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Differences in standing balance between patients with diplegic and hemiplegic cerebral palsy

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Research Highlights

(1) Improving postural balance in patients with cerebral palsy is crucial to improve motor function.
(2) This study innovatively investigated the postural balance control ability in patients with spastic diplegia from the perspective of standing balance and confirmed that spastic diplegia patients with cerebral palsy exhibited worse postural balance control ability compared with spastic hemiplegia patients with cerebral palsy, as demonstrated by the greater center of pressure sway in the medial-lateral direction in both conditions and the center of pressure area during eye opening.
(3) More special attention to spastic diplegia patients with cerebral palsy will help improve their motor functions.

Abstract

Maintaining standing postural balance is important for walking and handling abilities in patients with cerebral palsy. This study included 23 patients with cerebral palsy (seven with spastic diplegia and 16 with spastic hemiplegia), aged from 7 to 16 years of age. Standing posture balance measurements were performed using an AMTI model OR6-7 force platform with the eyes open and closed. Patients with diplegic cerebral palsy exhibited greater center of pressure displacement areas with the eyes open and greater center of pressure sway in the medial-lateral direction with the eyes open and closed compared with hemiplegic patients. Thus, diplegic patients exhibited weaker postural balance control ability and less standing stability compared with hemiplegic cerebral palsy patients.

Key Words

neural regeneration; cerebral palsy; postural balance; postural control; center of pressure; children; diplegia; hemiplegia; grants-supported paper; neuroregeneration

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Conflicts of interest: None declared.

Ethical approval: This study was approved by the Bioethics Committee of University of Talca, Chile, No. 00068.

INTRODUCTION

Cerebral palsy is described as a group of permanent disorders of movement and posture development that cause limitations in daily activity[1]. Cerebral palsy disorders are attributed to non-progressive alterations that occur during fetal or infant development of the brain[1]. Patients with cerebral palsy can present cognitive, sensory or motor impairment[2-5]. Cerebral palsy can be topographically divided into several different motor impediments: diplegia, hemiplegia, quadriplegia, monoplegia and triplegia[6-7]. Postural control measurements are often performed in diplegia and hemiplegia cerebral palsy patients [8-10].

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The objectives of rehabilitation in patients with cerebral palsy include improving walking and handling abilities, such as reaching tasks, participants were asked to reach forward to a target, for example a toy[11-13]. Maintaining standing postural balance is important for walking and handling abilities[11-15]. An evaluation of standing postural balance was adopted in this study to analyze the differences between diplegic and hemiplegic patients.

Postural balance can be described using a simple standing paradigm on a force platform, which measures the center of pressure, sway and velocity in the medial-lateral and anterior-posterior directions and area[16-21]. Center of pressure data have been shown to be sensitive in discerning balance performance in healthy adults[19, 22], patients with post- stroke hemiparesis[23], cerebellar deficits[23] and Parkinson's disease[23-25], healthy adolescents[26] and children with cerebral palsy[27-29]. Children with cerebral palsy exhibit greater sway in the medial-lateral direction in both seated and standing positions compared with normally developing children[29-32]. However, the greatest differences in balance between patients with cerebral palsy and healthy patients have been established in the seated position[29-31]. A lack of information is available regarding the differences in standing balance between diplegic and hemiplegic patients[32]. Using force platform measurements, we comparatively analyzed the differences in the standing postural balance between diplegic and hemiplegic cerebral palsy patients.

RESULTS

Baseline data of the participants

Twenty-three cerebral palsy patients comprising 7 with spastic diplegia and 16 with spastic hemiplegia were included in the study.

Baseline data for all the subjects were shown in Table 1. There were no significant differences in patients' baseline data between spastic diplegia and spastic hemisplegia groups (Table 1). Gross motor function classification in diplegic and hemiplegic patients were shown in Table 2.

Postural balance of patients with their eyes open

The variables of center of pressure between diplegic and hemiplegic cerebral palsy patients were shown in Table 3. The center of pressure area was significantly increased in the spastic diplegia group than in the spastic hemisplegia group (P = 0.01). The center of pressure sway in the medial-lateral direction significantly increased in diplegic cerebral palsy patients than in hemiplegic cerebral palsy patients (P = 0.03).

Postural balance of patients with their eyes closed

The significant increase in center of pressure sway in the medial-lateral direction for patients with diplegic *versus* hemiplegic cerebral palsy patients were shown in Table 4. The other variables of center of pressure were not significantly different.

Comparison between eyes-open and eyes-closed conditions

Standing balance of patients from each group in the eyes-open and eyes-closed conditions were shown in Table 5. Only diplegic cerebral palsy patients showed significant differences in center of pressure sway in the medial-lateral direction between these two conditions.

Table 1 Baseline characteristics of diplegic and hemiplegic cerebral palsy patients

Group	*n*	Gender (M/F, *n*)	Age (year)	Weight (kg)	Height (m)	BMI (kg/m^2)
Diplegic	7	3/4	12.3±1.2	42.8±1.3	1.4 ±0.5	20.0±0.7
Right Hemiplegic	9	5/4	11.0±0.6	44.5 ±1.1	1.4±0.2	20.9±1.2
Left Hemiplegic	7	4/3	11.0±0.5	38.8±0.8	1.4±0.6	20.2±1.1

Measurement data were expressed as mean ± SD. M: Male; F: female; BMI: body mass index (mass (kg)/ height (m^2)).

Table 2 Gross motor function classification system (GMFCS) in diplegic and hemiplegic cerebral palsy patients

GMFCS	Diplegic	Hemiplegic
I	6 (85.7)	15 (93.8)
II	1 (14.3)	1 (6.3)
III	0	0
IV	0	0
V	0	0

The data were expressed as *n* (%).

DISCUSSION

The literature indicates that children with cerebral palsy present a lower postural balance ability compared with typically developing children[29-31]. Velocity and center of pressure sway, mainly in the medial-lateral direction, exhibit the greatest increases in patients with cerebral palsy[30, 32].

The greatest differences in this study occurred in patients with spastic diplegia who presented a significant increase in their center of pressure sway in the medial-lateral direction with the eyes opened and closed compared to patients with hemiplegic patients.

These findings are similar to other studies[33-34]. For example, using a dual static force platform evaluation, Ferdjallah *et al* [34] explored postural strategies in spastic diplegic patients (11 volunteers between 6 and 18 years of age) and normally developing patients (8 volunteers between 5 and 13 years of age). Ferdjallah *et al* [34] showed that the children with diplegia and normally developing children utilized the limb protraction and retraction strategy during balance measurements in the medial-lateral direction. In addition, to maintain standing balance during the center of pressure measurement in the anterior-posterior direction, the body transverse rotation strategy was used in both groups. The previously indicated postural strategies are crucial for attaining postural stability during balance measurements with eyes both opened and closed[34]. Furthermore, this study presents a significantly greater center of pressure displacement area in patients with diplegic cerebral palsy when the eyes are open compared to patients with hemiplegic cerebral palsy. We consider that the increases in variable sway in the medial-lateral direction in patients with diplegia consequently generate an augmentation in the center of pressure area. For this reason, deplegic patients demonstrate weaker postural balance ability compared to hemiplegic patients.

Another contributing factor to the understanding of differences in control standing balance between both types of patients, deplegic and hemiplegic, is basal muscular activity[35].

Table 3 Variables of center of pressure in the eyes-open condition

Group	*n*	Area (cm^2)	Velocity ML (cm/s)	Velocity AP (cm/s)	Sway ML(cm)	Sway AP (cm)
Diplegic	7	4.5[b]	0.8	0.8	0.5[a]	0.4
Hemiplegic	16	2.6	0.8	0.9	0.3	0.4

Measurement data were expressed as median. [a]P = 0.03, [b]P = 0.01, *vs*. hemiplegic patients (the Mann-Whitney *U* test for independent samples). Area: Area of center of pressure; CP: cerebral palsy; ML: medial-lateral direction; AP: anterior-posterior direction.

Table 4 Variables of center of pressure in the eyes-closed condition

Group	*n*	Area (cm^2)	Velocity ML (cm/s)	Velocity AP (cm/s)	Sway ML(cm)	Sway AP (cm)
Diplegic	7	5.4	0.8	0.8	0.7[a]	0.6
Hemiplegic	16	3.5	0.8	1.1	0.4	0.5

Measurement data were expressed as median. [a]P = 0.01, *vs*. hemiplegic patients (the Mann-Whitney *U* test for independent samples). Area: Area of center of pressure; ML: medial-lateral direction; AP: anterior-posterior direction.

Table 5 Comparison of standing balance of patients from each group between eyes-open (OE) and eyes-closed (CE) conditions

Group	*n*	Area OE/CE (cm^2)	Velocity ML OE/CE (cm/s)	Velocity AP OE/CE (cm/s)	Sway ML OE/CE (cm)	Sway AP OE/CE (cm)
Diplegic	7	15.0/14.9	13.0/13.0	10.1/9.9	16.4/17.4[a]	13.3/13.4
Hemiplegic	16	9.9/10.9	11.5/11.9	12.7/13	10.0/9.9	11.3/11.4

Measurement data were expressed as median. [a]P = 0.04, *vs*. hemiplegic patients (the Mann-Whitney *U* test for independent samples). Area: Area of center of pressure; ML: medial-lateral direction; AP: anterior-posterior direction.

Giralomi and collaborators[35] compared the electric muscular activity between diplegic and hemiplegic cerebral palsy patients and with typically developing subjects using surface electromyography. Surprisingly, they found that increased basal muscular activity (rectus femoris and biceps femoris muscles) prior to movement justified the decreased postural control in diplegic cerebral palsy patients compared with hemiplegic cerebral palsy patients[35].

Patients with cerebral palsy present diverse impairments that directly and indirectly affect postural balance. Cognitive impairments indirectly affect postural balance, which is crucial for learning new postural control strategies[2-5]. Sensory and motor disabilities directly affect center of pressure variables. Sensory dysfunctions generate increases in center of pressure amplitude and velocity[36]. Open eyes permit visual feedback. In this study, patients with cerebral palsy fixed their gaze on a target located on the wall, which generated a focusing point for their visual system. This aspect positively contributed to the center of pressure variables studied and caused a lower value to occur with the eyes open compared with the eyes closed in diplegic cerebral palsy patients[32].

Taken together, patients with spastic diplegia presented a lower standing balance compared with patients with spastic hemiplegia. The affected center of pressure variables included sway in the medial-lateral direction in both eyes-open and eyes-closed conditions and center of pressure area only with the eyes opened. Rehabilitation therapies for patients with cerebral palsy should focus on improving standing balance and postural stability because postural balance is integral to all motor abilities. Therefore, improving postural balance will improve function. Among the alternatives, we propose future research on postural work in all directions, with special focus on the medial-lateral plane of movement.

SUBJECTS AND METHODS

Design

A cross-sectional study.

Time and setting

The study was performed at the Laboratory of Human Motor Control, University of Talca, Chile from May to September of 2012.

Subjects

The study included 23 patients with cerebral palsy. Seven subjects aged from 7 to 15 years exhibited spastic diplegia, and 16 subjects from 7 to 16 years of age exhibited spastic hemiplegia. Children with cerebral palsy were recruited from a rehabilitation center that receives outpatients from various towns in the central zone of Chile, especially of the Maule region. The parents and children voluntarily agreed to participate in the study and signed the informed consent.

All of the patients included in the study presented a topographic diagnosis of spastic diplegia and/or hemiplegia. The patients exhibited functional engagement level I and/or II according to the Gross Motor Function Classification System, where grade I and grade V for the highest and lowest motor function, respectively[37-40]. All of the patients were able to walk independently or with minimal assistance.

Patients with moderate or severe cognitive impairments and associated disabilities (uncorrected visual or vestibular impairments) were excluded.

Methods

An AMTI model OR6-7 force platform (Advanced Mechanical Technology Inc., Watertown, MA, USA) was used to measure balance in patients with cerebral palsy. The platform with dimensions of 46.4 cm × 50.8 cm was floor-mounted and leveled. For signal acquisition, the AMTI NetForce software (Advanced Mechanical Technology Inc.) was used. The data were filtered using a finite impulse response (FIR) filter with a 40 Hz cutoff frequency and a 200 Hz sampling frequency. Using the AMTI platform, the moments and forces were obtained on the X, Y and Z axes: Mx, My, Mz, Fx, Fy and Fz. These physical variables were used to calculate the center of pressure using the following formula:

$COPx = -(My + Fx \times z)/Fz$ and $COPy = (Mx - Fy \times dz)/Fz$.

In the formula, COP = center of pressure; dz = plate thickness = 41.3 mm.

The center of pressure was measured in the medial-lateral and anterior-posterior directions to obtain the following variables: area, center of pressure velocity in the medial-lateral direction, center of pressure velocity in the anterior-posterior direction and center of pressure sway in the medial-lateral and anterior-posterior directions. These variables were processed by the first author of this article using the Matlab r2012b software (Mathworks Inc., Natick, MA, USA).

The balance measurement test required each subject with cerebral palsy to stand on the force platform in a relaxed position with the arms at each side of the body. In a bipedal position, subjects were asked to place their feet at a shoulder-width distance and maintain the position in a relaxed manner. Patients were evaluated in two states: staring at a target located on the wall 1.5 meter away and with the eyes closed for 30 seconds for each condition. Each state was repeated three times in each volunteer with a randomly chosen order.

Statistical analysis

The statistical analysis was conducted utilizing the SPSS 14.0 software (SPSS, Chicago, IL, USA). The results of the age, weight, height and body mass index were expressed as mean ± standard deviation and were compared using the *t*-test for independent samples. Data relating to the center of pressure variables were presented as median, and the differences between two groups (Table 3 and Table 4) and condition (Table 5) were tested using the Mann-Whitney *U* test for independent samples. A value of $P < 0.05$ was considered to be statistically significant.

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