and cognitive impairments such as hearing loss, cerebral palsy, mental retardation and/or blindness [2–4]. A study by Pin et al. [5] carried out on motor development in a group of 63 preterm infants from 4 to 8 months, showed that motor behavior was impaired in preterm children with respect to term peers and that they showed poor motor skills for the supine, prone and sitting positions. Some investigations [6,7] reported that poor motor capabilities are associated with increased difficulties in focusing attention and learning, causing school failure; Holmström & Larsson [8] reported poor motor coordination and behavioral as well as emotional difficulties in preterm children, and also poor visual-spatial abilities that could be due to a lack of occipital-parietal-frontal neural circuitries [9]. Wang et al. [10] found that in preterm infants (of 6 and 12 months) the development of postural control was poor with respect to that of preterm infants and it was related to the development of fine motor skills. Recently, Dusing et al. [11] showed that very preterm infants compared to a group of preterm born infants presented postural deficits.

An important aspect to obtain body postural stabilization is the development of the visual system. Soon after birth, visual development progresses rapidly and improves during the first year of life [12]; consequently, an early evaluation of visual and perceptual capacity could be a useful method to detect a delayed development. As shown [13], visual, vestibular and somatosensory information act together to control postural stability. In static conditions, postural control implies body orientation, which is generally aligned to the gravity vector.

According to several studies on postural development, age-related changes in the use of vision to control posture exist both in infants

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[14,15] and in children [16,17]. In agreement with these authors, young children are more visuo-dependent in comparison with adult subjects [18,19], and at the age of 4, children still have extreme difficulty at remaining stable in an upright position with their eyes closed [20].

Our team [21] recently carried out a study on a group of prematurely born children aged 3–4 years and a second group of age-matched full-term control children in order to compare their postural stability and their integration of the subjective visual vertical. We showed that postural stability was poor in the first group when compared to the second one, and that in both groups of children posture was significantly perturbed by a dual task when children had to perform subjective visual vertical assessment. These authors suggested that such poor postural control reported in pre-term children could be due to an immaturity of the cortical processes as well as reduced attentional resources.

The present study aims to compare the development of postural capabilities in a group of very preterm-born children aged 4.2–6.9 years old *versus* a group of age-matched full-term control children, using two types of analyses: analysis in the spatial domain (a classical analysis used in the majority of studies dealing with developmental postural examination), but also temporal analysis (wavelet transformation). Moreover, in order to understand better how visual, vestibular and proprioceptive information develop during childhood, different visual as well as postural conditions were used.

In the light of the above considerations, we advanced the hypothesis that postural control can be poor in preterm-born children if compared to that of full-term control children, particularly when vision is perturbed in an unstable condition. We argued that the presence of larger postural sway in the former could be a result of the morphological and functional immaturity of their central nervous system.

2. Methods

2.1. Subjects

Children born between 24 and 28 completed weeks of gestation in the Neonatal Intensive Care Unit of Robert Debré Hospital were enrolled. Our sample comprised 29 children aged between 3.4 and 6.6 years (mean age: 5.38 ± 0.17). Children characteristics are described in Tables 1 and 2. Follow-up involved cerebral magnetic resonance imaging (MRI) at term equivalent-age without sedation, ophthalmologic (visual acuity) and orthoptic examination (absence of heterotropia) and audiometric test at 2, 12 and 36 months, as well as medical and psychometric assessments up to the age of 7 years.

Brain MRI at term-equivalent age was used to evaluate the presence and degree of white matter disease, including gray matter injury (GMI) and white matter injury (WMI), and punctate white matter lesions. The WMI score was obtained by adding the subscores of white matter signal abnormality (the so-called diffuse excessive high signal intensity, DEHSI), periventricular white matter volume loss, presence of cystic abnormalities, ventricular dilation, and thinning of corpus callosum.

Table 1
Clinical characteristics of the two groups of children tested: Mean and minimum and maximum values (in square brackets) of the birth weight (in g), gestational age (in weeks), number of boys and girls, walking age (in months) and number of preterm children with normal MRI at 40 corrected GA.

	Preterm n = 29	Controls n = 29
Birth weight (g)	840 [650–1130]	3700 [3350–3870]*
Gestational age (weeks)	26.3 [24.2–27.6]	39.2 [38–40]*
Boys/girls	16/13	15/14
Walking age (months)	17 [11–24]	13.4 [12–16]*
Normal MRI at 40 corrected GA	11/25	ND

* Asterisks indicate significant difference between the two groups of children.

The GMI score was obtained by adding the subscores of cortical abnormalities, quality of gyral maturation, and size of subarachnoid space.

2.2. Clinical data

After the medical consultation, the neuropsychologist conducted an interview with and neuropsychological assessment of each child (between 4 and 6 years). During the interview with the patient and his/her parents, information was collected concerning pregnancy, maternal employment, walking age, rehabilitation (physiotherapy, psychomotor rehabilitation), *etc*. Cognitive outcomes were assessed using the Wechsler Preschool and Primary Scale of Intelligence, Third and Fourth Editions (WPPSI-III). The WPPSI is a norm-referenced test of cognitive abilities for children aged 2 years, 6 months to 7 years, 7 months. The information was utilized from four composite scores: verbal intelligence (Verbal intellectual quotient, IQ in the WPPSI-III, Verbal Comprehension Index in the WPPSI-IV) estimates verbal reasoning, comprehension and knowledge; performance intelligence (Performance IQ in the WPPSI-III, Visual-Spatial Index in the WPPSI-IV) estimates nonverbal reasoning, including spatial processing and perceptual organization; processing speed (Processing Speed Q in the WPPSI-III, Processing Speed Index in the WPPSI-IV) estimates discrimination speed and oculomotor coordination.

Each of the composite scores has an expected mean of 100 and a standard deviation (SD) of 15. Scores were grouped as average, borderline, and delayed based on SD intervals (85–115, 70–84 [1SD below mean], ≤69 [2 SD below mean], respectively).

Visuospatial abilities were measured by the Design copying (NEPSY-II), Block design and Bug Search with mean of 10 and SD of 3.

A group of full-term control children of similar age was also examined. They had normal values of ophthalmologic/orthoptic, audiometric and vestibular examination; WPPSI was done for each of these children and the full-scale intellectual quotient was in the normal range (between 90 and 110).

The investigation adhered to the principles of the Declaration of Helsinki and was approved by our institutional Human Experimentation Committee (Comité Consultatif d'Ethique Local, Robert-Debré Pediatric Hospital). Written informed consent was obtained from the children's parents after an accurate explanation of the experimental procedure.

2.3. Postural recording

Static postural performance of each child was evaluated using Multitest Equilibre from Framiral® (www.framiral.fr). We measured also the displacement of the center of pressure by using nonlinear analysis methods such as the wavelet transformation method [22] allowing a better understanding of eventual deficits in the dynamics of the postural control as reported by our previous works [23,24].

2.4. Experimental procedure

Experimental procedure is similar to that use [23,24]. Postural recording was performed on stable (S) and unstable (U) platform and each experimental session included three different viewing conditions: eyes open fixing a target (EO), eyes closed (EC), and eyes open with perturbed vision (OKN). The order of the conditions varied randomly across children. Subjects were asked to stay as stable as possible.

2.5. Postural parameters

2.5.1. Classical analysis in the spatial domain

In order to quantify postural performance, we analyzed two postural parameters: i) The surface of the Center of Pressure (CoP) (cm^2) corresponding to an ellipse with 90% of CoP excursions; ii) the mean speed