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Postural adjustments in infants at very high risk for cerebral palsy before and after developing the ability to sit independently

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ABSTRACT

Background: Children with cerebral palsy (CP) have impaired postural control. Posture is controlled in two levels: direction-specificity, and fine-tuning of direction-specific adjustments, including recruitment order. Literature suggests that direction-specificity might be a prerequisite for independent sitting.
Aim: To study development of postural adjustments in infants at very high risk for CP (VHR-infants) during developing the ability to sit independently.
Method: In a longitudinal study surface electromyograms of the neck-, trunk- and arm muscles of 11 VHR-infants and 11 typically developing (TD) infants were recorded during reaching in sitting before and after developing the ability to sit unsupported (median ages: VHR 8.0 and 14.9 months; TD 5.7 and 10.4 months). Sessions were video-recorded.
Results: In VHR- and TD-infants the prevalence of direction-specific adjustments and recruitment order did not change when the infant learned to sit independently. In VHR-infants able to sit independently more successful reaching was associated with a higher frequency of bottom-up recruitment (Spearman's rho = 0.828, p = 0.006) and a lower frequency of simultaneous recruitment (Spearman's rho = −0.701, p = 0.035), but not with more direction-specificity. In TD-infants not able to sit independently, more successful reaching was associated with higher rates of direction-specific adjustments at the neck level (Spearman's rho = 0.778, p = 0.014), but not with recruitment order.
Conclusions: In VHR- and TD-infants postural adjustments during reaching in terms of direction-specificity and recruitment order are not related to development of independent sitting. Postural adjustments are associated with success of reaching, be it in a different way for VHR- and TD-infants.
Clinical trial registration number: NTR1428.

1. Introduction

Infants at high risk (HR) for cerebral palsy (CP), such as infants born preterm or with perinatal asphyxia, often show a delay in the development of motor milestones like sitting, walking, reaching and grasping [1]. These motor activities are highly dependent on postural control [2]. However, little is known on the organization of postural adjustments in HR-infants.

Postural control is a complex neural task involving activity of many muscles. In terms of muscle activity two levels of control can be distinguished. The first level consists of direction-specificity, implying that if balance is compromised by a forward body sway, the muscles on the dorsal side of the body are primarily activated and in case of a backward sway the muscles on the ventral side. At the second level of control the direction-specific postural pattern is fine-tuned to the specifics of the situation by means of e.g. adaptation of the recruitment order of the direction-specific muscles [2,3].

Typically developing (TD) infants aged 1 to 3 months show pre-reaching movements accompanied by postural activity without direction-specificity [4]. Four-month-olds, who just have mastered the ability to reach for a toy, show direction-specific postural adjustments during 40% of reaching movements [5]. The study of De Graaf-Peters et al. showed that infants aged 4 to 6 months, who demonstrated direction-specific adjustments during at least half of their reaches, were more successful in reaching and had reaches with a better kinematic quality than infants whose reaches were less often accompanied by direction-specific postural activity [6]. This suggests that direction-specificity is not a prerequisite for reaching, but that it is associated with better reaching. During infancy the rate of direction-specific adjustments during reaching gradually increases to about 60% at

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18 months [5] and 100% at 2 years of age [7]. Throughout infancy direction-specific adjustments are characterized by variation, for instance variation in recruitment order [5]. Despite the large variation, a developmental trend in recruitment order is observed. At 4 months, a mild preference for top-down recruitment (the neck muscle is activated prior to the trunk muscles) is present, which changes into a preference for bottom-up (trunk muscle activated prior to the neck muscles) at 18 months [5].

Relatively little is known on the organization of postural adjustments of infants at high risk for CP. The data of Van Balen et al. indicated that the development of direction-specificity during reaching in high risk infants is delayed [8]. But at preschool age, most children with CP do show consistent direction-specific adjustments during reaching while sitting [9]. The limited data available suggest that only children with CP functioning at Gross Motor Function Classification System (GMFCS) [10] level V – who do not develop the ability to sit independently – show a total lack of direction-specificity [9,11]. This might mean that direction-specificity is a prerequisite for the development of sitting ability. But direction-specificity is not the only factor involved in the development of the ability to sit without support, as the study of Hedberg et al. showed that one-month-old TD-infants virtually always showed direction-specific postural adjustments in response to external perturbations of balance, while they were unable to sit independently [12].

Others studied the development of reaching and postural control using the theoretical framework of the dynamic systems theory [13]. For instance, the longitudinal data of Thelen and Spencer indicated that in typical development stable head control precedes the emergence of reaching [14]. Harbourne and Stergiou [15], who applied non-linear dynamics to study center of pressure (COP) behavior of sitting infants, reported that infants decreased the degrees of freedom in body motility when the ability to sit emerged, to return to increased levels of degrees of freedom when they could sit properly without help — a flexibility allowing them to adapt to the environment. Kyvelidou et al. [16] noted that COP behavior of infants with CP and infants born preterm with motor delays at the emergence of early sitting differed from that of TD-infants. The data suggested that the infants with CP had a severely limited repertoire of adjustments, those with developmental delay a moderately reduced repertoire, while TD-infants had a large and flexible repertoire.

Non-linear measures, such as used in the above mentioned studies on COP-behavior [15,16], do not provide information on the muscular strategy to achieve the stability needed to sit without support. Therefore we wondered whether in infants at very high risk for CP (VHR-infants) and TD-infants the development of the ability to sit without help (requiring active neural control instead of reactive neural control) is related to the development of direction-specific postural adjustments during reaching (also requiring active control). Thus, the aim of this longitudinal study is to increase the understanding of postural development in VHR-infants, during the phase of the development of sitting ability. To this end, postural control during reaching was studied in infants participating in the LEARN2MOVE 0–2 year project (L2M0-2). L2M0-2 aims to evaluate whether intervention with the newly developed COPCA-program (Coping with and Caring for infants with special needs — a family centered program [Dirks et al. 2011]) [17] results in a better outcome in terms of functional capabilities of the VHR-infant and developmental potential of the family, compared to traditional infant therapy [18]. Similar data on postural control of TD-infants were available from a previous project [5].

We addressed the following questions: [1] Does postural control in terms of direction-specificity and recruitment order of VHR-infants change when the infant develops the ability to sit independently? [2] Does postural control in terms of direction-specificity and recruitment order of VHR-infants before and after development of the ability to sit independently differ from that of TD-infants? [3] Is postural control in terms of direction-specificity and recruitment order in VHR-infants associated with reaching performance, and with the presence of CP at 21 months corrected age?

2. Method

2.1. Participants

This study comprised 11 VHR-infants (nine boys, two girls), and 11 TD-infants born at term without perinatal complications (seven boys, four girls). The VHR-infants were included in the L2M0-2 project before 9 month corrected age based on one of the following criteria (Hielkema et al.) [18]: 1) cystic periventricular leukomalacia; 2) parenchymal lesion of the brain (uni- or bilateral); 3) brain lesions on MRI with Sarnat 2 or 3 [19] caused by term/near-term asphyxia; and 4) neurological dysfunction which might lead to the development of CP. Infants were excluded in case of presence of a severe congenital disorder, or presence of an inadequate understanding of the Dutch language by caregivers. For the present study, VHR-infants who fulfilled the following additional criteria were included: a) they developed the ability to sit independently, and b) they had two postural electromyography (EMG) recordings: one when they were not able to sit independently (EMG recording 1: E1), the other when they could sit without support as noted during the Touwen Infant Neurological Examination [20] (EMG recording 2: E2). Clinical details of the participants are summarized in Table 1. The ethics committee of the University Medical Center Groningen approved the protocol (L2M0-2 is registered under trial number NTR1428) and informed consent was given by the parents.

2.2. Procedure

Postural control in VHR-infants was assessed at inclusion (T0), 6 months after inclusion (T2), 12 months after inclusion (T3) and at the corrected age of 21 months (T4). For this study, two assessments were selected: 1) the first assessment available when the infant was able to reach but unable to sit unsupported (E1); and 2) the first assessment available when the infant could sit unsupported (E2).

Similar data of 11 TD-infants were present at the ages of 4, 6 and 10 months [5]. According to the Touwen Infant Neurological Examination (TINE) [20], six of the TD-infants could not sit independently at 6 months (E1 for the present study); in the remaining five infants who could sit independently at 6 months, the data recorded at 4 months, when the infants could not sit independently were used for E1. All TD-infants were able to sit independently at 10 months; these 10 months data were used for E2.

Table 1
Participant's characteristics.

	VHR-infants	TD-infants
Gestational age (wk), median (range)	36.3 (26.3–41.1)	40.5 (37.6–42.0)[a]
Birth weight (g), median (range)	2375 (1070–5400)	3463 (3000–4000)[a]
Corrected age E1 (mo), median (range)	8.0 (4.7–9.6)	5.7 (3.8–6.5)
Corrected age E2 (mo), median (range)	14.9 (11.4–22.4)	10.4 (9.6–11.4)[a]
Type of brain lesion, n (%)		
Posthemorrhagic porencephaly	6 (55)	Not applicable
Basal ganglia/thalamic lesion	2 (18)	
Cortical infarction	1 (9)	
Other lesions[b]	2 (18)	

g: grams, E1: electromyography recording 1 (not able to sit unsupported), E2: electromyography recording 2 (able to sit unsupported), mo: months corrected age, TD: typically developing, VHR: very high risk, wk: weeks.

[a] Mann–Whitney: $p < 0.01$.

[b] Other brain lesions: arachnoid cyst with hydrocephalus and bilateral intraventricular hemorrhage grade 3.