Original Article

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Decreased Head Sway in Children with Cerebral Palsy on Custom-Made Powered Mobile Stander

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Objective: An innovated custom-made powered mobile stander has been developed for children with cerebral palsy (CP). To verify the safety of this appliance, the purpose of this report is to investigate the degree of head shaking on using this device.

Patients and Methods: This study included 10 subjects, namely, 5 children (M/F = 2/3, Mean age 7.42 ± 1.5) with bilateral spastic diplegia cerebral palsy and 5 children (M/F = 2/3, Mean age 4.34 ± 1.2) with typical development. Custom-made powered mobile stander and accelerometer were used to measure the degree of head sway in three conditions.

Results: The results showed that the maximal rate of head sway was 15.02 m/s^2. The maximal rate j-PMS in children with cerebral palsy was 10.60 ± 3.6 m/s^2. There were no significant differences in their acceleration of head movement under the coniditions of passive-PMS, j-PMS and s-PMS (p = 0.786, p = 0.189, and p = 0.132) in children with CP.

Conclusion: There was no risk of head or neck injury for children with cerebral palsy associated with the use of powered mobile stander. There is little difference in head shaking among children with cerebral palsy in three conditions.

Key words: powered mobile stander, cerebral palsy, shake syndrome

Introduction

According to the international definition and classification, cerebral palsy is defined as a group movement and postural development disorders resulting in restricted activity, which is attributed to non-progressive brain injuries during fetal or infant development. In addition to motor impairment, cerebral palsy is usually combined with other issues, such as epilepsy or sensory, cognition, perception or behavioral issues.[1] Defective postural control is a significant motor impairment in children with cerebral palsy, and head control ability plays an incredibly important role in daily activities. Since the vision and vestibular systems are located in the head and determine a person's orientation and balance ability, good head control can reduce the

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degree of head shaking during dynamic walking activities.[2]

For children with cerebral palsy who are unable to walk independently, electric lifting devices are assisting devices that enhance their chances of independent movement or participating in daily activities.[3] Previous studies have shown that using a non-electric lifting support standing device or the implementation of a standing plan may improve the neuromusculoskeletal and movement-related function and movements of children with motor impairment. Neuromusculoskeletal and movement-related functions have been shown in previous studies to potentially increase weight-bearing, improve range of motion, reduce the occurrence of contractures, reduce the chance of subluxation, and increase bone density.[4-7] However, there have not been a number of studies that explore the use of electric lifting standing support devices for children with cerebral palsy.[7]

Additionally, children with cerebral palsy have difficulty in autonomous control of swing direction. To explore whether the postural control provided by segmental trunk training led to improvements in children with cerebral palsy,[8] 28 children with cerebral palsy received segmental training in the study of Curtis et al.[9] That study found improvements in head and body shaking conditions after segmental training. However, the improvement was limited after one year of tracking,[9] highlighting the importance of continuous training.

A new custom-made powered mobile stander (PMS) was used in this study. The control panel of the PMS had bilateral joysticks, and bilateral switches (Fig. 1). (1) The bilateral joysticks on the control panel were modified from two commercially-available game car joysticks. (2) The bilateral switches were two ultra-low and thin big round switches with a pressing area of 12.5 cm^2 (Smoothie 125; Pretorian Technologies, Gainsborough, UK) set on the control panel. The two controllers on the control panel had the same control interface. They both used the 3.5 mm audio cable connector to plug into the direction control box. The directions represented the front left, back left, front right, and back right direction of the rotation of the wheels. When the subject controls a the front left and front right respectively with both hands, the PMS would go straight forward. If one hand is released from the joystick or switch, the PMS would immediately shift toward the released side. The standing frame could provide support for the pelvis, knee joints and ankle joints. The electronic control devices were the motor (BLH450K-15; Oriental Motor, Taipei, Taiwan) and battery (SSE-013; Create Battery, China). In terms of safety, the maximum moving speed was 0.12 m/s, and an emergency stop line was set. Previous studies have shown that if the acceleration of the heads of children exceeds the threshold of 95.73 m/s^2 when driving an electric toy car, it may lead to the risk of head injury[10] and result in shaken baby syndrome. Therefore, this study recorded the acceleration of the heads of all children when driving a PMS.

The primary purpose was to describe the degree of head shaking in children with cerebral palsy when using the PMS.

Materials and Methods

Research subjects

Data from a total of 13 children were collected in this study. After exclusion of three children with incorrect video recordings ten subjects were recruited for the present study including five children with bilateral spastic cerebral palsy and five children showing typical development. The average age of the typical development group was 4.34 ± 1.2 years and that of the cerebral palsy group was 7.42 ± 1.5 years. The basic information for the age (p = 0.009), height (p = 0.16), and weight (p = 0.26) of the two groups are shown in Table 1. This study enrolled volunteers for the test by adopting a convenience sampling method. The subjects were divided into the cerebral palsy group (CP group) and typical development group (TD group). The inclusion criteria for the CP group were: (1) children diagnosed with bilateral spastic cerebral palsy based on physician's decision, (2) aged between 2 to 12 years, (3) level I to IV in the Gross Motor Function Classification System (GMFCS),[11] (4) level I to II in the Manual Ability Classification System (MACS),[12] (5) level I to II in the Bimanual Fine Motor Function (BFMF) classification,[13] (6) level I to III in the Communication Function Classification System (CFCS),[14] (7) level I to V in the Eating and Drinking Ability Classification System (EDACS),[15] (8) level N to 6 in the Functional Mobility Scale (FMS),[16] and with (9) normal or corrected visual or auditory function. The exclusion criteria were: (1) subjects with uncontrolled epilepsy, or (2) if the supportive stance could not be maintained for more than 30 minutes even with the body support and fixed position. The criteria for the TD group were: (1) aged between 2 to 12 years, (2) normal or corrected visual or auditory function, and (3) no neuromusculoskeletal disease. The test procedures in this study were reviewed and approved by the Human Test Ethics Committee of Chang Gung Memorial Hospital (Case No. 201601324A3C502).

Research process and tools

The test items and the instructions for the participants were first explained to the children and their parents. After the explanation, an consent form signed by the subject or the guardian was obtained. The trunk control level of the child with cerebral palsy was evaluated. The Modified Segmental Assessment of Trunk Control (SATCo) was used for the CP group. The SATCo mainly assesses the level of trunk control of children with cerebral palsy, including measurements in sitting and standing positions. The child was placed in a sitting posture for the sitting measurements. The angle between the hip joint and the knee joint was 90 degrees, and the pelvis was fixed in a median posture with a Y-shaped fixation band. The fixation method involved the use of Y-shaped fixation straps, including two thigh straps and one pelvic belt, and two fixation rings, to fix the subjects on the bench. First, the subject sat on a bench with the thigh straps under them, and the two thigh straps were pulled upwards between the thighs to pass through the fixing ring on the back before being pulled back and fixed to the thighs. Next, the pelvic belt was pulled upward from

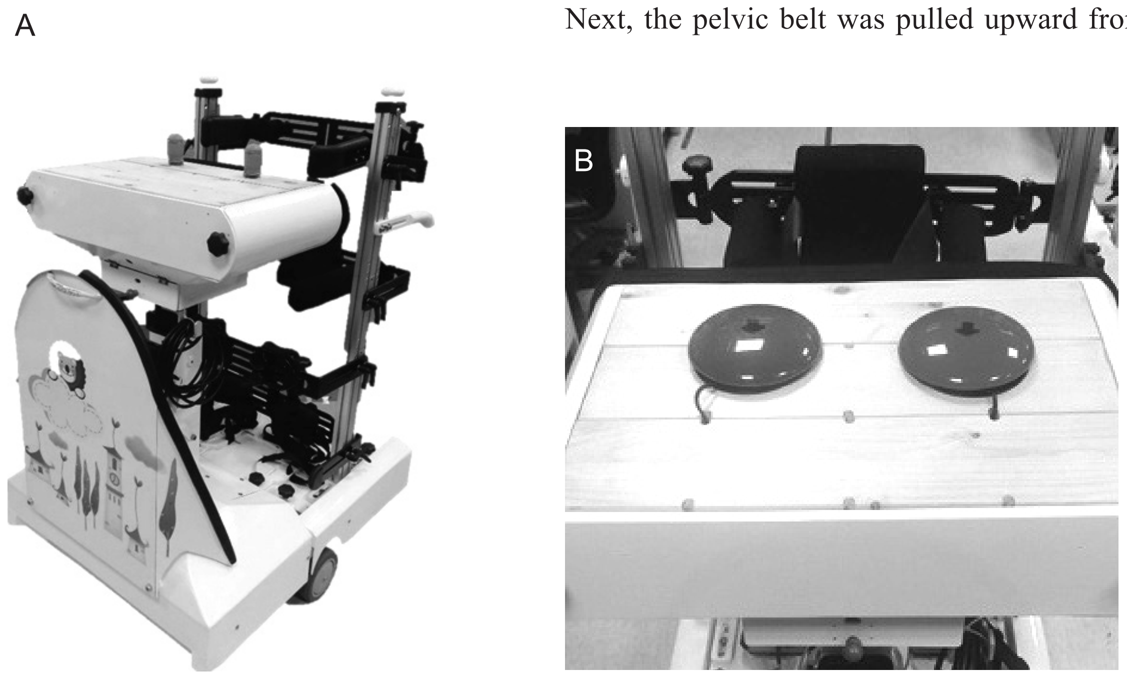

Fig. 1 The control panel of powered mobile stander (PMS). (A) bilateral joysticks, (B) bilateral switches.

Table 1. The differences in basic information of subjects

	Subject	Age (years)	Height (cm)	Weight (kg)	SATCo	GMFCS	MACS	BFMF	CFCS	EDACS	FMS 5 m	FMS 50 m	FMS 500 m
Cerebral palsy group (2 Male; 3 Female)	1	6.5	106	16	6	IV	II	II	I	I	2	2	N
	2	7.3	120	23	8	II	I	I	I	I	6	4	4
	3	5.6	107	16	8	I	I	I	II	I	6	5	5
	4	7.9	120	19	8	II	II	II	III	I	5	5	N
	5	9.8	120	20	7	II	I	I	I	I	5	5	5
Mean		7.42 ± 1.5	114 ± 7.4	18.8 ± 2.9									
Typical development group (2 Male; 3 Female)	1	4.6	110	19									
	2	3.2	105	17									
	3	3.6	100	15									
	4	4	100	15	NA	NA	NA	NA	NA	NA	NA	NA	NA
	5	6.3	120	18.8									
Mean		4.34 ± 1.2	107 ± 8.3	16.9 ± 1.9									
p		0.009	0.16	0.26									

SATCo: the Modified Segmental Assessment of Trunk Control, GMFCS: Gross Motor Function Classification System, MACS: Manual Ability Classification System, BFMF: Bimanual Fine Motor Function, CFCS: Communication Function Classification System, EDACS: Eating and Drinking Ability Classification System, FMS: Functional Mobility Scale the front of the subject to go around the back of the pelvis, and then fixed to the front of the bench.[17] In the standing test, the child was in a standing posture with both lower limbs shoulder-width apart. The nine levels of scoring items, in descending order, were head control, upper thoracic control, mid thoracic control, lower thoracic control, upper lumbar control, lower lumbar control, hip control, knee control, and ankle control. The measurement method was from top to bottom and was divided into static and dynamic states. The supporting positions were shoulder girdle, axillae, inferior scapula, ribs, pelvis, femur greater trochanter, knee joint, and ankle joint. In the static state, the children were asked to look forward and keep the trunk in midline for 5 seconds. In the dynamic state, the children were asked to look forward and raise their hands. If the trunk remained in the midline, the assessment proceeded to the next level, continuing until trunk shaking appeared. The results were used to set the height and support points required for the PMS. The TD group did not receive any support.

Before each data collection session, the force gauge was corrected and reset to zero. Four cameras (HDR-CX450, SONY; Shenzhen, China) and an accelerometer (CA-DR-1001; Global Sensor Technology, Manchester, UK) were set up to record the performance of the subjects driving the PMS throughout the test. The length of the straight test path for each round was 300 cm. An accelerometer was set up in the helmet to record the head safety measurements. The data was read through the strain measurement system (EL-210 Elogger system; ShenZhen Cybroad Technology Co., Ltd, Shenzhen, China). The unit of head acceleration was m/s^2. Another accelerometer was placed on the PMS to record the acceleration of the PMS to confirm whether the acceleration of the PMS resulted in a risk of head injury. The measurements assessed three situations: passive propulsion of the PMS by the examiner (passive-PMS), the PMS driven forward by bilateral joystick (j-PMS), and PMS driven forward by bilateral switches (s-PMS).

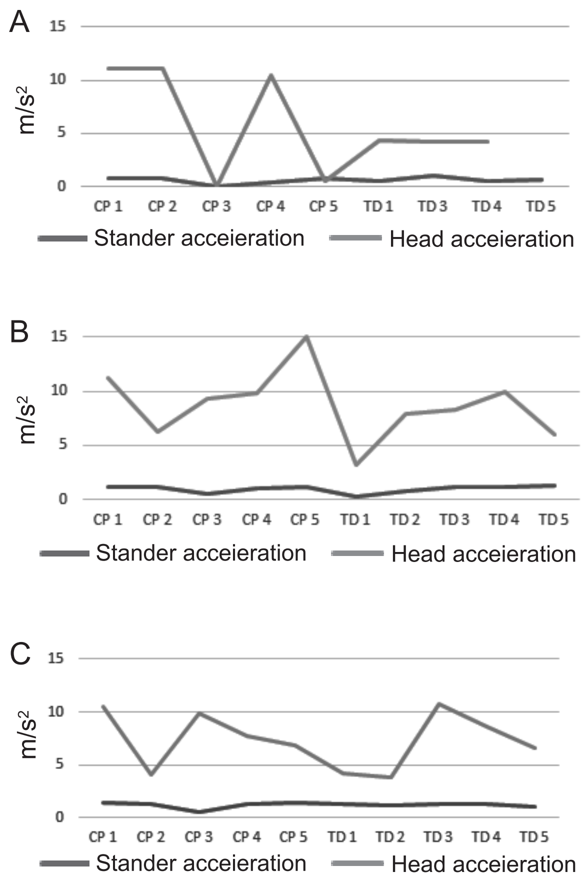

Fig. 2 The head acceleration of the cerebral palsy (CP) and typical development (TD) groups when using the powered mobile stander (PMS).(A) Passive propulsion of the PMS by the examiner, passive-PMS, (B) The PMS driven forward by bilateral joystick, j-PMS, (C) The PMS driven forward by bilateral switches, s-PMS.

Statistics

This study evaluated weight-bearing ability through the head shaking of children with cerebral palsy when using the PMS. The statistical analysis software SPSS 21.0 (SPSS for Windows, version 21.0) was used for data analysis. The descriptive analysis presented the basic information and weight-bearing capacity test of subjects using descriptive statistics (mean ± standard deviation). Paired t-tests were used to compare the acceleration of the

Table 2. The head acceleration of subjects when using the powered mobile stander (PMS)

	Subject	passive-PMS (m/s^2)	j-PMS (m/s^2)	s-PMS (m/s^2)	passive-PMS vs. j-PMS	passive-PMS vs. s-PMS	j-PMS vs. s-PMS
Cerebral palsy group	1	11.09	11.20	10.55			
	2	11.09	6.31	4.02			
	3	NT	9.33	9.85			
	4	7.31	9.86	7.43			
	5	10.52	15.02	6.84			
mean		10.00 ± 1.82	10.60 ± 3.60	7.21 ± 2.68			
p					0.786	0.189	0.132
Typical development group	6	0.60	3.22	4.13			
	7	4.33	7.89	3.83			
	8	6.82	8.36	10.73			
	9	4.19	9.90	8.66			
	10	4.29	6.00	6.54			
mean		4.05 ± 2.22	7.07 ± 2.56	6.78 ± 2.95			
p					0.016*	0.037*	0.802

passive-PMS: passive propulsion of the PMS by the examiner, j-PMS: the PMS driven forward by a bilateral joystick, s-PMS: the PMS driven forward by bilateral switches, $*p \le 0.05$ indicates a significant difference

PMS and head between the CP group and the TD group.

Results

The results showed that the maximum head acceleration of all subjects in PMS was 15.02 m/s^2. As shown in Table 2, the maximum mean head acceleration of the CP group in j-PMS was 10.60 ± 3.6 m/s^2. There was no significant difference in the head acceleration of the CP group among passive-PMS, j-PMS, and s-PMS ($p = 0.786$, $p = 0.189$, $p = 0.132$). As shown in Table 2, the maximum mean head acceleration of the TD group in j-PMS was 7.07 ± 2.56 m/s^2. There were significant differences in head acceleration between passive-PMS and j-PMS or s-PMS ($p = 0.016$, $p = 0.037$, respectively) but without significant difference in head acceleration between j-PMS and s-PMS ($p = 0.802$) in the TD group. Therefore, the degree of head shaking during the use of the PMS was small with minimal chance of injury. Furthermore, the difference in the degree of head shaking in children with cerebral palsy under different dynamic situations was small.

Discussion

Motor control is considered to rely on the neuromuscular control of the trunk to maintain stability during the process of walking. Therefore, the nervous system would prioritize the stability of the trunk, which means that trunk control affects overall body shaking.[18] However, the coordination between the lower limbs and the trunk also affects the movement of the trunk in the frontal and sagittal planes. In this regard, Degelean et al. found that, compared with children showing typical development, children with spastic cerebral palsy showed excessive trunk shaking in both the frontal and sagittal planes which could be improved by the use of ankle stents.[18] Previous literature showed that children with spastic cerebral palsy could reduce body shaking with reasonable trunk control and lower limb control.[18] However, this study showed that there was no significant difference in head acceleration among children with cerebral palsy when using the PMS under three different conditions. It was speculated that the modified segmental assessment of trunk control in this study gave each subject the most suitable fixed position for the trunk or lower limbs, which may result in less head shaking. A previous study on 28 children with cerelral palsy demonstrated a postive impact of segmental training on head and body shaking, highlighting the importance of good support.

Previous literature showed that excessive head shaking of children may cause shaken baby syndrome, which can result in intracranial hemorrhage, permanent nerve damage, mental retardation, and impaired vision.[19] Brain imaging and fundus examinations in patients with shaken baby syndrome found that all patients had subdural hematomas.[20] Some patients also exhibited subdural hematomas in combination with subarachnoid hemorrhage and cerebral edema. Fundus examinations revealed bleeding in the retina or eyeball.[20] Therefore, the degree of head shaking is crucial for children. Jones et al. developed an infant model (MD Adams) that simulated the maximum head acceleration and speed of rotation that occurred when shaking a baby. The results showed that if the baby's head acceleration exceeded the threshold 95.73 m/s^2, it may cause shaken baby syndrome and head damage.[10] This study demonstrated that the maximum head acceleration of all subjects using the PMS in a dynamic state was 15.02 m/s^2. Thus, our study confirmed that the use of the PMS was safe and would not cause head injuries. However, the correlation between the speed of the PMS and head acceleration was not analyzed in this study. This correlation could be further explored in future research.

The limitations of this study and the future considerations that may affect the results of this study are: (1) Subject sampling: A convenience sampling method was used to study children with cerebral palsy at Chang Gung Memorial Hospital. Therefore, the results of this study may not be extrapolated to other populations. (2) Control panel: The bilateral joysticks used in this study were modified from commercially available joysticks for car games. They cannot be compared with the existing electronic mobile products with high sensitivity and better control stability, such as driving straight or turning. (3) Evaluation tool: This study analyzed the degree of head shaking by using a strain measurement system to track the movement of the accelerometer. However, as children with the cerebral palsy need to control their direction during movement, their heads may turn in certain situations. This may cause significant acceleration or a drop in the recorded values shown on the accelerometer.

Conclusion

The use of PMS for children was associated with minimal head shaking, underscoring the safty of this device. To determine the effectiveness of balance control when using the PMS, further research is needed.

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