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Effect of Sensorimotor Training Using a Flexi-bar on Postural Balance and Gait Performance for Children With Cerebral Palsy: A Preliminary Study

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Abstract

Background: Children with cerebral palsy (CP) have impaired postural control, but critically require the control of stability. Consequently, therapeutic interventions for enhancing postural control in children with CP have undergone extensive research. One intervention is sensorimotor training (SMT) using a Flexi-bar, but this has not previously been studied with respect to targeting trunk control in children with CP.

Objects: This study was conducted to determine the effect of SMT using a Flexi-bar on postural balance and gait performance in children with CP.

Methods: Three children with ambulatory spastic diplegia (SD) participated in the SMT program by using a Flexi-bar for forty minutes per day, three times a week, for six weeks. Outcome variables included the pediatric balance scale (PBS), trunk control movement scale (TCMS), 10 meter walking test (10MWT), and 3-dimensional movement coordination measurement.

Results: The SMT provided no statistically significant improvement in PBS, TCMS, 10MWT, or 3-dimensional movement coordination measurement. However, positive changes were observed in individual outcomes, as balance and trunk control movement were improved.

Conclusion: SMT using a Flexi-bar may be considered by clinicians as a potential intervention for increasing postural balance and performance in children with SD. Future studies are necessary to confirm the efficacy of Flexi-bar exercise in improving the functional activity of subjects with SD.

Key Words: Cerebral palsy; Sensori-motor training; Trunk control; Vibratory stimuli.

Introduction

Postural control is defined as the ability to maintain a body segment in space to gain stability and orientation (Duarte and Freitas, 2010). Stability is the ability to control the center of body mass within a limited base of support in functional activities (Corrêa et al, 2007). During the upper and lower extremity movement, the trunk provides a stable ground. Additionally, it leads to active participation during reaching, sitting, walking, and activities of daily living (Prosser et al, 2010; Saavedra et al, 2009). Maintaining a stable position during daily functional activities is challenging because stability requires complex interactions among the central nervous, sensory, and musculoskeletal systems (Corrêa et al, 2007). These interactions are impaired in patients with cerebral palsy (CP), which may be one reason why postural control is impaired and the control of stability is critical in these patients (Woollacott et al,

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2005). Children with CP show a major effect of postural dysfunction as an inability to coordinate the activation of postural muscles, especially during functional activities (de Graaf-Peters et al, 2007). This problem then limits gross motor function during voluntary movement and can result in falls (Ju et al, 2010). Therefore, they need a trunk stabilization exercise and a carry-over effect on functional balance (Unger et al, 2013).

Previous studies have extensively researched therapeutic interventions, such as gross motor training (Katz-Leurer et al, 2009), hippotherapy (Zadnikar and Kastrin, 2011), and functional electrical stimulation (Karabay et al, 2012), for enhancing postural control in children with CP. Researchers have recently recommended trunk-targeted training on a vibration board (Unger et al, 2013) and reactive balance training through perturbation (El-Shamy and Abd El Kafy, 2014), which are types of sensorimotor training, as described by Janda. Sensorimotor training includes the passive and active facilitation of afferents that have a strong impact on posture control and equilibrium and is effective for facilitation of the muscle spindle (Umphred et al, 2001). Several devices can be used during oscillation exercises to facilitate muscle activation. Current evidence indicates that proprioception plays a part in maintaining the proper function of the lower leg and balance and in decreasing the risk of injury (Hrysomallis, 2007). Additionally, arousing the sole of the foot enhances postural sway and kinesthesia (Maki et al, 1999), indicating the effects of proprioception in sustaining proper posture.

However, trunk-targeted training on a vibrating board is less commonly conducted due to the expense of the device, space limitations, and its passive mechanism. An alternative device is the Flexi-bar (Flexi-Sports, Bisley, Stroud, United kingdom, 510 g weight, 118 ㎝ length), a portable, inexpensive, useful, and active device that activates muscles (Mileva KN et al, 2010). When the Flexi-bar oscillates, minimal additional energy is required to maintain this oscillation. The Flexi-bar is commonly used for upper extremity stabilization and to augment grip strength by performing oscillating movements. It provides various degrees of resistance to match the individual's competency. It is used to produce vibratory stimuli, in which co-activation of the muscles of the shoulder girdle and core generates vibration of the device, with the aim of increasing muscle strength and endurance. Flexi-bar is claimed to enhance the trunk stabilizing muscles, such as transverse abdominis, rectus abdominis, errector spinae and latissimus dorsi (Mileva KN et al, 2010).

Previous study has examined the activation pattern of the trunk muscles in healthy subjects or have quantified upper and lower extremity muscle activation in healthy subjects during common shoulder exercises when using an oscillatory device (Moreside JM et al, 2007). And several studies have found that flexi-bar exercise improve functional reach, shoulder stability and trunk muscle activity (Chung JS et al, 2015; Kim and Kim, 2016). It is a useful device to enhance limb muscle activation and trunk stability in healthy subjects; however, to our knowledge, no previous studies have targeted trunk control in CP using a Flexi-bar. The purpose of this study was to determine the effect of SMT using a Flexi-bar on postural balance and gait performance in children with CP.

Methods

Subjects

Three children with spastic diplegia (2 females, 1 male mean age=12.7 years) took part in this study. They were received conventional physiotherapy two times a week. Inclusion criteria were: 1) a sufficiently cooperative attitude to obey verbal instructions, 2) Gross Motor Function Classification System (GMFCS) level Ⅰ or Ⅱ, modified Ashworth scale 0~2, and 3) ability to sit without trunk support. Exclusion criteria were: 1) cognitive disorder, 2) visual disorder, 3) cardiorespiratory disorder, 4) orthopedic intervention and 5) undergoing botulinum toxin injections in the past

Table 1. General characteristics of subjects (N=3)

Subjects	Gender	Age (year)	Height (㎝)	Weight (㎏)	MAS[a]	GMFCS[b] level
Child 1	Female	10	132.0	30.0	G1+	Ⅰ
Child 2	Female	14	149.3	55.0	G1+	Ⅱ
Child 3	Male	14	153.2	49.0	G1+	Ⅱ

[a]modified Ashworth scale, [b]gross motor function classification system.

one year. Children and their legal proxies were provided a consent form prior to this study. The study protocol was approved by Yonsei University (approval number: 1041849-201611-BM-062-02).

Child 1 was a 10-year-old female with GMFCS Ⅰ, delivered by a normal spontaneous vaginal delivery after a 32-week gestation. The cause of CP was periventricular leukomalacia. Child 2 was a 14-year-old female with GMFCS Ⅱ, delivered by cesarean section after a 27-week gestation. The cause of CP was fetal alcohol syndrome during her mother's pregnancy. Child 3 was a 14-year-old male with GMFCS Ⅱ, delivered by cesarean section after a 30-week gestation. The cause of CP was viral meningitis. Table 1 shows the characteristics of subjects.

Pediatric Balance Scale

The Pediatric Balance Scale (PBS) is a clinical test that evaluates balance ability in school-age children with motor disabilities. The PBS consists of 14 items and allows a quick and easy examination without specialized equipment. The extent of performance yields scores ranked from 0 to 4 points. The PBS score ranges from a minimum of 0 to a maximum of 56. The PBS has inter-rater reliability [intra-class correlation coefficient; ICC (2,1)=.972] and test-retest [ICC (2,1)=.923].

Trunk Control Movement Scale

The Trunk Control Movement Scale (TCMS) is derived from the Trunk Impairment Scale. The TCMS, consisting of 15 items, examines trunk control of spastic CP, GMFCS levels Ⅰ～Ⅴ, and ages from 8 to 15 years. The TCMS assesses static sitting balance, dynamic sitting balance, and dynamic reaching. The total TCMS score ranges from a minimum of 0 to a maximum of 58. Heyrman et al (2013) showed that a higher score means a better ability of the child. ICCs ranged from .91 to .99 for inter-rater and test-retest reliability.

10 meter walking test (10MWT)

Subjects were requested to walk as fast as they could through a 12 m hallway, using assistive devices when needed. The influence of acceleration and deceleration was avoided by taking the, test results from the middle 10 m of the hallway. Walking speed was derived by dividing the distance by the time (in seconds) required to walk the 10 m (Yang et al, 2008).

3-dimensional movement coordination measurement

A 3-axis accelerometer was used to assess the trunk acceleration during the Flexi-bar exercise. Movement acceleration has been used to estimate movement acceleration coordination (Michaelsen et al, 2013). The accelerometer was attached over the sternum (Janssen et al, 2008), with the participant in a prone position, to measure lineal acceleration, where the X-axis means anterioposterior motion; Y-axis, mediolateral motion; and Z-axis, vertical motion. The participant then assumed a supine, kneeling, standing against wall, and standing position, and the 3-axis accelerometer sensor was attached over the L3 region of the participant's lower back (Saether et al, 2014). The LabPro interface (Vernier Software & Technology, Oregon, USA) was used to connect the sensor, and software (Logger Pro3, Vernier Software & Technology, Oregon, USA) was used to process and graphically display the data on a computer

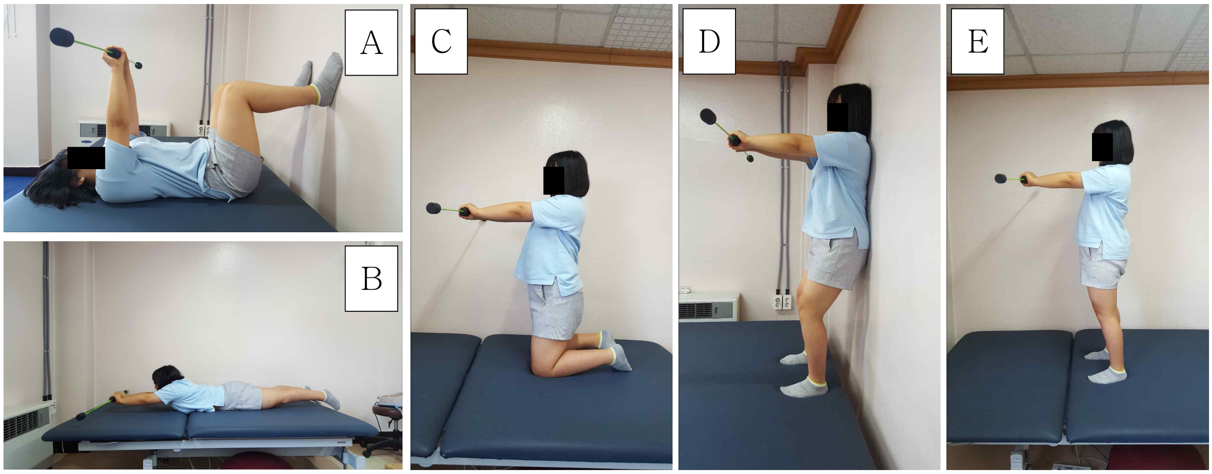

Figure 1. Flexi-bar exercise positions (A: supine, B: prone, C: kneeling, D: wall standing, E: standing).

monitor. Of the total data received for 24 seconds (1200 data points), the most consistent and representative data acquired for 2 seconds (100 data points) of movement was used. Trunk movement coordination was measured by computing the standard deviations of the X-axis, Y-axis, and Z-axis acceleration movements and used for further statistical analysis. The test-retest reliability for movement acceleration measurements was also determined using the 3-axis accelerometer, as described in a previous study, and showed an excellent reliability (r=.92) (Yoo, 2015).

Experimental procedures

Each child received 40 minutes of Flexi-bar exercise per day, three days a week, for six weeks (i.e. a total of 18 sessions). The exercises were composed of 5 sets, repeated 3 times for each session. The orthosis was removed prior to performing the exercises. Prior to exercise, a therapist performed muscle stretching (hip flexor, hamstrings and ankle plantar flexor) for 5 minutes to inhibit muscle tone and to correct posture. The children then performed Flexi-bar exercises in the supine, prone, kneeling, wall standing, and standing positions. The exercises were performed with moderate assistance and then carried out without assistance. Finally, the therapist released their muscles for 5 minutes to prevent muscle fatigue. The outcomes were measured before and after intervention. The physiotherapy that they had previously received was continued during the intervention period.

Sensorimotor training

The exercises consisted of: A) the child lying on the back with hip, knee 90° flexion and placing the feet on the wall, and moving the Flexi-bar; B) the child lying on the stomach, hands over the head, and moving the Flexi-bar; C) the child kneeling and moving Flexi-bar on the floor with both hands; D) the child standing against the wall and moving the Flexi-bar; E) the child standing and moving the Flexi-bar (Figure 1).

Statistical analysis

The data were analyzed using the SPSS ver. 18.0 (SPSS Inc., Chicago, IL, USA) statistical package. The differences in pre- and post-test measurements within group were compared using the Wilcoxon signed-rank test. Statistical significance was set at $p<.05$. The difference in each child was assessed by calculating the percent changes from pre-test to post-test [improvement (%)=(post-pre)/pre×100].

Results

No significant differences were noted in the PBS, TCMS, and 10MWT ($p>.05$) (Table 2). However,

Table 2. Results of the PBS, TCMS, and 10MWT (N=3)

Variables	Pre	Post	p
PBS[a] (score)	47.33±6.03[b]	48.67±6.50	.10
TCMS[c] (score)	37.67±8.74	43.00±9.64	.11
10MWT[d] (sec)	8.42±.63	7.70±.67	.11

[a]pediatric balance score, [b]mean±standard deviation, [c]trunk control measurement scale, [d]10 meter walking test, p values are the results of Wilcoxon signed-rank test.

Table 3. Pre- and post-test scores of PBS and TCMS (N=3)

	PBS[a]			TCMS[b]		
	Pre	Post	Improvement (%)	Pre	Post	Improvement (%)
Child 1	53.00	55.00	3.77	40.00	50.00	25.00
Child 2	41.00	42.00	2.44	28.00	32.00	14.29
Child 3	48.00	49.00	2.08	45.00	47.00	4.44
Mean±SD[c]	47.33±6.03	48.67±6.50	2.77	37.67±8.74	43.00±9.64	14.58

[a]pediatric balance score, [b]trunk control measurement scale, [c]standard deviation.

Table 4. 3-dimensional movement coordination measurement

	X-axis		p	Y-axis		p	Z-axis		p
	Pre	Post		Pre	Post		Pre	Post	
Supine	.97±.17[a]	.69±.23	.11	.41±.08	.44±.11	.59	.45±.14	.34±.11	.11
Prone	.72±.12	.60±.25	.29	.49±.08	.46±.12	.29	.16±.06	.09±.05	.11
Kneeling	.67±.23	.53±.09	.11	.97±.14	.58±.07	.11	.45±.17	.31±.03	.11
Wall standing	.81±.08	.55±.01	.18	.66±.28	.50±.05	.18	.49±.09	.34±.02	.18
Standing	.71±.02	.45±.09	.18	.45±.03	.36±.18	.65	.51±.12	.22±.06	.18

[a]mean±standard deviation.

some positive changes were observed in the percent changes for each child and walking speed. All children showed improvements in their total percentage scores on the PBS and TCMS and increased walking speed. The results for the PBS and TCMS for each child are presented in Table 3. No significant statistical differences were noted in the 3-dimensional Movement Coordination Measurement, but the standard deviations for kneeling and wall standing were decreased (Table 4).

Discussion

This study examined sensorimotor training using a Flexi-bar in children with CP. Our study results showed no statistically significant differences in postural balance and gait performance in children with spastic diplegia. The PBS score did not show a significant difference, but positive changes were noted in the PBS score. The children showed improvement in standing on one leg. One leg standing balance is associated with locomotion function and participation in activities and is considered to provide lower limb stability. Balance control requires the displacement of the center of gravity on a limited base of support, as well as skilled movement.

The TCMS score did not show a significant difference, but the changes in all the children's TCMS scores showed an enhanced performance in crossing one leg over the other leg. This ability requires maintaining a stable trunk position in a seated position, which distributes the weight appropriately during static sitting. The 3-dimensional movement coordination measures the postural response to external perturbation during Flexi-bar oscillating vibration. The 3-dimensional movement coordination did not show significant differences, but the change in the x, y, and z coordination showed smaller movements related to the resulting perturbation in the prone, kneeling, wall standing, and standing positions. This means that the participant's postural sway during this exercise was decreased after six weeks of sensorimotor training.

The Flexi-bar is claimed to give a very low frequency vibration-like stimulus (5 ㎐) through the grip point (hand) to the rest of the body, although this still has not been directly quantified. In a previous study, the Flexi-bar exercise successfully imparted a 5 ㎐ vibration to the arm muscles, which was effectively transmitted from the hand, through the arm and trunk, to the leg muscles, at least when the participant was in a one-leg squat position (Mileva et al, 2010).

Several studies (Damiano et al, 1995; Eagleton et al, 2004) have researched the effects of a significant component of resistive muscle strength training and have reported promising improvements in gait performance and muscle strength in subjects with CP. Damiano et al (1995) reported a progressively resistive quadriceps muscle strength program, which involved the performance of exercises for six weeks, significantly improved the gait speed, crouch pattern, and stride length in children with diplegia. Similarly, Eagleton et al (2004) showed that a generalized progressive strengthening exercise, associated with the trunk and lower extremity muscles, improved the gait speed, step length, cadence, distance, and energy consumption. Thus, subjects with CP need at least six weeks to achieve muscle strengthening.

The results of the present study suggest that therapists should consider sensorimotor training using a Flexi-bar during the rehabilitation of children with CP and that this training should be included in conventional treatment programs. The results also support a recommendation for the use of the Flexi-bar as an efficient postural control training device for enhancing postural balance and gait performance in children with spastic diplegia.

The present study had two major shortcomings. One limitation was that the impact of Flexi-bar exercise on changes in abdominal muscle activity was not investigated in this study. Further studies using ultrasonography or electromyography are needed to examine the changes in abdominal muscle activity related to trunk stability. Second, this preliminary clinical trial examined the effects of sensorimotor training using a Flexi-bar only in children with spastic diplegia. And ceiling effects were probably seen in clinical tests which were unable to measure quality of movement. Future studies need to target different age groups, different types of CP, different severity of disability, the specific intensity of Flexi-bar training, and larger sample sizes of children with CP for generalization of these findings. Third, we didn't measure control group data. Other exercises for improving postural control in children with SD were also not explored in this study.

Conclusion

This study investigated the effects of sensorimotor training using a Flexi-bar in three children with spastic diplegia. The results showed small but potentially important changes in trunk control, balance, and walking speed after the intervention. The findings suggest that sensorimotor training using a Flexi-bar may be promising for some children with CP. Generalization of the findings is limited due to the small sample size of children with CP, but sensorimotor training using a Flexi-bar may be considered by clinicians as a potential intervention. Future studies with larger sample sizes are necessary to confirm the efficacy of Flexi-bar exercise in improving the functional activity of subjects with CP.

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