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Children with cerebral palsy effectively modulate postural control to perform a supra-postural task

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ABSTRACT

The purpose of this study was to determine whether signatures of adaptive postural control remain present in children with cerebral palsy (CP) when they performed a supra-postural task (i.e., a task performed above and beyond the control of posture) requiring them to balance a marble inside a tube held in the hands. Measures of center of pressure (COP) dynamics (how regular or predictable were the COP data as quantified by the sample entropy metric) and variability (as quantified by the COP standard deviation) were obtained from a sample of children with CP ($n = 30$) and compared to the same measures taken from typically developing (TD) children. Children with CP demonstrated an apparent inefficiency in postural control (greater irregularity, greater sway variability) relative to TD peers during a quiet-stance (no supra-postural task) condition ($p < .05$). During supra-postural task performance, those differences were attenuated, though they remained statistically different ($p < .05$). The findings illustrate flexibility and adaptability in the postural control system, despite the pathological features associated with CP.

1. Introduction

Balance is a primary problem in Cerebral Palsy (CP [1]). Children with CP show a general deficit in postural stability compared to typically developing (TD) children. This results from poorly sequenced and destabilizing synergistic or antagonistic muscle activity [2]. Postural control in children with CP is characterized by increased postural sway compared to TD children during quiet stance and in perturbation studies [2–6]. Children with CP also exhibit distinct temporal patterns of postural sway, reflecting a change in postural sway complexity believed to indicate less effective physiological control [7].

Previously [8], however, we found that when CP and TD children performed a goal-directed, supra-postural task [9–13], postural differences between the groups were strongly attenuated. Supra-postural tasks are behaviors performed concurrently with postural control, like holding a lunch tray, writing on a chalkboard, or conversing with a friend. In the only study to date on the effects of a supra-postural task on postural control in CP, the supra-postural task was to hold a stylus inside a target without touching the target's perimeter (the "temperature-taking" task was framed such that the stylus was described as a thermometer and the targets as open animal mouths). Both children with CP and TD peers modulated postural sway during task performance, and group differences in postural sway variability and irregularity were dramatically reduced when performing the task. In the present study we extended that work by investigating a different supra-postural task and by determining the role of focus of attention in moderating the influence of supra-postural tasks on postural control.

Attention can either be directed toward movements of the body itself (internal focus) or to the effects of body movement on the environment (external focus). Wulf et al. [14] found that when

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participants completed a supra-postural task, performance improved when participants were instructed to focus on the external, environmental effects of their actions. The advantages of adopting an external attentional focus appear robust and have been explained in terms of the constrained action hypothesis, which states that trying to consciously control one's movement (internal attentional focus) interferes with automatic motor control processes that normally work autonomously and efficiently [15].

The influence of directed attention on the interaction between postural control and supra-postural tasks has been studied in clinical populations. Landers and colleagues [16] instructed individuals with Parkinson's disease to put equal amounts of pressure on their feet (internal focus) or on rectangular pieces of contact paper under each foot (external focus) while standing in conditions employed in the Sensory Organization Test [17]. They found a decrease in postural sway in individuals identified as fallers when attention was directed externally under difficult stance conditions. Similarly, Fasoli et al. [18] found better performance in individuals who had sustained a stroke when they performed activities of daily living under instructions that encouraged them to adopt an external attentional focus.

It has also been hypothesized that feedback can be used to generate an external attentional focus and enhance motor relearning. This was examined clinically in children with CP [7]. Although no direct relation between feedback and the amplitude of postural sway was demonstrated, feedback appears to alter the dynamics of postural sway, making it more irregular (i.e., complex), which is believed to reflect a more efficient or effective postural control strategy.

Purposeful activities of daily living are often super-ordinate to postural control and involve an externally directed focus of attention. Accordingly, tasks that manipulate attentional focus during supra-postural task performance may more accurately expose the postural facilities of individuals with motor deficits than quiet stance protocols that do not constrain attentional focus. This is especially given that differences between controls and impaired individuals could indicate, in part, an adaptive change in motor control strategies [19,20] or constraints [12] rather than simply a motor deficit. Patterns of movement used to successfully complete a task may be atypical but may not be ineffective [21]. Adaptive modulation of postural control in response to supra-postural tasks by children with CP would indicate system adaptability that allows the children to respond to the constraints imposed by supra-postural behaviors [12] despite the pathological state [22]. A demonstration of this adaptability, or the lack thereof, would enhance the current understanding of postural deficiency associated with CP.

This study investigated postural stability in children with CP and age-matched TD peers during performance of a supra-postural precision task (balancing a marble in the center of a hollow tube [17]) that included an attentional focus manipulation. We hypothesized that differences in postural behavior between children with CP and TD children would be attenuated during performance of the supra-postural task, paralleling our earlier findings using the target-pointing task [8]. We also hypothesized that an external attentional focus would promote better balance performance for all participants and further attenuate differences between children with CP and TD children.

2. Methods

2.1. Design and participants

Sixty children (n = 30 with CP, age = 8.30 (2.26) years; n = 30 TD children, age = 9.20 (1.98) years) participated. Children with CP were referred for participation from an academic pediatric medical center in the Midwest. TD children were invited to participate through convenience sampling methods. The sample was the same as described in Schmit et al. [8]; within a single measurement session, all children completed requirements for two supra-postural task studies. Children participating in the study were between 5 and 12 years old and able to stand independently for 1 min. No participants had additional medical comorbidities known to impact postural stability. None of the children with CP had undergone surgical intervention within 12 months of the test date or botulinum toxin injections within 3 months of the test date. Table 1 further describes the study sample.

2.2. Procedure

Each participant began the study by completing six 20 s quiet stance trials in which no supra-postural task was performed. These trials were conducted to reveal any baseline differences between TD and CP participants. Children then completed an additional series of trials involving performance of a precision manual supra-postural task (tube-leveling) [14]. Participants held a 45 cm (length) × 5 cm (diameter) translucent, hollow tube at the approximate height of the illiac crests. A marble (3.5 cm diameter) was placed inside the tube and secured by small bells mounted at either end of the tube. If the marble rolled to either boundary of the tube it would strike a bell, providing auditory feedback regarding task performance. The tube was covered with an opaque fabric, and a 15 cm detachable (Velcro) viewing window was constructed in the middle of the tube.

During conditions intended to foster an internal focus of attention, visual information about the marble's location in the covered tube was not available; the viewing window was covered.

Table 1
Characteristics of the sample.

	CP (n)	TD (n)
Total	30	30
Sex		
Female	13	17
Male	17	13
Handedness		
Left	16	4
Right	14	26
Race		
Caucasian	27	30
African American	2	0
Asian	1	
Gross Motor Functional Classification[a]		
I	19	30
II	5	0
III	6	0
Manual Ability Classification[b]		
I	11	30
II	16	0
III	3	0
Distribution of cerebral palsy		
Diplegia	9	N/A
Hemiplegia	19	
Mixed	2	
Orthotic use		
Yes	26	0
No	4	30

CP, cerebral palsy; TD, typically developing.

[a] The Gross Motor Function Classification System (GMFCS) is a 5 level classification system that describes the gross motor function of children and youth with cerebral palsy on the basis of their self-initiated movement with particular emphasis on sitting, walking, and wheeled mobility.

[b] The Manual Ability Classification Scale is a 5 level classification scale for children and youth with cerebral palsy that is based on the children's self-initiated ability to handle objects and their need for assistance or adaptation to perform manual activities in everyday life.