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Are postural adjustments during reaching related to walking development in typically developing infants and infants at risk of cerebral palsy?

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ABSTRACT

Background: In typical development, postural adjustments during reaching change in the second half of infancy, including increasing rates of direction-specific adjustments. These changes are absent or different in infants at risk of cerebral palsy (CP). To discover whether these changes are related to acquisition of independent walking, we studied postural adjustments during reaching in infants before and after they learned to walk.
Methods: Ten typically developing (TD) infants and 11 infants at very high risk (VHR) of CP were assessed before and after they learned to walk. Reaching movements were elicited during supported sitting, while surface electromyography was recorded of arm, neck, and trunk muscles. Percentages of direction-specific adjustments (first level of control), and recruitment patterns and anticipatory activation (second level of control) were calculated.
Results: In both groups, postural adjustments during reaching were similar before and after acquisition of independent walking. Direction-specificity increased with age in typically developing infants but not in VHR-infants.
Conclusion: Increasing age rather than the transition to independent walking is associated with increasing direction-specificity of TD-infants during reaching while sitting, while infants at very high risk of CP show no increase in direction-specificity, suggesting that they gradually grow into a postural deficit.

1. Introduction

Typically, the development of motor skills and development of postural control are closely intertwined. It is therefore expected that changes in motor development be related to changes in postural control and vice versa. This may be true especially for the acquisition of independent walking, which is a posturally demanding skill. Acquisition of independent walking has been associated with changes in postural control. For example, in typically developing (TD) children stabilization of the hip in space appears in the first week of independent walking (Assaiante, Thomachot, & Aurenty, 1993; Assaiante, Thomachot, Aurenty, & Amblard, 1998). In addition, walking experience has been found to facilitate control over postural sway through an increase in sensorimotor integration

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(Barela, Jeka, & Clark, 1999; Metcalfe et al., 2005; Sundermier & Woollacott, 1998). The close relationship between postural control and learning to walk is also observed in children with developmental motor disorders, such as cerebral palsy (CP): dynamic postural control during sit-to-stand activity is a predictor of learning to walk in children with CP (Begnoche et al., 2016).

The study of Chen, Metcalfe, Jeka, and Clark, (2007) suggested that learning to walk also affects postural adjustments in a sitting position, as changing postural sway patterns during sitting were observed in infants during the acquisition of independent walking. Also, infants sitting on a moving platform after acquisition of independent walking showed more adult-like anticipatory adjustments to platform movements than before learning to walk (Cignetti, Zedka, Vaugoyeau, & Assaiante, 2013). In our current study, we aimed to investigate the relationship between learning to walk and postural muscle recruitment strategies during reaching, both in typically developing (TD) infants and in infants at risk of CP.

In terms of muscle recruitment strategies, postural control can be considered to consist of two levels. The first or basic level is direction-specificity, meaning e.g., that a forward body sway is counteracted by activation of dorsal muscles. The second level consists of fine-tuning of the postural adjustment, for example in the number of muscles activated, the recruitment order and use of anticipatory adjustments. Our previous studies indicated that in TD-infants aged 4–10 months, direction-specific activation of the trunk muscles is only present in about 60% of reaching movements in a sitting position, but this increases to 88% at the age of 18 months (Van Balen, Dijkstra, & Hadders-Algra, 2012). The studies also showed that the second level of postural control during this age period is characterized by variation, typical of infancy (Hadders-Algra, 2002). Nevertheless, a mild preference for top-down (i.e., cranial-to-caudal) recruitment appeared to be gradually replaced by a mild preference for bottom-up recruitment between 4 and 18 months (Van Balen et al., 2012).

In infants at high risk (HR) of CP, no increase in direction-specificity was observed between 6 and 18 months (Van Balen, Dijkstra, Bos, Van Den Heuvel, & Hadders-Algra, 2015). Top-down recruitment in these infants was initially lower than that of TD-infants but increased to similar rates at 18 months (Van Balen et al., 2015). As older children with CP do show direction-specificity during reaching (van der Heide et al., 2004), these differences between HR- and TD-infants suggest that development of postural control is delayed in HR-infants. This raises the question of whether development of postural control in infancy depends on age or stage of motor development. During the interval of 4–18 months, in which we found changes in postural control during reaching while sitting (Van Balen et al., 2012; Van Balen et al., 2015), the infants learned to sit, stand and walk. Previously we examined direction-specificity in both typically developing infants and infants at very high risk (VHR) of CP before and after learning to sit independently, but found no differences, either within or between the groups (Boxum et al., 2014). In the current study, we examined postural adjustments during reaching while sitting in both TD- and VHR-infants before and after learning to walk independently. We hypothesized that, if independent walking facilitates direction-specificity during sitting or vice versa, there would be an increase in direction-specificity in both groups after learning to walk independently. Similarly, if the change to a modest preference for bottom-up recruitment in TD-infants reported earlier (Van Balen et al., 2012; Van Balen et al., 2015) is related to walking, then we would expect to replicate this change after learning to walk.

2. Methods

2.1. Participants

Eleven VHR-infants (six boys, five girls), and 10 TD-infants (four boys, six girls) participated in this study. The VHR-infants were included in the LEARN2MOVE 0–2 years (L2M 0–2) project (Hielkema et al., 2010) before 9 months corrected age (CA) based on one of the following criteria: 1) cystic periventricular leukomalacia; 2) parenchymal lesion of the brain (uni- or bilateral); 3) severe asphyxia with brain lesions on magnetic resonance imaging; and 4) neurological dysfunction suspect for CP. Exclusion criteria were the presence of a severe congenital disorder, or 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 walk independently by the age of 21 months CA, and b) they had two postural electromyography (EMG) recordings: one just before and one after learning to walk independently (see Assessment procedure).

Typically developing infants born at term without perinatal complications were recruited from infant public health agencies in Groningen, The Netherlands. Clinical details of the participants are summarized in Table 1. The ethics committee of the University Medical Center Groningen approved the protocols (registration numbers NTR1428 and NL51701.042.14) and informed consent was given by the parents.

2.2. Assessment procedure

The Alberta Infant Motor Scale (AIMS; (Piper & Darrah, 1994)) was used to determine the developmental stages at which the infants were assessed. TD-infants were assessed 1) when they were able to pull up to standing but unable to walk independently (Time A; item 'Pulls to Stand with support' of the AIMS); and 2) when they could walk independently for about one month (Time B; item 'Walks Alone' of the AIMS). Postural control in VHR-infants was assessed at inclusion (T0), 6 months after inclusion (T2), 12 months after inclusion (T3) and at 21 months CA (T4). Two assessments matching the abovementioned developmental criteria of Time A and B were selected for each VHR-infant. Thus, the interval between Time A and B for the VHR-infants resulted from the assessment schedule of the L2 M 0–2 trial, but the developmental stages of the VHR-infants of the selected assessments matched the developmental stages of time A and B, respectively, as determined by the AIMS. This implied for Time B that the infants had walked independently for 1–9 months, i.e., the VHR-infants may have had some months more walking experience at time B than the TD-