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Planning and coordination of a reach–grasp–eat task in children with hemiplegia

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ABSTRACT

Children with hemiplegia have deficits in motor planning in addition to their impairments in movement of their more-affected upper extremity (UE). However, little is known about the relationship between motor planning and multi-segment coordination during functional activities in this population. In the present study, motor planning strategies and multi-segment coordination of the head, trunk, and UE were examined during a functional reach–grasp–eat task in children with hemiplegia. Ten children with hemiplegia (age 4–10 years; MACS levels I–II) and ten age-matched, typically developing children participated in the study. Children were asked to reach, grasp and transport a cookie to the mouth with one hand while 3-D kinematic analyses were performed. A more extended wrist ($p = 0.001$) and higher end-point position of grasping ($p = 0.001$) were found for both UEs of children with hemiplegia. The less-affected UE had greater trunk contribution ($p = 0.018$) and greater shoulder flexion ($p = 0.002$) and elbow extension ($p = 0.005$) during reaching compared to the TDC. The more-affected UE had impaired movement control with greater head rotation ($p = 0.011$), higher variability of end-point location in space ($p = 0.001$), greater trunk contribution ($p = 0.018$), and reduced wrist rotation ($p = 0.007$) compared with the less-affected UE and TDC. Additionally, delayed timing of maximum shoulder ($p = 0.03$) and elbow flexion ($p = 0.008$) during reaching, and maximum wrist pronation ($p = 0.004$) during eating were found for the more-affected UE. The results showed different multi-segment control for both UEs in children with hemiplegia compared to TDC. They also reflect impaired motor planning since the same movement strategies were used for both UEs. Furthermore, we suggest that inefficient multi-segment coordination of the more-affected UE is used to compensate for impaired motor planning and control.

1. Introduction

Children with hemiplegia have been shown to have less capability in motor planning in addition to their motor impairments of the more-affected upper extremity (UE) (Steenbergen, Craje, Nilsen, & Gordon, 2009; Steenbergen & Gordon, 2006). Mutsaarts, Steenbergen, and Bekkering (2006) suggested children with hemiplegia have anticipatory planning deficits and do not take into account the forthcoming task demands associated with the goal of the action sequence (Johnson-Frey, McCarty, & Keen, 2004). For example, when flipping an upside down cup, one would normally grasp it with a grip that

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leads to a comfortable posture at the end point (e.g., Elsinger & Rosenbaum, 2003). Such anticipatory motor planning deficits were found in the less-affected UE as well. It is assumed with deficient motor planning, children with hemiplegia would have different multi-segment coordination for both UE compared to typically developing children (TDC). However, such interaction between motor planning and multi-segment coordination for children with hemiplegia during functional activities has not been evaluated.

Some daily activities require coordination between body parts without pre-defined stationary end-point locations. For example, when eating one can bring the food to the mouth or have the mouth move closer to the food (i.e., the intersection of the head and hand is not predetermined). A greater number of degrees of freedom are available for tasks without pre-defined end-point locations, and thus, motor planning and multi-segment coordination are more challenging than simple reaching and grasping tasks. Better understanding of the interaction between motor planning and multi-segment coordination for children with hemiplegia requires challenging sequential tasks, such as hand-to-mouth task.

Aside from the deficits in motor planning, there are impairments in the more-affected UE movement control, with less straight hand paths and more proximal joint motion to compensate for the reduced distal joint motion (Coluccini, Maini, Martelloni, Sgandurra, & Cioni, 2007; Domellof, Rosblad, & Ronnqvist, 2009; Kreulen, Smeulders, Veeger, & Hage, 2007). Several studies have investigated hand-to-mouth task in children with hemiplegia and found reduced joint motion of the UE with proximal joint compensatory strategies (Butler et al., 2010; Fitoussi, Diop, Maurel, Lassel, & Pennecot, 2006; Mackey, Walt, & Stott, 2006). However, these studies did not investigate motor planning (e.g., grasping strategies or end-point position planning) or head control. Head control is critical since it defines the location of the mouth in space for eating. Head control is suggested to develop around 3–6 year old during walking and reaching tasks for TDC (e.g., Assaiante, Mallau, Viel, Jover, & Schmitz, 2005; Sveistrup, Schneiberg, McKinley, McFadyen, & Levin, 2008). However, little is known about head control for children with hemiplegia. Other than joint excursion, the detailed *temporal multi-segment coordination* has not been studied.

Although, deficits in motor planning were found for the less-affected UE (Steenbergen et al., 2009; Steenbergen & Gordon, 2006), relatively little attention has been given to the quality of joint motion of the less-affected UE. The less-affected UE has been reported to move slower (Brown et al., 1989; Mercuri et al., 1999) and less continuously during reaching than the dominant UE of TDC (Heide, Fock, Otten, Stremmelaar, & Hadders-Algra, 2005). Given the deficits in motor planning, the less-affected UE of children with hemiplegia may have different multi-segment coordination than the dominant UE of TDC.

In the present study we investigated motor planning strategies and multi-segment coordination during a functional reach–grasp–eat task. We hypothesized that: (1) both UEs will show different motor planning strategies (i.e., the grasp location on the cookie will not reflect the subsequent requirements to efficiently lift and transport it to the mouth) than the TDC, (2) as a result, the less-affected UE will have different multi-segment coordination (i.e., require different shoulder motion) than the dominant UE of TDC, and (3) due to the impairments of both motor planning and movement control, the more-affected UE will show deficits in multi-segment coordination (i.e., inefficient multi-segment temporal coordination) compared to the less-affected UE and to TDC.

2. Methods

2.1. Participants

Ten children with hemiplegia (4 y, 3 m to 10 y, 1 m, 5 males, 5 females) and ten age-matched, typically developing right-handed children (4 y, 1 m to 10 y, 4 m, 7 males, 3 females) participated in this study (Table 1). Handedness of TDC was defined by the Edinburgh Handedness Inventory (mean absolute L.Q. = 79, Oldfield, 1971). Six of the participants had right-side hemiplegia. UE length was similar in each group ($p > 0.05$). Written informed consent was obtained from all participants and their parents, and the study was approved by the Institutional Review Board.

2.2. Experimental setup

Participants reached forward to a cookie (3 cm × 7 cm, positioned vertically on a 1 cm high stand) with one hand, and brought the cookie to their mouth while seated (Fig. 1A). At the starting position, each child sat 15 cm in front of the table with their elbows flexed at right angles and hands positioned 30 cm apart at the edge of the table. A head rest bar was placed

Table 1
Baseline participant characteristics.

Group	Mean age (SD) y,m	Dom/LA side	UE length (SD), cm		MACS level	Jebsen–Taylor test mean/(SD), s	
			Non dom/MA	Dom/LA		Non dom/MA	Dom/LA
Hemiplegia	7,3 (1.9)	R ($n = 4$) L ($n = 6$)	46.3 (7.5)	47.4 (7.4)	I ($n = 2$) II ($n = 8$)	202.9 (90.3)	43.6 (12.5)
Typically developing	7,4 (2.0)	R ($n = 8$) L ($n = 2$)	48.2 (5.2)	48.3 (6.0)		48.3 (21.4)	40.4 (16.7)

Abbreviations: SD, standard deviation; UE, upper extremity; MA, more-affected UE; LA, less-affected UE; Non dom, non-dominant UE; Dom, dominant UE; R, right; L, left.