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Whole body organization during a symmetric bimanual pick up task for children with unilateral cerebral palsy

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ABSTRACT

Background: Information on whole-body coordination involving bimanual coordination for children with unilateral spastic cerebral palsy (USCP) is limited.
Research Question: The purpose of the current study is to test the hypothesis that during a whole-body pick up task, children with USCP will organize their whole- body movements and bimanual coordination differently than typically-developing children (TDC).
Methods: Twelve children with USCP (average age: 8.3; MACS levels: I–II) and twelve age-matched TDC participated in the study. Children were asked to reach down, grasp, and pick up an empty box to waist height while Kinematic and Kinetic data were recorded and analyzed using a VICON system and two AMTI force plates.
Results: Children with USCP had longer overall movement time, reaching down time, and grasping movement time (all $P < 0.05$) than TDC. Less bimanual coordination was indicated by greater finger vertical position differences and movement onset and offset timing differences (all $P < 0.05$). Additionally, greater bilateral joint position on differences were found for shoulder, elbow, hip, and knee when reaching down and for shoulder and elbow at the end of the task (all $P < 0.05$). Greater asymmetric bilateral ground reaction force and greater lateral and anterior center of pressure excursion were also found in children with USCP (all $P < 0.05$).
Significance: Impairments in both bimanual and whole-body coordination were found during a simple whole-body task in children with USCP. Future treatments or assessments should consider whole-body tasks involving dual task constraints.

1. Introduction

Children with unilateral spastic cerebral palsy (USCP) have early non-progressive lesions of their brain that result in several motor impairments, predominantly on one side of the body. Most children with USCP are able to stand and walk independently with posture and gait impairments. Asymmetric posture and greater variability with less control in anterior-posterior center of pressure (COP) were found for children with USCP during standing [1–3]. General gait impairments for children with USCP include slower speed, reduced step length, wider step width [4], impaired gait stability [5,6], and asymmetric weight bearing [7]. However, most of the posture and gait analyses for children with USCP were done during simple standing or over ground walking conditions. It is not clear how children with USCP perform under the influence of dual task constraints that require simultaneous upper extremity coordination and posture control.

Children with USCP also have movement deficits in upper extremities, especially the more affected hand [e.g., 8–11], and bimanual coordination problems [e.g., 12–16]. Children with USCP demonstrate their ability to coordinate their bimanual movements by compensating with their less affected hand during simple bimanual tasks [10,17,18]. However, they showed impaired bimanual coordination especially when the task has increased complexity or higher accuracy constraints. Their less affected hand was unable to compensate for the more affected hand during complex tasks [14,17,18]. Nevertheless, all of these upper extremity studies for children with USCP were performed in a sitting position; it is not clear how the whole-body organization and posture control would affect simple bimanual coordination for children with USCP. Greater balance demands during standing than sitting might interfere with bimanual coordination performance for children with USCP.

Most previous studies focused on either upper or lower extremity impairments separately. Hung and Meredith investigated bimanual coordination (carrying objects) during a walking task for children with USCP [19]. They found that children with USCP showed greater gait impairments, poor bimanual coordination, and less upper extremity movement control under dual task conditions. Thus, dual task constraints with a secondary motor task like walking and carrying a box is

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challenging for children with USCP.

Given that both upper and lower extremities are affected in children with USCP, understanding the movement impairments during functional tasks involving both are essential. Many daily activities require performing more than one task at a time (e.g. picking up an object while standing requires postural control and multi-joint movements). Nevertheless, studies focusing on detailed whole-body movement control especially under dual task constraints for children with USCP are limited [19]. Greater dual task interference was found for secondary motor task than cognitive task on posture control for post-stroke individuals [20]. Thus, activities involving motor dual-task constraints (i.e., completing more than one task simultaneously) are particularly challenging and may increase safety risks. A better understanding of children's movement difficulties during whole–body tasks may potentially lead to the creation of targeted interventions to improve motor abilities and decrease safety risks.

In the present study, we investigated how children with USCP maintain their standing posture while organizing whole body movements during a functional task; that being a simple box pick-up task (dual task condition). Specifically, we examined four factors related to whole-body organization: movement time, joint motion, center of mass (COM) control, and COP control during a pick-up task. We hypothesized that when compared to typically-developing children (TDC), children with USCP would: 1) increase their movement time, 2) demonstrate less symmetric joint movement control, and 3) modify their COP and COM control.

2. Methods

2.1. Participants

Twelve children with Unilateral CP (age 6–11 years; MACS levels I—II; GMFCS levels: I—II) and twelve age-matched, typically-developing children (TDC) participated in the study. Descriptive information for each group is shown in Table 1. All the children's BMI were within normal range. Based on our previous experience, this age group was chosen because the complexity of the tasks and the extensive nature of the testing sessions with children with USCP. Children who were not significantly cognitively impaired, were able to follow instructions, and were able to pick up an empty box independently were chosen to participate in this study. Children who had: 1) any health problems which were not associated with CP, 2) seizures, and 3) visual problems that would prevent them from carrying out the testing tasks were excluded from this study. Children with USCP were recruited through online supporting group, United Cerebral Palsy of New York City, Hemi-kids and our previous participants. Informed consent was obtained from all participants and their caregivers, and the study was approved by the University Institutional Review Board.

2.2. Procedure and experimental setup

Children participated in one experimental session in this prospective cohort study. Children stood quietly with their feet separated about shoulder width and then picked up the empty plastic box (length: 45 cm, width: 29 cm, height: 17 cm) one inch in front of their toes to waist height without touching their body at a self-selected pace. Two practice trials were given prior to the five collected trials to familiarize participants with the task. If a trial was not collected successfully (e.g., the box touched the body), the participant was asked to perform the trial again. Each trial began with an auditory go signal and ended when children held the box quietly in front of their stomach for about 5 s. Children were asked to count to 5 slowly.

Kinetics and kinematics were collected during pick up movement. Two AMTI OR6-6 force platforms (each 46 × 50 cm) embedded in the floor under each foot to collect foot ground reaction forces and calculate the location of COP. Three-dimensional kinematic data were collected using the whole-body plug-in-gait model with eight infrared cameras using VICON Nexus 1.51. Forty-one reflective markers were placed bilaterally on the anterior and posterior portions of the head, the shoulders (acromion process), the elbows (lateral epicondyle), the wrists (radio and ulnar styloid processes), the hands (index metacarpophalangeal joint), the upper arms, the forearms, the anterior and posterior superior iliac spines, the lateral thighs, the knee joints (lateral epicondyle), the tibias, the ankle joints (lateral malleolus), the heels, and the toes (second metatarsal head). Markers were also placed between the clavicles, on the sternum, on C7, on T10, and on the right scapula. All markers were digitized at a rate of 120 Hz and were processed with a low pass digital filter with a cutoff frequency of 6 Hz. Kinetic data from both force plates were processed and synchronized with the kinematic data at a rate of 1200 Hz with VICON Nexus 1.51.

Table 1
Baseline Participant Characteristics.

Characteristics	USCP (n = 12)	TDC (n = 12)
Mean Age (*SD*) y,m	8,3 (1,9)	8,6 (2,7)
Average Height (*SD*) m	1.35 (0.12)	1.38 (0.18)
Average Weight (*SD*) kg	35.7 (11.8)	33.8 (12.9)
Average Leg Length (SD) m		
Dominant	0.66 (0.10)	0.70 (0.14)
Non-dominant	0.65 (0.09)	0.70 (0.14)
Gender		
Male	7	6
Female	5	6
Dominant Hand		
Right	4	12
Left	8	
Brain Lesion Location (type)		
Right	4 (1[a];2[b];1[c])	
Left	8 (0[a];4[b];4[c])	
MACS		
I	3	
II	9	
GMFCS		
I	7	
II	5	

Abbreviations: SD = Standard deviation; USCP = children with unilateral spastic cerebral palsy; TDC = Typically developing children; MACS = Manual Ability Classification System for individuals with CP. GMFCS = Gross Motor Function Classification System for individuals with CP.

[a] Brain malformation.

[b] Abnormalities of periventricular white matter.

[c] Cortical/subcortical lesions.

2.3. Analyses

For kinematic analyses, the onset of the total movement was defined when either hand's velocity reached above threshold (5% of the maximum velocity) and the offset of the total movement was when both hands' velocity decreased below the threshold. The whole movement was further divided into three parts: reaching down, grasping, and picking up. Reaching down started with the onset of the trial (either hand's velocity reached above threshold) and ended with the offset of reaching (both hand velocity decreased below threshold). After reaching down, picking up started when either hand's velocity increased again to be above the threshold and ended after both hand's velocity decreased below the threshold. The time period between reaching down and picking up was the grasping time. Temporal variables from kinematic analyses were total movement time, reaching down time, grasping time, and picking up time. The values were then averaged and compared between groups. For whole body movement, we measured knee, hip, elbow, shoulder joint and spine excursion on