Postural Adjustments under Two Different Verbal Instructions in Children with Cerebral Palsy and Children with Typical Development

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Background and Purposes: Children with cerebral palsy (CP) frequently experience problems in maintaining effective standing balance during their daily activities. Although previous studies showed that postural adjustments could be modified by different task commands in healthy adults, limited study had examined changes of postural adjustments in children with CP under different verbal instructions. Therefore, it was unknown whether postural adjustments of children with CP were modified based upon the requirements of the tasks. The purposes of this study were (1) to explore the difference of postural adjustments in children with CP between two different task commands, and (2) to explore the regulatory difference of postural adjustments between children with CP and children with typical development (TD). **Methods:** A sample of convenience with 56 ambulatory children, 28 children with CP and 28 children with TD, participated in this study. The subjects were repeatedly tested in sets of fifteen trials at two different reach speeds: reach at a comfortable speed and reach as fast as possible, sequentially in a block fashion. Postural adjustments were qualified by center of pressure (COP) measurements. **Results:** The findings indicated that children with CP, as well as their peers with TD, were able to modulate to their anterior-posterior (A-P) and medial-lateral (M-L) COP excursions based upon different commands. Children with CP exhibited slower and less straight A-P excursion than the children with TD. **Conclusion:** These findings suggest that children with CP were able to modulate their postural adjustments based upon the different task requirements. However, they had difficulty in producing a quick and straight COP excursion during the functional reach tasks. (FJPT 2002;27(6):283-291)

Key Words: Postural adjustment, Cerebral palsy, Center of pressure

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Previous studies showed that children with cerebral palsy (CP) frequently experience problems in maintaining effective balance during their daily activities.[1] In order to plan appropriate therapeutic interventions, it is important for physical therapists to understand the specific differences in controlling postural stability that children with CP have in comparison to children with typical development (TD).

In clinical practice, verbal instructions were frequently provided to children with CP by pediatric physical therapists in order to modify their movements or postures. Previous studies showed that healthy adults are capable to modify their postural adjustments based upon different task commands. For example, Burleigh et al. (1994) showed that healthy adults were able to modify their postural adjustments, included anticipatory postural adjustments (APA) and automatic postural responses, by changes in body position and in the intended movement goals.[2] Their findings indicated the importance of subjects' own intentions, which could be changed by the external verbal cues, to their postural adjustments. In spite of an increasing amount of studies related to postural adjustments in children with CP,[1,3-10] limited research had examined their ability to regulate postural adjustments under different verbal instructions.

It has been well known that children with CP tend to demonstrate slower postural adjustments than their peers with typical development (TD).[1] In order to encourage them to move quicker, verbal cues were one of the common strategies frequently used in clinical settings by pediatric physical therapists. Without knowing whether children with CP were capable to modify their postural adjustments according to verbal cues, the worthiness of using verbal cues would be unknown. In the present study, children were asked to perform functional forward reaching in a self-paced condition at two different speeds - reaching at a comfortable speed (i.e. the preferred reaching speed used during daily activity) and reaching as fast as possible. If the children are able to modulate their postural adjustments under verbal instructions (self-intention), the quicker the reach movement is, the stronger postural adjustments will be observed. This study focused on two questions. First, can children with CP regulate their postural adjustments based upon the intended different speed of reaching? Second, are there differences between children with CP and children with TD in the control of postural adjustments during the forward reach tasks?

METHOD

Subjects

All children were from the northern portion of Taiwan, including the Taipei metropolitan area. They were recruited to participated in an original study which was intended to compare the APAs between children with CP and children with TD.[11] A sample of convenience of 65 children, 28 children with CP and 37 children with TD were included in the original study. For the specific purposes of this study, only 56 children, 28 with CP and 28 with TD were chosen for the present analyses. Children with CP were recruited from the pediatric physical therapy section of the Department of Rehabilitation Medicine, Chung Gang Children's Hospital, Lin-Kao in Taiwan. The children with TD were recruited among acquaintances of the investigators for comparison purposes. Each of these children was recruited to match for age within 11 months and gender with a child with CP. Table 1. showed general characteristics of all children. The etiological factors in children with CP included 71% of prenatal or perinatal factors and 14% of postnatal factor. Twenty-nine percent of those children received selective posterior rhizotomy and 7% of them received orthopedical surgery such as Achilles tendon lengthening. The classification of motor function included 39% of GMFCS level I and 61% of level II.

The inclusion criteria of children participating in this study were: (1) Children able to maintain a standing position independently for at least 30 seconds without using any assistive device or external support; (2) Children's age ranges from 4 to 12 years old; (3) Children able to cognitively understand and follow verbal instruction, such as "reach at a comfortable speed", or "reach as fast as possible" in Mandarin dialect; (4) Children did not receive any surgical procedures and within the previous 3 months.

The original study was approved by the Institutional

Review Board (IRB) of MCP Hahnemann University in USA and the IRB of Chang Gung Memorial Hospital in Taiwan. Children participated in the study after they provided informed assent and their parents gave informed consent.

Instrumentation

Kinetic measurements - Center of pressure.

AMTI force plates (Advanced Mechanical Technology Inc., Watertown, MA) were used to measure force and velocity during the forward reaching tasks. The signals from force plate were sampled at 1,920 Hz. The force plates provided information on anterior-posterior (A-P), medial-lateral (M-L), and vertical forces along with moments in the A-P, M-L and vertical axis. A customized Lab View program was used to analyze the kinetic data and calculate the center of pressure (COP). Based upon Zaino's work,[10] the raw data were band pass filtered at 10-1,000 Hz and then a second order low-pass Butterworth filter set at 16 Hz was used prior to the COP calculations and further analysis of the kinetic data. The test-retest reliabilities were established prior to the beginning of the study. (intraclass correlation coefficient = .89~ .96)

Testing procedures

There were two experimental protocols to be conducted. Protocol I was conducted using a verbal instruction of "reaching to a stationary ball at a comfortable speed", and protocol II was done with another verbal instruction "reaching to a stationary ball as fast as possible". Under the specific verbal instruction, each child regulated the reach velocities following instruction either with "reaching to a stationary ball at a comfortable speed" or "reaching to a stationary ball as fast as possible". All the instructions were in the Mandarin dialect. These protocols were sequentially tested in fifteen trials per protocol in a block fashion.

For each trial of both protocols, the child was asked to reach to a ball in a pre-determined comfortable maximum reach distance for each child without moving his feet from the outlined foot position or losing his balance. The ball to be reached was placed in front of the participants at the height of their acromion. If the child moved his feet during the test, he was required to repeat a trial. However, some younger children from both groups were not asked to repeat those trials, especially for protocols II, as long as they activated the switch properly on that specific trial due to concerns about the child's endurance, frustration level, and attention span in participation. The interval between the trials within a set was approximately 5 seconds. There was a 5-minute rest period between each experimental protocol during which the child sat. However, for the children with CP, the additional resting period was provided if the child indicated he felt tired or needed a short break.

Each child started with putting his/her dominant hand on the reach start switch attached on his ipsilateral thigh of the dominant hand, and looked straight ahead to the ball. After the child assumed the experimental position, the child had been instructed to stand still and press down on the start switch when he heard the "Ready" signal. Upon hearing a "Go" signal by a buzzer the child was instructed to reach to the ball and then bring the ball back to contact with the start switch which meant inactivation of the start switch. The interval between the "Ready" and "Go" signals was randomly varied between 3 and 5 seconds. In addition, one random trial without "Go" signal was added into each protocol. The randomized auditory cues and an additional trial without the "Go" signal both were used to eliminate the anticipation of the interval length between the "Ready" and "Go" signals.

Data reduction and analysis

Of the 15 trials for each protocol, only the last five trial were used for data analysis which would met criteria that as followings: (1) the child activated the switch properly; (2) the child was concentrated on the specific trial; and (3) the child kept his/her feet within the outlined foot position without an external support during the test.

The time point of "0" in this study was defined as the release time of the start switch (the initiation of reach movement). The movement time (MT) was defined as the time from the activation of the thigh release switch to the inactivation of the thigh release switch.

The COP was calculated according to the following equations:

$$COPx \cong My/Fz \quad (1)$$

$$COPy \cong Mx/Fz \quad (2)$$

Based upon the present experimental set-up, COPx denotes the M-L COP, COPy denotes the A-P COP, Fx denotes the M-L force, Fy denotes the A-P force, Fz denotes the force in the vertical direction, Mx denotes the moment along the M-L axis, and My denotes the moment along the A-P axis.

The dependent variables for the COPx and COPy measurements included three quantitative parameters (pathlength, amplitude, maximum of velocity (VMax of COPy) and mean of velocity (VMean of COPy) during the APA period). Pathlength represented the summation of all COPy excursion segments, while amplitude represented the absolute COPy excursion distance.[10,11]

Statistical analyses

Descriptive statistics were used to report summary information for the COP excursions. The two-way repeated measure analysis of variance (ANOVA) (2×2) was used to examine the differences and interactions between the groups (CP vs. TD) and between the experimental protocols (protocol I vs. II). In the study, all the statistical analyses were based on a significant level (alpha) of 0.05.

In order to explore the possibility of attribute variables that could interfere with the APA activities in children with CP, the children with CP were divided into subgroups based upon their ages, primary CP diagnosis, Gross Motor Function Classification System (GMFCS) level, and walking experience by selecting 4 years of age because gait pattern is considered to be as that of adults.[12] Independent samples t tests were used to explore the possible differences in the COPy measures.

RESULTS

Movement time (MT)

The MT were shorter for the "reaching as fast as possible" protocol in both groups ($p < 0.01$). The MT were significantly shorter for children with TD than children with CP ($p < 0.001$). There was no interaction between protocol and group ($p = 0.56$). These findings suggested that children in both groups reached quicker with the "reaching as fast as possible" protocol than with the "reaching at comfortable speed" protocol. Furthermore, children with TD reached quicker than children with CP.

COPx excursions

The COPx measures showed statistically significant differences in amplitude and V_{Max} between the two protocols ($p < 0.001$ and $p < 0.005$) (Table 2.). Except V_{Max} ($p < 0.05$), there were no significant differences between groups for COPx measurements ($p = 0.11$, $p = 0.37$ and $p = 0.84$, for V_{Mean}, pathlength, and amplitude, respectively). That is, children in both groups were able to produce quicker COPx excursions momentarily with intended increased reach speed. However, there were no difference in the V_{Mean} of COPx excursions between the protocols, as well as the groups. That is, momentarily quick COPx excursion was not accompanied with overall quicker COPx excursion. In addition, with intended and decreased reach MT (quicker reach movement), children in both groups produced shorter COPx pathlength. With increased reach speed, children in both groups produced straighter COPx excursion. Furthermore, children with CP showed significantly longer pathlength of COPx than children with TD. Since there was no difference in COPx amplitude between the groups ($p = 0.84$), it suggested that children with CP demonstrated less straight COPx excursion than children with TD during the reach forward tasks. In addition, compared to COPy excursion, children in both groups produced relatively small and slow excursion, especially in children with TD.

COPy excursions

Children produced quicker and longer COPy excursions in the "reach as fast as possible" protocol ($p < 0.05$, $p < 0.001$, and $p < 0.05$ for V_{Mean}, V_{Max}, pathlength, and amplitude respectively) (Table 2.). Children with CP showed significantly slower and smaller COPy excursions than children with TD ($p < 0.001$, $p < 0.001$, $p < 0.001$, and $p < 0.05$ for V_{Mean}, V_{Max}, pathlength and amplitude respectively). There was also a significant interaction effect for the V_{Mean}

Table 1. General characteristics for all children with typical development (TD) and children with cerebral palsy (CP)

	TD (N=28) (Boy=18;Girl=10) Mean			CP (N=28) (Boy=18;Girl=10) Mean		
Age(year)	6.6	±	1.6	6.8	±	1.4
Weight(kg)	24.1	±	6.6	22.1	±	4.9
Height(cm)	117.8	±	11.8	112.7	±	9.4
Arm Length(cm)	36.1	±	4.5	35.1	±	4.0
Start to walk age(yr)	1.1	±	0.2	2.8	±	1.1
Approximate Walking Experience(yr)	6.3	±	2.3	4.0	±	2.1

Table 2. Comparisons of Movement time (MT) and center of pressure (COP) excursions measures for children with TD and children with CP between protocol I (reach at the comfortable speed) and protocol II (reach as fast as possible)

	TD (N=28)						CP (N=28)					
	Protocol I			Protocol II			Protocol I			Protocol II		
	Mean	±	SD	Mean	±	SD	Mean	±	SD	Mean	±	SD
MT (S)	2.3	±	0.9	1.6	±	0.7	2.8	±	0.9	2.0	±	0.5
V_{Mean} of COPx(M-L) (mm/s)	1.5	±	6.4	6.1	±	14.4	-0.6	±	5.3	1.3	±	12.0
V_{Mean} of COPy(A-P) (mm/s)	14.8	±	16.4	29.3	±	36.8	2.6	±	6.9	4.1	±	11.5
V_{Max} of COPx(M-L) (mm/s)	300.9	±	136.4	403.3	±	188.5	227.7	±	119.0	300.1	±	165.2
V_{Max} of COPy(A-P) (mm/s)	526.4	±	165.5	670.9	±	210.8	251.3	±	138.8	344.4	±	200.2
Pathlength of COPx (M-L) (mm)	176.9	±	66.4	174.9	±	59.7	198.9	±	83.1	187.1	±	83.3
Pathlength of COPy (A-P) (mm)	286.2	±	54.2	270.3	±	54.7	208.0	±	73.7	198.2	±	69.8
Amplitude of COPx (M-L) (mm)	53.1	±	16.6	62.4	±	27.5	55.5	±	20.2	57.9	±	21.2
Amplitude of COPy (A-P) (mm)	118.7	±	19.7	125.4	±	22.6	76.0	±	32.1	79.2	±	32.8

of COPy ($p < 0.05$).

Possible influencing attribute variables

The duration of walking experience appeared to be an important influencing factor on postural control in standing. There were significant differences in COPy excursion measures in protocol II, including pathlength, V_{Max}, and amplitude, between children who had walked independently more than 4 years and those who had walked less than 4 years (Table 3.). There were significant differences in COPy excursion measures, including pathlength and V_{Max} in protocol II, between children who had a diagnosis with spastic diplegia and those who had spastic hemiplegia ($p < 0.05$ and $p < 0.005$ for pathlength and V_{Max} of COPy excursions). In addition, a significant difference between the children in the GMFCS levels I and II was noted in VMean of COPy for protocol I. No significant differences in other variables were noted between the children among the above attribute variables, including walking experiences, the GMFCS level, and physician's diagnosis.

DISCUSSION

The present study demonstrated that children with CP were able to modulate reach speeds under the verbal instructions, as their peers with TD. With decreasing MT, COP excursions in both groups, especially COPy, tended to

Table 3. Comparisons of some COPy excursion measures for different subgroups according to attribute variables

Dependent Variables		Attribute Variables	N	Mean	±	SD	t-test		
							t	df	*p**
		Walking Experience							
Protocol II	COPy Pathlength	< 4 Years	15	165.3	±	57.4	-3.1	26	<0.005
	(mm)	> 4 Years	13	236.2	±	64.8			
Protocol II	COPy VMax	< 4 Years	15	254.6	±	183.3	-2.9	26	<0.01
	(mm/s)	> 4 Years	13	447.9	±	171.2			
Protocol I	COPy Amplitude	< 4 Years	15	60.2	±	29.5	-3.3	26	<0.005
	(mm)	> 4 Years	13	94.2	±	25.1			
Protocol II	COPy Amplitude	< 4 Years	15	60.4	±	28.2	-4.1	26	<0.001
	(mm)	> 4 Years	13	100.8	±	23.4			
		Motor Function							
Protocol I	COPy VMean	GMFCS I	11	6.4	±	6.4	2.6	26	<0.05
	(mm/s)	GMFCS II	17	0.1	±	6.1			
		Physician Diagnosis							
Protocol II	COPy Pathlength	Spastic Hemiplegia	7	223.6	±	47.0	2.2	23	<0.05
	(mm)	Spastic Diplegia	18	170.1	±	56.4			
Protocol II	COPy VMax	Spastic Hemiplegia	7	467.4	±	213.3	3.3	23	<0.005
	(mm/s)	Spastic Diplegia	18	246.2	±	119.6			

*2-tailed

be quicker and larger. Therefore, in order to facilitate quicker and larger postural adjustments in children with CP who were able to walk independently, verbal instructions could be an effective strategy. However, since the subjects' inclusion criteria were considerably limited to certain characteristics in the present study, our findings should not be applied to children who were unable to walk or unable to understand verbal instructions. Thorpe and Valvano showed that some children with CP appeared to benefit from the use of cognitive strategies to enhance their motor learning during practice of novel motor skills, while some children with CP were not.[13] Therefore, future studies might need to further identify whom would be most beneficial from verbal instructions, as well as their effective and specific cognitive strategies.

Several interesting findings concerning the control of reach movement and postural adjustments were noted in the present study. Firstly, slow reach movement in children with CP can be a combined result of inadequate control of postural adjustments and upper extremities. When children with CP were asked to reach as fast as possible, they were capable to produce quicker reach movements. It suggested that children with CP were able to understand the verbal instructions, plan different reach speeds under different verbal instructions, and further produce reach movements with different speeds. However, their reach speeds were significantly slower than children with TD. Unexpectedly, children with CP produced similar reach speeds in the "reach as fast as possible" protocol to children with TD in the "reach at the comfortable speed" protocol. It was uncertain why children with CP did not produce a quicker reach speed at their comfortable speed, even though they were capable to achieve quicker reach speed when they were asked to reach as fast as possible. However, it was possible that children with CP might decrease their reach speeds in order to assume a more stable postural stability.

Secondly, the quicker reach movement the child produced, the larger postural perturbations would be expected. The larger postural perturbations the child had experienced, the larger postural adjustments would be needed in order to compensate or counteract larger postural perturbations. Therefore, it could be hypothesized that significantly slower COPy excursion was a result of slow reach movement. Unfortunately, this hypothesis was not supported by the comparisons of COPy excursions between two groups at the comparable reach speed. MTs of the whole reach in protocol II for children with CP and in protocol I for children with TD were very similar in the present study, but children with CP showed slower and smaller COPy excursions in protocol II than children with TD in protocol I. Therefore, the slow reach movement was not the only reason for the inabilities to produce quicker and larger COPy excursions in children with CP. This finding suggested that even though at the comparable reach speed with children with TD, children with CP still produced slower and shorter COPy excursions. Consequently, in order to improve postural control in children with CP, therapeutic intervention might need to focus on improving quicker and straighter COPy excursions.

Thirdly, compared to the COPy excursions, children in both groups demonstrated relatively slower and shorter COPx excursions. It suggested that during reach forward tasks children primarily moved COP in the A-P direction. Since the movement direction of the forward reach task was somewhat restricted in the A-P direction, it was possible that children in both groups did not have to move COPx excursion a lot due to the nature of the forward reach task. Therefore, it was unable to determine whether children with CP had difficulty in moving their COP excursions in the M-L direction. In addition, this study showed that several factors, such as the experience of walking, the functional abilities, and diagnosis, might be related to the performance of postural adjustments in children with CP. Those findings suggested that children with CP who demonstrated better and more meaningful functional abilities tended to have better postural adjustments. Those results were somewhat similar to Liao et al.[3] They showed that dynamic balance significantly correlated with walking function in children with CP. However, without further investigation, the exact cause-effect relationships between the functional abilities and the postural control were unable to be determined.

In summary, the findings of this study suggested that children with CP were able to modulate their postural adjustments according to the requirements of the intended tasks. However, they demonstrated deficits in producing longer and quicker A-P COP excursions, as well as straighter M-L COP excursions during the forward reach tasks. The reasons for those deficits needed to be further examined.

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在兩種不同語言指令下腦性麻痺兒童和正常兒童的姿勢調整

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背景與目的：過去的研究顯示，正常人可以因不同語言指令而調整顯現出不同的姿勢調整，但對於腦性麻痺兒童在不同語言指令下的姿勢調整的研究則很缺乏。所以，對於腦性麻痺兒童是否能在兩種不同要求下做不同的姿勢調整則仍屬未知。因此，本研究的目的為：(一)探討在兩種不同語言指令下腦性麻痺兒童的姿勢調整，(二)探討腦性麻痺兒童和正常兒童在姿勢調整的調節能力的不同。**方法**：藉由就近取樣的方式徵召了56名有行走能力的兒童(名腦性麻痺兒童和名正常兒童)。所有的測試者被按順序重複在兩種不同的速度下(在最舒服的速度下和越快越好)，各測了十五次功能性伸手向前。姿勢調整是用壓力中心(Center of Pressure)來量化。**結果**：腦性麻痺兒童和正常兒童一樣可以根據不同的要求速度而產生不同的速度伸手向前及不同的前後及左右的壓力中心線移動。相對於正常兒童，腦性麻痺兒童的前後的壓力中心線移動明顯的較慢且不直。**結論**：腦性麻痺兒童能夠依外在的要求而自己調節他們的姿勢調整，但是在功能性伸手向前時，他們仍難以快速且筆直的移動他們的壓力中心線，特別在前後的方向。(物理治療2002；27(6)：283-291)

關鍵詞：姿勢調整、腦性麻痺、壓力中心線

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