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Effect of the severity of manual impairment and hand dominance on anticipatory and compensatory postural adjustments during manual reaching in children with cerebral palsy



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ABSTRACT

Aim: To investigate the role of the severity of manual impairment and of hand dominance on postural sway during anticipatory [APA] and compensatory [CPA] postural adjustments in a seated manual reaching task performed by children with cerebral palsy (CP) and typical children (TC).

Methods: We tested 26 TC (mean age 9.5 ± 2.1 years) and 29 children with CP (age 9.6 ± 3 years) classified based on manual impairment levels as mild (Manual Ability Classification System [MACS] I; $n = 18$) or moderate-to-severe (MACS II-III, $n = 11$). Participants were instructed to reach towards a target using their dominant vs. non-dominant arm while sitting on a force-plate. Center of pressure (CoP) sway was analyzed during APA and CPA.

Results: For all groups, using the non-dominant arm determined greater amplitude and velocity of CoP sway in CPA. Children with moderate-to-severe manual impairment showed greater sway during APA and CPA compared to mild impairment and TC groups.

Conclusion: More severe manual impairment resulted in higher sway during the anticipatory and compensatory phases of the reaching task. Using the non-dominant arm resulted in greater compensatory adjustments during reaching.

What this paper adds?

Arm coordination is expected to affect and be affected by postural adjustments during manual tasks. Therefore, successful reaching requires precise postural adjustments to stabilize the body and facilitate task accomplishment. In this study, we showed that poorer manual ability in children with cerebral palsy is related with larger and faster postural sway during the anticipatory and compensatory phases of reaching. The use of the non-dominant arm increases compensatory adjustments during reaching. Therefore, rehabilitation programs should train using the non-dominant arm during seated manual tasks to challenge the postural control system more intensely. This may be especially relevant for children with more severe manual impairments

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1. Introduction

Functional tasks, such as manual reaching, challenge postural stability because they change the alignment of body segments and project the center of mass forward, (Hadders-Algra, Fits, Stremmelar, & Touwen, 1999). Therefore, successful reaching requires precise postural adjustments to stabilize the body and support the correct positioning of the arm in space to touch the target (Liao & Hwang, 2003; Pin, Butler, & Shum, 2018). In addition, postural control deficits during reaching may affect functional ability in self-care tasks (Cherng, Lin, Ju, & Ho, 2009; Visicato, da Costa, Damasceno, De campos, & Rocha, 2015).

Strategies for postural control during functional tasks include anticipatory postural adjustments (APA) and compensatory postural adjustments (CPA). APAs involve movements generated by the central nervous system to counteract the expected mechanical effects of perturbations in a feedforward manner (Bigongiari et al., 2011). They are associated with direction-specific patterns of postural muscle activation or inhibition and anticipatory changes in center of pressure (CoP) (Santos & Aruin, 2009). CPAs are reactive responses to postural perturbations. These adjustments use sensory feedback to respond to and to counter disturbs of posture (Girolami, Shiratori, & Aruin, 2011).

Considering the postural challenges caused by reaching (van der Fits, Flikweert, Stremmlaar, Martjin, & Hadders-Algra, 1999) and the relationship between arm positioning and trunk control (Pin et al., 2018), arm coordination is expected to affect postural adjustments during manual tasks (Bigongiari et al., 2011). In the presence of neuromotor conditions, such as cerebral palsy (CP), postural adjustments during upper limb movements may be impaired, resulting in greater postural sway during tasks (Girolami et al., 2011).

There is a large variation in the severity of motor disabilities among individuals with CP (Palisiano et al., 1997). Manual ability is affected by injuries in neural pathways underlying arm movement control, with poorer patterns of arm movements being performed by children with poorer manual ability (Domellöf, Rösblad, & Rönnqvist, 2009; Kukke et al., 2016). More severe arm impairment also seems to determine poorer reaching trajectories both in the dominant and the non-dominant arms in children with unilateral CP (Rönnqvist & Rosblad, 2007), showing that impairment severity and hand dominance should be accounted for when studying arm function and postural control in CP.

Regarding postural control during reaching, no studies were found assessing CPAs across levels of motor impairment. Only a few studies addressed these issues during APA and found that children with more severe gross motor impairments (GMFCS level II) show lower back muscles activation during APA than children with GMFCS level I (Tomita, Fukuya, Takagi, & Yokosawa, 2016). Moreover children with diplegic CP showed and larger postural sway and higher baseline muscle activity in some leg and trunk muscles compared to children with hemiplegic CP during the task of holding an object compared to typical children (Shiratori, Girolami, & Aruin, 2016). These studies demonstrated that impaired gross motor function influences the effectiveness of the postural adjustments during manual reaching, thus highlighting that children demand different levels of assistance and have specific rehabilitation needs based on their impairment levels. Nevertheless, we did not find studies testing the role of manual ability or hand dominance on postural adjustments.

Assessing seated postural control is functionally relevant in children with CP, since many children (especially the ones with moderate-to-severe motor impairments) perform most activities of daily life in the sitting posture (Brogren, Hadders-Algra, & Forsberg, 1996). Understanding how manual ability and hand dominance impact postural adjustments during manual reaching may help rehabilitation professionals guide their interventions considering the individual motor difficulties of the child, thus promoting more personalized rehabilitation.

Based on this background, the aim of this study was to investigate the impact of manual impairment and hand dominance on postural sway (APAs and CPAs) performed during a seated manual reaching task in children with CP and age-matched typically-developing children.

Considering that movement coordination influences postural sway (Bigongiari et al., 2011; Cherng et al., 2009; Ju, Hwang, & Cherng, 2012), we expect that lower manual abilities and hand dominant will influence postural sway during APA and CPA in a seated reaching task in children with CP than in typical ones. More postural sway is expected in the group with more severe arm impairment and when reaching is performed with the non-dominant arm in both groups.

2. Methods

2.1. Participants

The present study was carried out in the Child Movement Analysis Laboratory and had a cross-sectional design. All the participants were recruited in pediatric rehabilitation centers and/or regular schools.

A convenience sample of 55 children with ages between 5 and 14 years was tested. The group of children with typical development included 26 children, 14 males and 12 females. Participants with current lower limb injury, with visual impairments not corrected by glasses or contact lenses, or who had any cardiovascular, pulmonary, neurological, or systemic conditions that limited physical activity were excluded from the study.

The group of children with CP comprised 29 children with spastic CP, 18 males and 11 females, levels I, II, III or IV of Gross Motor Function Classification System (GMFCS) and levels I, II or III of Manual Ability Classification System (MACS). The children were split into two groups according to their MACS levels. Based on MACS, children at level I were classified as mild impairment ($n = 18$), and at children levels II and III as moderate to severe impairment (Chagas et al., 2008) ($n = 11$). Out of 29 participants with CP, 17 children presented unilateral distribution of motor impairments (hemiplegia) and 12 bilateral distribution of motor impairments

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