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Original Research Article

Hamstrings muscle tightness, posterior pelvic tilt and sitting balance in children with cerebral palsy spastic diplegia

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ABSTRACT

Background: School going children in the age group of 7-12 years have to spend long hours in sitting, and maintain adequate balance in order to use their upper limbs efficiently and functionally during play and in the performance of Activities of Daily Living (ADLs). Studies that have examined trunk control and the effect of underlying muscle tightness and spasticity that cause biomechanical constraints in children with Cerebral Palsy (CP) is scarce.

Aim: This study aims to assess the effect of Hamstring muscle tightness on Sitting Balance in children with CP spastic diplegia.

Materials and Methods: Thirty (30) children with CP spastic diplegia (n=30) belonging to GMFCS Levels I, II, and III, in the age group of 7-12 years, and thirty (30) age and sex-matched typically developing(TD) children were recruited for this study. Hamstring tightness was assessed by calculating the R2 angle using the modified tardieu scale. Pelvic tilt was measured in sitting using the pelvic inclinometer and sitting balance by Paediatric reach test & Trunk control measurement scale (TCMS). Centre of pressure excursion in forwarding direction was measured using the limits of stability protocol in sitting on the neurocom balance Master.

Results: Children with CP spastic diplegia sat with a greater posterior pelvic tilt compared to TD children ($p<0.0001$). There was a moderate positive correlation of hamstrings muscles tightness with posterior pelvic tilt in both groups of children (r value=0.6, $p<0.01$). Also, there was a low correlation between hamstrings muscle tightness and reach in forward and lateral direction and moderate negative correlation of pelvic tilt with reach in forward and lateral direction (r value = 0.6, $p<0.01$). Trunk control as measured by the TCMS scores showed a moderate negative correlation with hamstrings tightness and posterior pelvic tilt (rho = 0.6). The maximum excursion of limits of stability showed a moderate negative correlation with hamstrings tightness and posterior pelvic tilt in the forward directions.

Conclusion: Greater tightness of the hamstring muscles was associated with a posterior pelvic tilt and reduced sitting balance. Therapeutic interventions that manage hamstring muscle tightness may improve the alignment of pelvis over the hip and or the trunk over the pelvis, resulting in an improvement in sitting balance in CP children with diplegia.

1. Introduction

Several neural factors constrain balance control in children with Cerebral Palsy (CP) such as spasticity, hyperactive stretch reflexes, problems with muscle coordination including poorly organized postural responses and increased muscle co-activation at individual joints.[1] Dynamic balance control includes proactive or anticipatory postural adjustments(APA), and reactive or compensatory postural adjustments(CPA) to enhance balance.[2,3] Thus, postural control for stability and orientation requires a complex interaction of the musculoskeletal and neural systems.[4–6] It has been shown that postural fine-tuning in typically developing children is based especially on information of trunk position.[7–9] In children with spastic diplegia sacral

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sitting is generally observed, andinvolves a posteriorly rotated pelvis, accentuation of thoracic kyphosis and a loss of lumbar lordosis.[10]

Children at GMFCS levels I to III have an intact basic level of control but have difficulties in fine-tuning the degree of postural muscle contraction to the task-specific conditions, a dysfunction prominently present in children with spastic CP.[11] Furthermore, acquisition of sitting balance is a significant predictor of function in both children and adults with neurological damage.[12–15] Several studies have shown that hand reach function is severely affected in children with cerebral palsy in sitting.[11,16,17]

Children with hypertonia develop joint contractures and muscle shortness from the neuromuscular impairments of excessive co-contraction and excessive sustained muscle shortening leading to a loss of range of motion as a secondary impairment. The muscles that tend to shorten are the superficial muscles, two-joint muscles, and muscles that were originally shortened at birth. Hamstrings muscles fall under all three categories.[18] Hamstring muscles are biarticular (except short head of biceps femoris), and they extend the hip joint and flex the knee.[19]

Children in the age group of 7-12 years are school-going children, they have to spend long hours sitting, while at the same time have to maintain adequate balance in order to be able to use their upper limbs efficiently and functionally most often in a sitting position as a majority of their play activity is in sitting.

Thus, the aim of this study was firstly, to measure hamstring muscle tightness, pelvic tilt and sitting balance in children with spastic diplegia and compare them to typically developing children, and secondly to study the relationship of hamstring muscle tightness with pelvic tilt and sitting balance.

2. Materials and Methods

2.1. Design

The study was an cross-sectional, observational, analytical, correlational study. Sampling was non-probability with Incidental sampling.

2.2. Participants

Thirty (30) children with CP spastic diplegia (GMFCS 1,2,3) in the age group of 7-12 years and thirty (30) age and sex matched typically developing children were included in the study. Children with structural deformities in the lower limb and spine, hip dislocation, history of lower limb surgery, or botulinum toxin /phenol injection in the previous 6 months, other types of Cerebral Palsy children, and visual/hearing impaired children were excluded.

2.3. Procedure

Assessment of participants was initiated after approval by the ethical committee of the Institute. Each subject and their parents were briefed about the procedure, duration. Following this, children provided assent and parents/caretakers signed an approved informed consent form. Safety of the subjects was ensured during the assessment by the researchers.

The Hamstring's R2 angle on the modified Tardieu scale (slow velocity stretch) was measured in the supine lying position on a plinth. The Pelvic tilt was measured with a pelvic inclinometer. Readings were taken in high sitting in a maximum active corrected sitting posture. The subject was made to sit on a wooden block with the thighs supported. Knees in 90 degrees of flexion. Feet and back were unsupported and the wooden block ensured the knees remained in 90 degrees of flexion.

The tips of the 2 arms of the inclinometer were kept at the ASIS and PSIS respectively and the angle of the tilt recorded.

Three tests were used to assess the Sitting balance - the Paediatric Reach Test, the Trunk Control Measurement Scale, and the Limits of Stability Test on the Balance Master with a long force plate.

The Paediatric reach test was performed with children sitting on a wooden block such that his feet were off the ground and back unsupported. Thighs were fully supported and the hips and knees were flexed to 90º. A tape measure was attached to the wall to measure finger-tip reach distance. Children were asked to "sit up tall" at the beginning of the test trial for each item. The initial and final positions were held for three seconds each and the maximum distance reached was measured in the forward as well as lateral directions.

Trunk control measurement scale(TCMS) was used to measure functional static and dynamic balance. For both balance tests the child's starting position was the same - sitting on the edge of a treatment table without back, arm or feet support and the thighs fully supported. Both hands resting on the legs, close to the body. The patient was asked to sit upright at the start of each item and encouraged to maintain the upright position during the performance of the task. Each item on the two tests were performed three times, and the best performance was recorded for scoring.

The limits of stability test was performed with the subject in high sitting on wooden blocks placed on the force platform (Neurocom Balance master), maximum Centre of Pressure excursion in the forward direction was recorded. The LOS quantifies the maximum distance a person can intentionally displace their Center of Gravity (COG), i.e. lean their body in a given direction without losing balance.

2.4. Data analysis

For intergroup comparison of tightness, pelvic tilt and sitting balance between the subjects with cerebral palsy spastic diplegia and typically developing children the "unpaired t-test" was used. For correlation between the tightness, pelvic and sitting balance within each group the Pearsons Correlation Coefficient was used for all correlations except Trunk Control Measurement Scale for which Spearman's Coefficient was used since it's an ordinal scale.

Statistical tests were done using the software SPSS 16.0. Normality of data was tested using the Shapiro Wilks test, and the level of significance was set at $p<0.05$.

3. Results

3.1. Demographics

Children in both the cerebral palsy and typically developing groups were matched for age, sex and BMI. (Table 1). In the cerebral palsy group, there were 10 participants each in the GMFCS levels I, II, III respectively.

Table 1: Demographics

	CPSD	TD	SIG
Males	20	20	
Females	10	10	
BMI (kg/m2)	14.4	13.72	p value 0.235 (NS)

CPSD-Cerebral Palsy Spastic Diplegia, TD- Typically Developing, AVG-Average, BMI: Body mass index, SIG-Significance, NS- Not Significant

3.2. Comparison of means

As seen in Table 2, the analysis revealed that Children with spastic diplegia had significantly greater hamstrings muscle tightness (R2 angle - mean=40.58 deg. vs mean=14.58 deg., $p<0.05$), greater posterior pelvic tilt (tilt angle – 9 deg. vs 4.26 deg., $p<0.05$) and significantly reduced sitting balance (reach test all directions, $p<0.05$; Trunk Control total score – 36.1 vs 50.06, $p<0.05$; Limits of stability – 92.7 vs 107.3, $p<0.05$) compared to the age and sex-matched typically developing children across GMFCS levels.

3.3. Correlations

It was observed that hamstring tightness correlated to some degree with posterior pelvic tilt in both groups of children ($r=0.6$, $p<0.05$). Please refer to Table 3.

As seen in Table 4, the correlations of hamstring tightness and pelvic tilt with the balance parameters were mixed - the CP data was relatively very different from the TD data with regards to the strength of the association as well as the trend (positive versus negative).

In children with cerebral palsy: the pediatric reach test showed a low negative correlation with Hamstring tightness but a moderate negative correlation in the forward direction with the pelvic tilt. However, TCMS scores which evaluate both static and dynamic balance in sitting showed a moderate negative correlation with hamstrings tightness as well as posterior pelvic tilt. The maximum excursion of limits of stability in forwarding direction showed a moderate negative correlation with hamstrings tightness as well as posterior pelvic tilt. Please refer to Table 4. The typically developing children on the other hand also showed a moderate positive correlation of Hamstrings muscles with the pediatric Reach the in all directions, whereas pelvic tilt showed a low correlation with Balance tests.

4. Discussion

In this study in children with cerebral palsy the degree of hamstrings muscle tightness was almost three times, and the posterior pelvic tilt two times that of typically developing children. Also, not surprisingly sitting balance and limits of stability in unsupported sitting were significantly lower in children with CP diplegia than that of typically developing children.

The correlation of the hamstrings muscle tightness to the posterior tilt of the pelvis and reach distances is one of the causes limiting forward reach in these children. Further the(-0.6) the negative correlation of Hamstring tightness to TCMS static and dynamic balance scores reflects the role of Hamstring tightness to trunk balance impairment. The reduction of the maximum excursion of COG recorded in the forward direction in Limits of Stability tests in sitting further corroborates the clinical findings. The spasticity may also come into the picture. Forward reach will trigger the hamstrings muscle spasticity, and the shortened length will not allow the full extent of reach. The medial and lateral reach also showed a low correlation with hamstrings tightness and a moderate correlation with the pelvic tilt. Thus implying that hamstrings muscle tightness may have a role in lateral reaching as well, preventing the maximum extent of reach. Also, the Adductor Magnus which is considered a part of hamstrings may play a role in limiting the lateral reach as it is placed more medially in the thigh. One other reason may be because a posteriorly tilted pelvis will probably not allow adequate postural adjustment of weight shifting in medial or lateral directions for lateral reach.

In this study, the hamstring tightness was tested in supine with the hip and knee in 90ºof flexion and tightness was measured by the Modified Tardieu. In supine lying, the pelvis was kept in neutral with the hip in 90º of flexion and the hamstring muscle was stretched at the knee passively. Accordingly, the hamstrings are stretched posteriorly at the hip as well as the knee. In sitting the shin-thigh angle was kept constant at 90º, consequently the hamstrings are now

Table 2: Comparison between children with cerebral palsyspastic diplegia and typically developing children

Parameter		CPSD AVG (SD)	TD AVG (SD)	P Value
Hamstrings R2-MTS		40.58 (16.19)	14.58(10.78)	0.0001
Pelvic Tilt		9(4.30)	4.26 (3.98)	0.0001
PRT	Forward	8.79 (3.19)	13.15 (2.52)	0.0001
	Lateral- Right	5.75(2.69)	11.17 (2.68)	0.0001
	Lateral-left	5.48 (2.41)	10.91(2.35)	0.0001
TCMS (total score)		36.1 (13.99)	50.06(1.64)	0.0001
LOS- COG max excursion-forward direction		92.73(27.91)	107.3(9.76)	0.009

CPSD-Cerebral Palsy Spastic Diplegia, TD- Typically Developing, AVG- Average; SD-Standard Deviation; MTS-Modified Tardieu Scale; PRT-Paediatric Reach Test; TCMS-Trunk Control Measurement Scale; LOS- COG-Limits of Stability- Centre of Gravity; p<0.05

Table 3: Correlation of hamstrings tightness with pelvic tilt in sitting in children with cerebral spastic diplegia and typically developing children

	r value	Correlation
Cerebral palsy	0.6	mod +ve
TypicallyDeveloping	0.5	mod +ve

Mod+ve-Moderate Positive

Table 4: Correlation of paediatric reach test, trunk control measurement scale (TCMS), Limits of Stability in the forward direction, with hamstrings tightness and pelvic tilt in children with cerebral palsys pastic diplegia and typically developing children

		Cerebral Palsy Spastic Diplegia				Typically Developing			
		HAMS R2-MTS		PELVIC TILT		HAMS R2-MTS		PELVIC TILT	
Balance Tests		r value	Correlation	r value	Correlation	r value	Correlation	r value	Correlation
Paediatric reach test	Forward	-0.4	low-ve	-0.6	mod –ve	0.49	Mod +ve	0.04	Nil
	LAT –RT	-0.3	low –ve	-0.4	low +ve	0.53	Mod +ve	0.2	Low +ve
	LAT -LT	-0.3	low –ve	-0.5	mod –ve	0.51	Mod +ve	0.22	Low +Ve
TCMS Total		-0.6	mod –ve	-0.5	mod –ve	0.312	Low +ve	0.139	Low +ve
LOS –F MXE		-0.45	mod –ve	-0.57	mod –ve	0.071	Nil	0.016	Nil

HAMSR2- MTS- Hamstrings –modified Tardieu Scale; LAT-RT-Lateral Right, LAT-LT-Lateral Left, TCMS- Trunk Control measurement Scale; LOS-F-Limits of Stability-Forward, MXE- Maximum Excursion, Mod- Moderate

being stretched only posteriorly at the hip. With the knee fixed in 90º flexion in sitting, the tightness and spasticity in hamstrings is manifests as the posterior tilt of the pelvis (Figure 1). The subjects were asked to sit in a maximum possible erect posture (active correction), and then asked to reach forward. Reaching forward involves the movement of the trunk forward over the pelvis, as well as the pelvis forward over the hips. This movement hence causes a stretch of the hamstring muscles posteriorly at the hip. Since the muscles are already short (tight) and pelvis is already in posterior tilt, hence any additional forward movement will be resisted by the tight hamstrings on the pelvis, consequently limiting the excursion/reach.

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It is observed that children with CP have difficulties with functional tasks. These difficulties to a great extent emerge as a result of them initiating muscle activity from a position of biomechanical insufficiency, such as a posteriorly tilted pelvis, that then consequently lead to poor functional outcomes. Muscles that initiate and or carryout movements are in a poor length/tension relationship for producing adequate force to move a joint. The decreased muscle force that is produced is inadequate to overcome the resistance due to spasticity/tightness present in the muscles, as well as the weight of the limb. In addition, a posteriorly tilted pelvis may not allow adequate anticipatory postural adjustments to be generated efficiently before reaching or may not allow adequate compensatory adjustments once the task has begun.

In the present study, pelvic tilt was measured in an actively corrected posture in high sitting necessitating the active contraction of the trunk muscles and hip extensors. Unfortunately, children with CP are unable to actively generate forces required to overcome the tightness and correct the tilt. A limitation of this study was that muscle activation patterns of the hip and trunk muscles was not carried out to confirm the above assumption. Even though the relationship of Hamstrings tightness and pelvic tilt was found to be related in this study other factors, such as weakness of the hip extensors and abdominal muscles, which could contribute significantly to posterior pelvic tilt and sitting balance, need to be assessed and controlled for

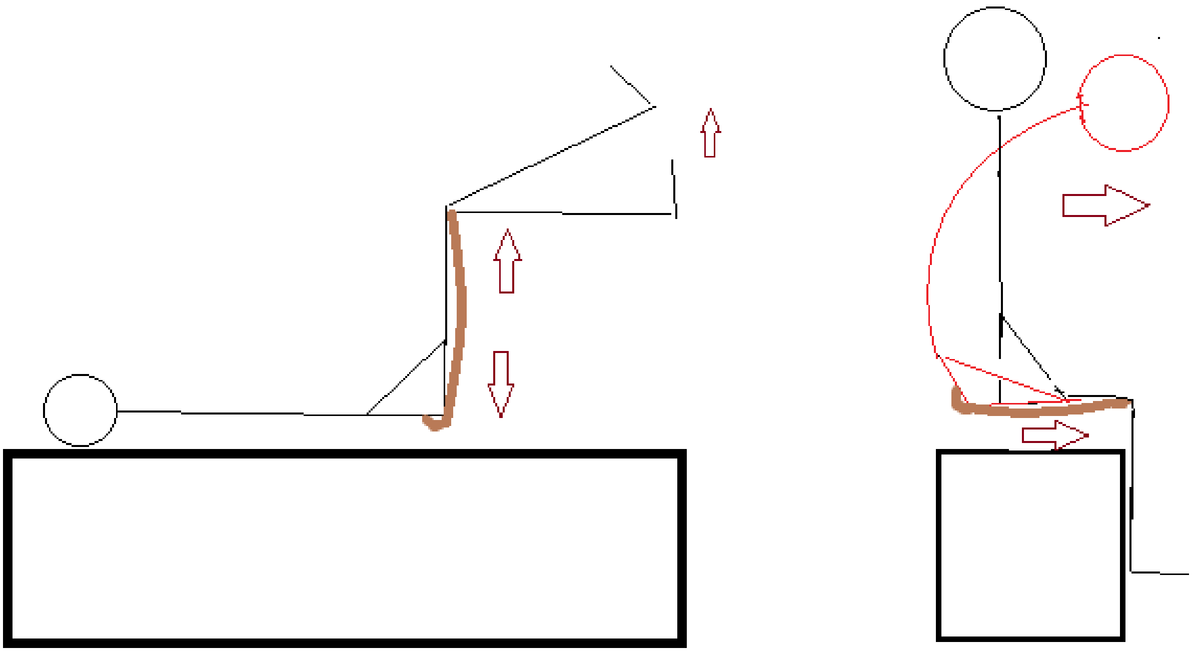

Fig. 1: Calculation of the R2 angle and the mechanical impact of hamstring muscle tightness on pelvic tilt

in future studies.

In the present study, it was observed that there was a correlation between the posterior pelvic tilt and reduced balance. The posterior tilt of the pelvis may not allow adequate force generation in the trunk muscles due to inadequate length-tension relationship. Also, due to inadequate alignment of the pelvis trunk muscles cannot be adequately recruited resulting in a craniocaudal recruitment pattern. A previous study on postural muscle dyscoordination in children with cerebral palsy reported that in contrast to typically developing children, children with CP showed a strong preference for a cranial-caudal recruitment order of the direction-specific postural muscles. The dominance for top-down recruitment is brought about by the slow recruitment of the trunk muscles and fast recruitment of the neck muscles. The latter was true in particular for children with a mild or moderate form of CP. The problems in the adaptation of the degree of muscle contraction might be the reason that children with CP, more often than typically developing children, show an excess of antagonistic co-activation during difficult balancing tasks and a preference for cranial-caudal recruitment during reaching.[11] Some studies have also hypothesized that the preference for top-down recruitment could be regarded as dysfunction or as a functional strategy to cope with task-specific circumstances.[20]

Previous studies have demonstrated that somatosensory signals derived from the posterior rotation of the pelvis, and not vestibular information from trigger postural responses during sitting. They suggested the use of a central pattern generator for postural adjustments that consists of two levels. At the first level, a simple format of the muscle activation would be generated; at the second level, the centrally generated pattern could be shaped and timed by interaction entirely from somatosensory, vestibular and visual inputs. Accordingly, it is suggested that (1) backward rotation of the pelvis triggers the postural adjustments in the independently sitting children; (2) a basic form of the postural adjustment develops in a predetermined manner before children practice independent sitting; and (3) the basic structure of ventral muscle activation pattern resembles that of adults, while the activation of the dorsal muscles (inhibition) differs in several aspects.[21] Thus, the importance of pelvis alignment in sitting postural control is supported by the findings of this study in which a significant correlation between posterior pelvic tilt and reduced sitting balance was observed. Furthermore, a pelvis fixed posteriorly may not elicit adequate somatosensory signals to generate an adequate postural response. Previous studies have shown that Children with CP have difficulties in fine-tuning the degree of postural muscle contraction to the task-specific conditions. Also, problems in adaptation of the degree of muscle contraction might be the reason that children with CP, demonstrate excessive eco-activation of muscles during balancing tasks and a preference for cranial-caudal recruitment during reaching.[11]

5. Conclusion

The systems model suggests that multiple neural and biomechanical factors interact to achieve the goal of balance. The task of balance requires that the centre of body mass be maintained over the base of support.[22] This interaction between the biomechanical and neural factors observed in this present study, as greater hamstrings muscle tightness was related to increased posterior pelvic tilt and consequently impacting muscle recruitment and reduced functional sitting balance. Thus, Hamstrings tightness in children with CP diplegia with increased posterior pelvic tilt, which in turn affects their sitting alignment/posture, sitting balance and hampers their prehensile and functional abilities. The present study population included CP diplegics that included children having GMFCS levels 1-3, all were independent walkers with or without a mobility aid. These children were in the age group 7-12 years, and all went to school that required long hours of sitting, and hence good balance was necessary for functional independence. The results of this study suggest that greater hamstring muscles tightness and increased posterior pelvic tilt resulted in reduced muscle efficiency and consequently poor sitting balance. Thus, it is suggested that physiotherapeutic interventions that address hamstring muscle tightness and the alignment of pelvis to the trunk and hip may improve sitting balance in CP children with diplegia.

As with all studies there were several limitations and thus, the results of this study should be implemented with caution. In addition to a small sample size that compromises external validity of the results, it is important to note that this was primarily a correlational study, thus cause and effect cannot or more importantly should not be considered.

6. Source of Funding

None.

7. Conflict of Interest

None.

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References

1. Woollacott MH, Burtner P, Jensen J, Jasiewicz J, Roncesvalles N, Sveistrup H. Development of Postural Responses During Standing in Healthy Children and Children with Spastic Diplegia. *Neurosci Biobehav Rev*. 1998;22(4):583–9.
2. Aruin AS. The Effect of Changes in the Body Configuration on Anticipatory Postural Adjustments. *Motor Control*. 2003;7(3):264–77.
3. Massion J. Postural Control Systems in Developmental Perspective. *Neurosci Biobehav Rev*. 1998;22(4):465–72.
4. Brodal P. The Neurological basis of balance. *Fysioterapeuten*. 2004;8:25–30.
5. Gjelsvik BEB. Thebobath concept in adult neurology. Stuttgart: Georg Thieme Verlag; 2008.
6. Shumway-Cook A, Woollacott MH. A lifespan perspective of mobility Motor Control: Translating research into clinical practice. Baltimore: Lippincott Williams & Wilkins; 2007.
7. Gurfinkel VS, Lipshits MI, Mori S, Popov KE. Stabilization of body position as the main task of postural regulation. *Hum Physiol*. 1981;7(3):155–65.
8. Bloem BR, Allum JHJ, Carpenter MG, Honegger F. Is lower leg proprioception essential for triggering human automatic postural responses? *Exp Brain Res*. 2000;130(3):375–91.
9. Heide CJCVD, Begeer C, Fock JM, Otten B, Stremmelaar E, van Eykern LA, et al. Mijna Hadders-Algra. Postural control during reaching in preterm children with cerebral palsy. *Dev Med Child Neurol*. 2004;46(4):253–66.
10. Pynt J, Higgs J, Mackey M. Seeking the optimal posture of the seated lumbar spine. *Physiother Theory Pract*. 2001;17(1):5–21.
11. van der Heide JC, Hadders-Algra M. Postural Muscle Dyscoordination in Children With Cerebral Palsy. *Neural Plast*. 2005;12(2-3):197–203.
12. Verheyden G, Vereeck L, Truijen S, Troch M, Herregodts I, Lafosse C. Trunk performance after stroke and the relationship with balance, gait and functional ability. *Clin Rehabil*. 2006;20(5):451–8.
13. Verheyden G, Nieuwboer A, Wit LD, Feys H, Schuback B, Baert I, et al. Trunk performance after stroke: an eye catching predictor of functional outcome. *Journal of Neurology, Neurosurgery & Psychiatry*. 2006;78(7):694–8.
14. Wu YW, Day SM, Strauss DJ, Shavelle RM. Prognosis for ambulation in cerebral palsy: a population-based study. *Pediatr*. 2004;114(5):1264–71.
15. Burtner PA, Qualls C, Woollacott MH. Muscle activation characteristics of stance balance control in children with spastic cerebral palsy. *Gait Posture*. 1998;8(3):163–74.
16. Girolami GL, Shiratori T, Aruin AS. Anticipatory postural adjustments in children with hemiplegia and diplegia. *J Electromyogr Kinesiol*. 2011;21(6):988–7.
17. van der Heide JC, Otten B, van Eykern LA, Hadders-Algra M. Development of postural adjustments during reaching in sitting children. *Exp Brain Res*. 2003;151(1):32–45.
18. Stamer M. Posture and Movement of the Child With Cerebral Palsy, Therapy Skill Builders; 2000.
19. Kendall M. Provance, Muscle Testing and Function. 4th ed. Lippincott Williams & Wilkins; 1993.
20. Popović MR, Pappas IPI, Nakazawa K, Keller T, Morari M, Dietz V. Stability criterion for controlling standing in able-bodied subjects. *J Biomech*. 2000;33(11):1359–68.
21. Hirschfeld H, Forssberg H. Epigenetic development of postural responses for sitting during infancy. *Exp Brain Res*. 1994;97(3):528–40.
22. Woollacott MH, Cook AS. Changes in Posture Control Across the Life Span—A Systems Approach. *Phys Ther*. 1990;70(12):799–7.

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