



Original Article

Evaluation of postural stability in children with hemiplegic cerebral palsy

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Abstract. [Purpose] Postural stability is the ability of to maintain the position of the body within the support area. This function is affected in cerebral palsy. The aim of the present study was to compare static and dynamic postural stability between children with hemiplegic cerebral palsy and healthy controls. [Subjects and Methods] Thirty-seven children between the ages of 5 and 14 diagnosed with hemiplegic cerebral palsy (19 right, 18 left) and 23 healthy gender- and age-matched controls were included in the study. Postural stability was evaluated in both of the groups using a Neurocom Balance. Sway velocity was measured both with the eyes open and closed. Sit to stand and turning abilities were also assessed. [Results] The sway velocities with the eyes open and closed were significantly different between the groups. The weight transfer time in the Sit to Stand test was also significantly slower in children with cerebral palsy. Children with cerebral palsy also showed slower turning times and greater sway velocities during the Step and Quick Turn test on a force plate compared with their healthy counterparts. [Conclusion] Both static and dynamic postural stability parameters are affected in hemiplegic cerebral palsy. Further research is needed to define rehabilitation interventions to improve these parameters in patients.

Key words: Balance, Cerebral palsy, Postural stability

(This article was submitted Nov. 24, 2015, and was accepted Jan. 19, 2016)

INTRODUCTION

Cerebral palsy (CP) is the most common cause of childhood disability and is seen in 2–2.5 out of 1,000 births¹). The non-progressive lesion in the brain that causes CP, has devastating effects on the musculoskeletal system. These effects, like spasticity, imbalance between agonist and antagonist muscles, and decreased voluntary muscle control, can result in contractures and deformities²). Maintainance of postural stability depends on continuous integration of the musculoskeletal and nervous system, which carries visual, somatosensory and vestibular information³). This integration is damaged in patients with CP due to its effects on both key systems, having a bad influence on postural stability. Postural stability is a key factor in keeping up with daily activities because it affects gross motor abilities⁴), and it must be a part of any rehabilitative intervention in children with CP.

Even though the effect of CP on postural stability has been previously studied and documented, one can easily see that studies usually do not have pure hemiplegic CP groups^{5–7}). Most of the rehabilitation studies have involved children with diplegic CP, and the effectiveness of interventions in these children^{8, 9}). Patients with hemiplegic CP are usually children who have higher levels of gross motor function¹⁰). This means that they are less restricted when it comes to activities and participation than other types of CP patients¹¹). Therefore it is essential to determine if there is a specific type of effect on

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postural stability in children with hemiplegic CP, considering how paramount postural stability is for activities of daily living, and how these patients spend their time around their typically developing counterparts.

The aim of the study was to investigate the level of effect of CP on active and passive postural stability in children with mild hemiplegic CP by comparing them with typically developing (TD) children and understand more about functional differences between these two highly functioning groups.

SUBJECTS AND METHODS

This was an observational, case-control study. Thirty-three children between the ages of 5 and 14 diagnosed with hemiplegic CP (19 right, 18 left) and 23 gender- and age-matched controls were included in the study. All the children were ambulatory without any the need for any assistive devices and were able to stand up without support. Therefore all of them had a Gross Motor Function Classification System (GMFCS) level of I to II and = an upper extremity functional level correlating to a Manual Ability Classification System (MACS) level of I to II. All children were able to stand up without support on the force plate bare feet, with full plantar contact. The patients could all understand instructions without any problems, and had no evident sensory or perceptual deficits. Each subject received information about the study and gave written consent to participate. The Marmara University Ethics Committee approved the study under approval number 70737436-O50.O6.04-130025194.

Each child was examined for spasticity in the affected ankle, with spasticity measured by the Modified Ashworth Scale.

Balance was evaluated on a Balance Master (NeuroCom International, Clackamas, OR, USA), a computerized device that can assess the patient's ability to perform specific balance tasks in real time. The Balance Master consists of a force plate connected to a computer and software that monitors the position and movement of the center of gravity (COG). The Modified Clinical Test for Sensory Interaction on Balance (mCTSIB) was used to test sensory dysfunction and static postural stability, while the Sit to Stand (STS) and Step and Quick Turn (SQT) tests were performed to test dynamic stability on the Balance Master. The tests were done in a quiet, discrete room to eliminate external stimuli. The Balance Master has previously been shown to be a valid and reliable method of measuring postural stability in children¹².

The mCTSIB quantifies the postural sway velocity in degrees per second while the subject is standing quietly on a platform, first with the eyes open (EO) and then with the eyes closed (EC), with the platform placed on a firm surface and on a foam surface. Stability is expected to be better in patients who have lower sway velocities. Three trials with the four conditions were performed and the length of each trial was 10 seconds. Due to the inability of the children with CP to perform on the foam surface, only the data from firm surface measurements were evaluated in this study.

The Sit to Stand test is a test for dynamic stability. In this test, the patient was required to move from a sitting position to standing up on the mark three consecutive times. Weight transfer, rising index and sway velocity (degrees per second) were measured in each of the three trials. The mean values of these parameters were used in analyses. Weight transfer can be defined as the time in seconds needed to shift the COG forward from a seated position to full weight bearing on both feet. Rising Index is defined as the force exerted by the lower extremities during the rising phase, which is calculated as a percentage of the patient's body weight. Lower values for these parameters signify better stability in this activity.

The Step up and Quick Turn test was the other test performed for dynamic stability. The patient began with his right leg, crossed the board over with his left leg, turned around and returned to the starting point. This sequence was repeated for the left side. Each test was done three consecutive times for each side, and the mean values were used in analyses. This test evaluates turn time and turn sway, which are supposed to be lower in individuals with better ambulatory balance control. Turn time is defined as the number of seconds required for the patient to complete a 180-degree in-place turn. The time begins with forward progression in the initial direction and ends when forward progression in the opposite direction is initiated. Turn sway quantifies the postural stability of the individual during the turn time, which is expressed as the average COG sway velocity in degrees per second.

SPSS 16.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The results of the balance tests records on the force plate were compared between groups using the Mann-Whitney U test. Analysis within the groups was done by using the Wilcoxon test. Correlations were analyzed with Spearman correlation coefficients. The significance level was set at $p < 0.05$.

RESULTS

In the mCTSIB test, there were statistically significant differences between sway velocities among typically developing children and patients with cerebral palsy under both the EO and EC conditions (Table 1). Sway velocities were lower under the EO conditions compared with the EC condition in both groups, but no statistically significant difference was found between right and left hemiplegic children. There was inverse correlation between age and sway velocity (EO and EC) in the CP group ($r = -0.350$, $p = 0.033$, and $r = -0.336$, $p = 0.042$, respectively). Also, there was negative correlation between sway velocity and age in the healthy control group ($r = -0.559$, $p = 0.006$). No correlation was found between level of ankle spasticity and gender with all parameters.

In the STS test, the weight transfer time of children with hemiplegic CP was slower compared with that of the children in control group. There was no significant difference in rising index and COG sway velocity (Table 2). There were no significant

Table 1. Differences in sway velocities among groups in the mCTSIB test

	CP group (n=37)	Control group (n=23)
Sway velocity EO* (degrees/sec)	1.07 ± 0.6	0.74 ± 0.6
Sway velocity EC* (degrees/sec)	0.82 ± 0.5	0.28 ± 1.2

*Statistically significant between groups

Table 2. Differences in STS parameters between groups

	CP group (n=37)	Control group (n=23)
Weight transfer time (sec)*	1.17 ± 0.7	0.81 ± 0.8
Rising index*	26.5 ± 18	27.5 ± 6.5
Sway velocity (degrees/sec)	4.1 ± 1.5	3.9 ± 3

*Statistically significant between groups

Table 3. Differences in SQT results between groups

	CP group (n=33)	Control group (n=23)
Turning time (sec)		
Left*	2.41 ± 1	1.68 ± 0.6
Right*	2.2 ± 0.88	1.5 ± 0.5
Sway velocity (degrees/sec)		
Left*	60.7 ± 23	47.4 ± 12
Right*	57.3 ± 16.6	46.1 ± 13

*Statistically significant between groups

relationships between STS parameters and age, sex, or spasticity.

Children with CP showed slower turning times and greater sway velocities in the SQT test. In both groups, there was no statistically significant difference for either side. Sway velocities and turn times were not significantly different for either side (Table 3). Turning time to the left was significantly slower in children with CP with right hemiplegia when the CP group was assessed separately ($p=0.44$).

DISCUSSION

This study assessed static and dynamic postural stability in children with hemiplegic CP. Children with CP had greater sway velocities in standing in the mCTSIB, slower weight transfer times in the STS test, and greater sway velocities and slower turning times in the SQT test. None of the parameters showed any significant relationship with age, gender, or the degree of spasticity, except age and sway velocity in the mCTSIB.

The mCTSIB is a test used to determine the effects of inputs from the visual and proprioceptive systems on static postural stability. In this study, proprioceptive inputs could not be determined, because the children could not stand on the foam surface for the time needed. The fact that we could not collect any data shows that proprioceptive inputs are key for children with hemiplegic CP and that these children cannot easily adapt to changes in proprioception. On a firm surface under the EO conditions, the children with CP had higher sway velocities compared with the typically developing children, and this was expected. This sway velocities increase under the EC conditions, and there was a significant difference between groups under both conditions. It has been previously shown that visual inputs play a major part in maintaining postural stability in diplegic cerebral palsy^{13, 14}. However, the data on hemiplegic CP are scarce. There is one other study that compared a mixed group of children with hemiplegic and diplegic CP with typically developing children and showed similar results¹⁵. Therefore, this study is important in that it emphasizes that visual inputs are also critical in hemiplegic CP. It has to be kept in mind that visual problems like homonymous hemianopsia, strabismus, and refraction disorders are not uncommon in children with hemiplegic CP¹⁶. These visual defects can also affect postural stability and therefore must be properly addressed during rehabilitation.

The weight transfer time in the STS test is related to the time at which the feet make full contact with the ground after standing up. Thus, it is not farfetched to claim that good plantar flexion can induce faster times in weight transfer. It has been previously shown that strengthening the ankle plantar flexors improves gait parameter in children with CP¹⁷. Since children with CP have problems in complete plantar flexion, the increase in this parameter is quite logical. It has also been shown that

decreased knee flexor torque affects sit-to-stand balance in children with hemiplegic CP¹⁸⁾ and that children with hemiplegic CP also show major postural oscillations at the beginning of the STS movement compared with typical children¹⁹⁾. The device used in this study does not measure these oscillations; therefore further investigations must be performed to investigate whether these oscillations affect the weight transfer time.

The purpose of the SQT test is to define the ability to turn around while walking, which is a common challenge related to postural stability during daily life. Greater sway velocities and slower turning times in this test in children with CP are also consistent with lower extremity issues and postural stability problems in these children when compared with typically developing children. It has been shown that children with CP have a variable step length, use more strides, and have a wider step width. These changes affect dynamic gait stability in children with CP²⁰⁾. However, the factors that affect turning around in these children could be further evaluated, and this could lead to new targets in rehabilitation.

There were no relationships between the balance parameters and spasticity, age, or gender in this research, except for the relationship between age and sway velocity in the mCTSIB. This might indicate that although musculoskeletal involvement may seem to be responsible for loss of postural stability, it might not be the case. The joint range of motion, spasticity and disability levels have been shown to be the main determinants of static balance in stroke survivors²¹⁾. The parameters that affect the postural stability in CP are more complex. Even though it is well known that abnormal muscle recruitment and agonist-antagonist muscle co-activation^{22, 23)} and overall gross motor function affects postural stability in CP⁴⁾, studies, including this one usually involve children with high GMFCS levels and still show differences in postural stability^{15, 24)}. It has also been shown that lower extremity muscles are thinner in children with cerebral palsy, which might also have a role in diminished postural stability²⁵⁾. As discussed before, patients with CP with higher GMFCS levels are more active in daily life. This means that they spend more time with their counterparts, which makes it important to define how much these children differ from their typically developing counterparts. Therefore, any data that help us understand more about these differences are valuable and could lead us to the reasons for the effect of CP on postural stability. These data can also help us find more ways to improve postural stability in children with hemiplegic CP.

The strength of this study was its use of a pure hemiplegic CP group, which is not common in the literature. Weak points of this study were that visual impairments were not defined and the number of patients involved might not have been enough to show a correlation between age, gender, and spasticity and postural stability parameters. This study was also a more defining work regarding what is affected in patients with hemiplegic CP, but there are still many questions about how and why postural stability is affected as it is in children with hemiplegic CP.

Due to the musculoskeletal asymmetry in children with hemiplegic CP, all balance parameters show significant differences when compared with those of typically developing children. This study showed that this difference does not significantly change with age, gender, or spasticity but it is usually coherent with the affected side. To our knowledge, this study is one of the rare studies that have compared the static and dynamic balance in a homogenous group of hemiplegic CP children with TD children via computerized assessment. Therefore, there is a definite need for further studies with larger sample groups.

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