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Effect of Horizontal Whole-Body Vibration Training on Trunk and Lower-Extremity Muscle Tone and Activation, Balance, and Gait in a Child with Cerebral Palsy

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Patient: Male, 10
Final Diagnosis: Cerebral palsy
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Medication: —
Clinical Procedure: —
Specialty: Rehabilitation

Objective: Unusual or unexpected effect of treatment

Background: The aim of the present study was to investigate the effect of horizontal whole-body vibration (WBV) training on trunk and lower-extremity muscle tone and activation, balance, and gait in a child with spastic diplegia cerebral palsy.

Case Report: A 10-year-old male with spastic diplegia cerebral palsy received horizontal WBV training followed by conventional physiotherapy (50 min per day, 12 days per month), but only conventional physiotherapy during follow-up. Muscle tone was assessed using the Modified Ashworth Scale (MAS) and muscle activation with surface electromyography. Balance was assessed using the Timed Up and Go test (TUG) and Pediatric Balance Scale (PBS), and gait parameters were assessed using the GAITRite system. Assessment was performed at 3 points: pre-intervention, post-intervention, and follow-up. Following the intervention, MAS decreased in both the hip extensor and right ankle plantar flexor. Muscle activation increased post-intervention in the bilateral erector spinae (ES), rectus abdominis (RA), rectus femoris (RF), and right tibialis anterior (TA) during standing, and in the left RA, bilateral RF, gastrocnemius (GCM), and left TA during squatting. At follow-up, activation increased in the right ES, left RA, and RF during standing. At post-intervention and follow-up, improvement was observed in PBS score, gait velocity, right step length, and right stride length, with decreased single-leg support time, and double support and toe deviation angle.

Conclusions: Horizontal WBV training can safely and effectively maintain and improve physical performance and can be considered for inclusion in rehabilitation programs.

MeSH Keywords: Cerebral Palsy • Gait • Muscle Hypertonia • Postural Balance • Vibration

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Background

Cerebral palsy is caused by non-progressive damage to the brain before, during, and after birth, resulting in motor and sensory impairments, such as muscle weakness, and abnormal muscle tone, and motor control [1]. Brain damage causes abnormal muscle activity, weight-bearing impairment, and limited range of motion due to shortened muscles, which in turn lead to secondary musculoskeletal problems and restricted movement [2]. In addition, postural control is limited due to reduced body response to restore stability after unexpected external force [3].

Recently, there has been an increasing focus on improving quality of life in patients with cerebral palsy using several interventions [4–7]. Among these, whole-body vibration (WBV) has been used to improve muscle activity, motor function, and bone development in patients with cerebral palsy [8–10]. Spasticity, movement control impairment [11], and reduction of postural control [3] in children with cerebral palsy are positively influenced through attention to the muscle-tendon unit, which is stimulated by tension-induced vibration reflexes, causing muscle spindles to sense the length of the muscle fiber bundle [12]. Therefore, stimulation by vibration improves motor function in children with cerebral palsy.

WBV involves transmission of low-amplitude, mechanical stimuli through the body with the feet on a vibrating footplate [10,14,15]. A synchronous vibration platform has been used, in which the whole footplate moves vertically; in addition, a side-alternating Galileo vibration platform is used, in which the left and right footplate alternately rotate. Thus, WBV alleviates the spasticity in subjects with upper motor neuron disease by altering the onset of muscle spindle stimulation and muscle contraction, and might therefore be an effective therapeutic approach for muscle strengthening [16–18]. In addition, Saquetto et al. (2015) reported that WBV training in a vertical direction is effective for improving gait velocity, muscle strength, and bone density, but not gross motor function, in patients with cerebral palsy [19].

However, in previous studies, WBV training on a synchronous vibration platform or side-alternating vibration platform has been associated both with benefits and adverse effects. These studies have shown that vibration can cause spinal problems or excessive muscle fatigue, depending on the frequency generated by the WBV scaffold, and the vibration transmitted to the head may have risks, with possible cerebral cortex damage [20–24]. In particular, the side-alternating Galileo vibration platform may have a greater impact on the cerebral cortex than that of the vertical vibrating platform [25,26]. A comparison of the vertical and horizontal platforms [27] showed that the amplitude of vibration provided by the horizontal platform is less than half the vibration amplitude in the vertical platform. The horizontal platform vibration was also found to improve neck stability and free movement of the head [3,28,29]. Weight-bearing is induced through a foot that moves in an anteroposterior direction [30,31] and improves decreased balance ability caused by neurologic disorders [32].

Thus, WBV provided in the horizontal vibrating platform can overcome the adverse effects or problems of conventional WBV in a vertical or rotational direction. In addition, previous studies also reported the possible effect of WBV on balance and gait in neurological disorders [3,28–32]. However, there have been no studies on the effect of WBV training using a horizontal vibration platform on children with cerebral palsy. Therefore, the aim of this study was to investigate the effects of WBV training using a horizontal vibrating platform on muscle tone, muscle activity, balance, and gait in a child with spastic diplegia cerebral palsy.

Case Report

Patient history and systems review

The patient was a 10-year-old boy diagnosed with spastic diplegia cerebral palsy who was treated at the J Rehabilitation Center in the Republic of Korea. The boy was 130 cm in height and 27 kg in body weight, and had been born at a gestational age of 39 weeks and 15 days. Magnetic resonance imaging at the time of delivery did not show any abnormal findings; however, the boy subsequently showed delayed development and whole-body hypotonicity.

The patient had restricted range of motion in all lower-extremity joints. Due to reduced stability of the trunk, he had difficulty controlling posture when standing. The patient did not have a history of additional developmental problems, but had secondary musculoskeletal problems, including scoliosis, due to cerebral palsy. As a result, leg length measured 66.2 cm on the right and 67.8 cm on the left. In addition, the pelvis was posteriorly tilted and a crouch gait pattern showing a reduced angle between the tibia and sole was observed.

The subject had no difficulty with independent living, and had functional movement using gross motor muscles for running or jumping, but speed, balance, and coordination of tasks were limited. Level I ratings were determined for the Gross Motor Function Classification System and Manual Ability Classification System, as there was no restriction in daily living activities, with respect to the speed and accuracy required. A Level 1 rating was also determined for the Communication Function Classification System, indicating good communication ability.

The study was conducted following approval by the Kyungnam University institutional review board. The subject and legal representative of the subject were informed about the purpose and procedures of the study and voluntarily signed pediatric and legal representative consent forms.

Examination

Examination of muscle tone, muscle activity, balance, and gait was performed pre-intervention, post-intervention, and at follow-up. The Modified Ashworth Scale (MAS) was used to examine muscle tone. Hip flexion, hip extension, knee flexion, knee extension, ankle dorsiflexion, and ankle plantar flexion were evaluated and the MAS score was based on the classification by Bohannon and Smith [33].

Surface electromyography was used to analyze muscle activity. The electromyography electrodes were attached to the muscle bellies according to the SENIAM guidelines [34]. The electrode for the erector spinae (ES) was attached at the lower costal margin, at approximately L2 level, 1 fingerbreadth from the center of the posterior superior iliac spine. The electrode for the rectus abdominis (RA) was attached 2–3 cm medial to the fourth part of the muscle or 2 cm below the umbilicus, and the electrode for the rectus femoris (RF) was attached midway between the upper patella and anterior superior iliac spine. The electrode for the tibialis anterior (TA) was attached at a point one-third of the distance between the end of the fibula and tip of the malleolus. The electrode for the medial gastrocnemius (GCS) was attached to the prominent muscle area. The activity of each muscle was measured 3 times at pre- and post-intervention and follow-up evaluation and the mean values were calculated. The sampling rate was 2000 Hz, and a 60-Hz high-pass filter and 10 Hz low-pass filter were applied (all were zero-lag 4th order Butterworth filters). For normalization, the root mean square (RMS) values of the raw EMG data were calculated. The EMG data for each muscle were normalized by calculating the RMS of the 5-s maximum voluntary isometric contraction (MVIC) of the muscle. The activity of the measured muscles was evaluated as 100% (MVIC); the muscle activity measured was expressed as a percentage. The activity of each muscle was recorded 3 times during pre- and post-intervention and follow-up evaluation, and the mean values were calculated. The Pediatric Balance Scale (PBS) and Timed Up and Go (TUG) test were used to examine static and dynamic balance ability. function was examined using a GAITRite® electric walkway [35]. Gait was measured while walking on a 461×88 cm pad at the most comfortable gait speed while looking ahead, with verbal cues by the examiner.

All measurements were repeated 3 times and the average value was calculated. One minute of rest was provided between trials to minimize muscle fatigue.

Clinical impression

On the MAS, hip flexion on the right side was scored 0 points, with hip extension 1+, knee flexion 0, extension 1, ankle joint dorsiflexion 0, and plantar flexion 1+. Left hip flexion was scored as 0, with hip extension 1+, knee extension 1, ankle dorsiflexion 0, and plantar flexion 1.

Muscle activity in the standing position for the ES was 20.50% on the right side and 20.78% on the left side; for RA, 22.59% on the right side and 28.05% on the left side; for RF, 6.12% on the right side and 9.17% on the left side; for GCS, 16.40% on the right side and 21.07% on the left side; and for TA, 8.76% on the right side and 23.87% on the left side. Muscle activity in the squatting position for the ES was 25.64% on the right and 31.57% on the left; for the RA, 18.61% on the right and 7.77% on the left; for the RF, 4.22% on the right and 8.41% on the left; for the GCS, 14.79% on the right and 15.08% on the left; and for the TA, 16.70% on the right and 13.28% on the left.

The TUG test score was measured at 9.90 s and the PDS was measured at 42 points. Gait velocity was 72.8 cm/s; cadence 95.6 steps/min; step length 46.15 cm on the right and 45.34 cm on the left; stride length 90.36 cm on the right and 93.26 cm on the left. Single-leg support time was 0.47 s on the right and 0.47 s on the left. Double-leg support time was 0.29 s on the right and 0.32 s on the left. The toe deviation was –2.1° on the right and –13.5° on the left.

Intervention

In the present case report, conventional physical therapy and horizontal WBV training were performed. Conventional physical therapy included range of motion exercises, with trunk stability exercises to reduce muscle tone, weight-bearing exercises, and balance and daily living activity exercises [36,37], The exercise program was performed 3 times a week for 30 min for a duration of 8 weeks. The WBV training in horizontal direction was applied 3 times a week for 20 min, for a total of 4 weeks [38].

Whole-body vibration training in horizontal direction

In the present study, horizontal WBV (Extream 1000; AMH International Inc., Incheon, Republic of Korea) transferred vibration to the whole body through the footplate. The footplate provided an amplitude of 30 mm in the anteroposterior direction and a frequency of 1–9 Hz. The frequency of the horizontal WBV footplate was classified from level 5 (1 Hz) to level 40 (9 Hz). In a previous study [39], a frequency of 30 Hz was reported to minimize damage to soft tissue in the head. The frequency was set to a level that was comfortable for the subject and was gradually increased. The frequency was set from level 15 to level 25 (approximately 2–4 Hz) [40]. The subject


[redacted]

Figure 1. Horizontal whole-body vibration training.

was allowed to stand on the vibration footplate with bare feet (knee flexion at 20°). In order to prevent foot movement, the researcher placed a foot on the marked location, with gaze centered at a point marked on the wall. If necessary, the subject could hold the safety bar at any time. The horizontal WBV training was performed for 20 min, followed by a half hour of physical therapy and a 10-min rest period. The horizontal WBV equipment was installed in a room without outside interference, with a safety mattress placed on the floor (Figure 1).

Data analysis

In the present study, the measured pre-evaluation, post-intervention, and follow-up values were analyzed using descriptive statistics.

Outcomes

Modified Ashworth Scale

The results obtained from the lower-extremity muscular spasticity scale are shown in Table 1. The extension of the hip joint was increased by 1 point in pre-evaluation and decreased by 1 point in post-evaluation and follow-up.

Muscle activities

Standing posture (knee 0°)

The results obtained for the activities of the ES, RA, RF, medial GCS, and TA are shown in Table 2. The activation of the right ES increased by 2.65% post-intervention and 19.52% in follow-up evaluation, while that of the left ES increased by 7.72% post-intervention and decreased by 7.49% in follow-up evaluation. The activation of the right RA was increased by 24.08% post-intervention and decreased by 7.49% in follow-up evaluation, while that of the left RA increased by 19.83% post-intervention and by 2.39% in follow-up evaluation. The activation of the right RF increased by 0.52% post-intervention and by 4.31% in follow-up evaluation, while that of the left RF increased by 2.14% post-intervention and by 2.11% in follow-up evaluation. The activation of the right medial GCS decreased by 7.15% post-intervention and increased by 0.83% in follow-up evaluation, while that of the left medial GCS decreased by 8.4% post-intervention and increased by 20.08% in follow-up evaluation. The activation of the right TA increased by 22.68% post-intervention and decreased by 15.18% in follow-up evaluation, while that of the left TA decreased by 7.97% and 2.45% in post-intervention and follow-up evaluation, respectively.

Table 1. Comparison of Modified Ashworth Scale.

		Pre	Post (1 month)	Follow-up (2 month)
Hip flexion	Right	0	0	0
	Left	0	0	0
Hip extension	Right	1+	1	1
	Left	1+	1	1
Knee flexion	Right	0	0	0
	Left	0	0	0
Knee extension	Right	1	1	1
	Left	1	1	1
Ankle dorsiflexion	Right	0	0	0
	Left	0	0	0
Ankle plantar flexion	Right	1+	1	1
	Left	1	1	1

Table 2. Comparison of muscle activity in standing posture.

		Pre	Post (1 month)	Follow-up (2 month)
Erector spinae (% of MVIC)	Right	20.50	23.15	42.67
	Left	20.78	28.50	21.01
Rectus abdominalis (% of MVIC)	Right	22.59	46.67	44.69
	Left	28.05	47.88	50.27
Rectus femoris (% of MVIC)	Right	6.12	6.64	10.95
	Left	9.17	11.31	13.42
Gastrocnemius (medial) (% of MVIC)	Right	16.40	9.25	10.08
	Left	21.07	12.67	32.75
Tibialis anterior (% of MVIC)	Right	8.73	31.44	16.26
	Left	23.87	15.90	13.45

MVIC – maximum voluntary isomeric contraction.

Table 3. Comparison of muscle activity in squat posture.

		Pre	Post (1 month)	Follow-up (2 month)
Erector spinae (% of MVIC)	Right	25.64	22.65	22.00
	Left	31.57	15.24	19.35
Rectus abdominalis (% of MVIC)	Right	18.61	12.67	44.32
	Left	7.77	15.70	50.99
Rectus femoris (% of MVIC)	Right	4.22	6.51	7.41
	Left	8.41	9.78	12.53
Gastrocnemius (medial) (% of MVIC)	Right	14.79	48.00	20.06
	Left	15.08	40.41	14.82
Tibialis anterior (% of MVIC)	Right	16.70	9.17	16.47
	Left	13.28	18.89	17.96

MVIC – maximum voluntary isomeric contraction.

Squatting posture (knee flexion 20°)

The results obtained for the activities of the ES, RA, RF, GCS, and TA are shown in Table 3. The activation of the right ES decreased by 2.99% post-intervention and by 0.65% in follow-up evaluation, while the left ES decreased by 16.33% post-intervention and increased by 4.11% in follow-up evaluation. The activation of the right RA decreased by 5.94% post-intervention and increased by 31.65% in follow-up evaluation, while the left RA increased by 7.93% and 35.29% post-intervention and in follow-up evaluation, respectively. The activation of the right RF increased by 2.29% post-intervention and 0.90% in follow-up evaluation, while the left RF increased by 1.37% and 2.66% post-intervention and in follow-up evaluation, respectively. The activation of the right medial GCS increased by 33.21% post-intervention and decreased by 27.94% in follow-up evaluation, while the left medial GCS increased by 25.33% and decreased by 25.59% post-intervention and in follow-up evaluation, respectively. The activation of the right TA decreased by 7.53% post-intervention and increased by 7.30% in follow-up evaluation, while the left TA increased by 5.61% and decreased by 0.93% in post-intervention and follow-up evaluation, respectively.

Balance

The TUG test and PDS results are shown in Table 4. The TUG test showed an increase from 0.31 s to 10.21 s in the post-intervention evaluation. However, the follow-up evaluation showed a decrease of 0.61 s. On the PDS, the post-intervention evaluation demonstrated an increase of 6 points (to 48 points) and the follow-up evaluation increased by 3 points (to 51 points).

Table 4. Comparison of Timed Up and Go test and Pediatric Balance Scale.

	Pre	Post (1 month)	Follow-up (2 month)
Timed Up and Go (sec)	9.90	10.21	9.60
Pediatric Balance Scale (point)	42	48	51

Table 5. Comparison of spatiotemporal gait parameters.

		Pre	Post (1 month)	Follow-up (2 month)
Gait Speed (cm/s)		72.80	96.60	136.40
Cadence (steps/min)		95.60	125.70	136.20
Step length (cm)	Right	46.15	47.15	60.77
	Left	45.34	44.83	59.13
Stride length (cm)	Right	90.36	92.29	122.84
	Left	93.26	91.29	118.33
Single support time (s)	Right	0.47	0.35	0.37
	Left	0.47	0.36	0.37
Double Support time (s)	Right	0.29	0.24	0.15
	Left	0.32	0.22	0.13
Toe deviation angle (˚)	Right	–2.1	–2.3	–1.1
	Left	–13.5	–7.6	–5.8

Gait

The spatiotemporal gait parameters are shown in Table 5. The velocity increased to 23.8 cm/s in post-intervention evaluation and 39.8 m/s in follow-up evaluation. The cadence per minute showed an increase of 30.1 steps/min post-intervention and an increase of 10.5 steps/min in follow-up evaluation. The right step length increased by 1.00 cm in post-intervention evaluation and by 13.62 cm in follow-up evaluation. The left step length showed a decrease of 0.51 cm in post-intervention evaluation, but an increase of 14.30 cm in follow-up evaluation. The right stride length increased by 1.93 cm in post-intervention evaluation and by 30.55 cm in follow-up evaluation. The left stride length showed a decrease of 1.97 cm in post-intervention evaluation, but an increase of 27.04 cm in follow-up evaluation. The single-leg support time on the right decreased 0.12 s post-intervention, but increased by 0.02 s in follow-up evaluation. The single-leg support time on the left showed a decrease of 0.11 s in post-intervention evaluation and of 0.01 s in follow-up evaluation. The right double-leg support time showed a decrease of 0.05 s post-intervention and 0.09 s in follow-up evaluation. The left double-leg support time showed a decrease of 0.10 s post-intervention and 0.09 s in follow-up evaluation. Post-intervention evaluation of right toe deviation showed an increase of 0.2° and follow-up evaluation showed a decrease of 1.2°. The left toe deviation decreased by 11.8° post-intervention and by 1.8° in follow-up evaluation.

Discussion

The present study investigated the effects of WBV training in the horizontal direction on muscle tone, muscle activity of the trunk and lower-extremity, balance, and gait in a patient with cerebral palsy. The results demonstrated that muscle tone, muscle activity of the lower-extremity and trunk, TUG and PDS scores, and gait parameters (velocity, cadence, step length, right stride length, single-leg support time, double-leg support time, and left toe deviation) were significantly improved.

Approximately 70–80% of patients with cerebral palsy display spasticity [41]. Patients with cerebral palsy have neuromuscular symptoms, such as sensory impairment and increased muscle tone, leading to loss of ability to control muscle activity and to movement disorders [41]. WBV training has been reported to contribute to reduction of spasticity and improvement of gross motor function in patients with cerebral palsy [16]. The mechanism is not clear, but Cardinale and Bosco (2003) reported that, based on a tonic reflex, vibration stimulates muscle spindles and α motor neurons to initiate muscle contraction. When this reflex contraction and voluntary contraction are combined, the synchronization of the motor unit increases. Stark et al. (2010) suggested that WBV had a significant effect on bone mineral density, muscle force, and gross motor function in patients with cerebral palsy [42]. WBV was also associated with increases in muscle mass and bone mass and density, and improved mobility [43], and may decrease spasticity and improve motor performance in patients with cerebral palsy [44]. In the present study, hip extensor and ankle plantar flexor muscle tone was reduced when horizontal WBV training was applied. These findings were maintained until the follow-up evaluation. Tupimai et al. (2016) [45] reported significant improvement in tone of lower-extremity muscles when WBV training with prolonged passive muscle stretching was applied in adolescents with cerebral palsy. When the muscle is exposed to vibration, the muscle spindle senses even the smallest changes in muscle length. The sensed information is transmitted to muscle fibers Ia or II and finally reaches the spinal cord [46,47]. In the spinal cord, this information plays a role in presynaptic inhibition through intercalated cells, and inhibition of α motor neurons. The activity of these sensory receptors triggers reflex activity of neural units, similar to that of tonic vibration reflexes [48]. Thus, it is possible that horizontal vibration stimulation directly transmitted to the ankle joint stimulates the sensory receptors of the surrounding tissues of each joint, thereby reducing muscle tone.

In the present study, muscle activity was measured at a knee angle of 0° and knee flexion of 20° (squat posture). The muscle activities of the right and left ES, the RA, the RF, and the right TA were improved following horizontal WBV training. In particular, there was a significant increase in right and left RA and TA muscle activity. In addition, the right and left RA and RF muscles continued to show effective muscle activity until 1 month after the intervention. Furthermore, in the squat position with the knee bent at 20°, the activity of the right and left RF, medial GCS, and TA increased. In addition, the activity of the right and left RF and TA was maintained until 1 month after the end of the intervention. Perchthaler et al. (2013) [49] reported that when whole-body vibration was applied under conditions in which the knee angle and frequency were different, pre-activation of the RF and biceps femoris increased as the knee angle increased, and that the smaller the knee angle, the greater the activity of the hamstring. WBV training is transmitted to the body through periodic concentric-eccentric contractions [10], and vibratory stimuli are more likely to be transmitted to produce faster and larger stretching of the muscle [50]. In addition, Rittweger (2010) [10] reported that the amount of WBV transmitted was different for each segment of the body due to the anatomic structure, with RMS (root mean square) of 85% in the ankle, 8% in the knee, and 2% in the hip. Thus, the trunk muscles, which are relatively far from the feet, would be expected to be less affected. While squat posture separates the upper extremity and lower extremity, standing posture connects from head to foot. Therefore, the latter posture seems to be affected more by vibration than the former. In addition, the activity of the right TA increased in standing posture, and the activity of the left TA increased in squat posture. This may be due to the difference in leg length and asymmetrical growth due to scoliosis in our subject [52–55]. Terry et al. (2005) [56] described static impairment of less than 2 cm due to scoliosis, with the shorter leg pushing up the foot with compensating movements to match the opposite leg [52,53,57]. In the present study, the subject's right leg was 1.6 cm shorter than the left leg. Thus, compensatory movements of the right foot appeared, such that the TA, one of the primary muscles in squat position, was more activated. On the contrary, in the squat position, while maintaining the knee flexed, more weight shifting and center of pressure (COP) is applied to the left leg than the right; thus, the activity of the left TA muscle may be increased for postural control. Chern et al. (2014) [58], who measured body COP during gait by grouping subjects according to the degree of idiopathic scoliosis, reported a higher level of asymmetry in the lower degree of scoliosis group than in the moderate degree of scoliosis group, resulting in restraint in heel adjustment, as well as ankle and toe locking in the ankle-foot complex to center. The PDS showed greater improvement after horizontal WBV training. Most of the items measured in the pre-evaluation showed high scores, but were rated low in standing, tandem standing, and single-leg standing. Cerebral palsy is characterized by decreased activity of proprioceptors involved in gait and postural control, leading to perceived movement of the joint due to lesions in the central nervous system and impaired sense of position [59–61]. In particular, spastic diplegia cerebral palsy is associated with reduced sensory and motor function of the lower limbs compared to that in hemiplegic cerebral palsy [62]. For this reason, children with spastic diplegia cerebral palsy are dependent on visual information and require more support compared to healthy children. In the present study, after horizontal WBV training, the subject improved his performance during standing with eyes closed, which is closely related to visual information, as well as during standing with both feet together, tandem standing, and single-leg standing. This suggests that WBV training in the horizontal direction promotes proprioceptors in each joint in the lower extremity [63], possibly due to the periodic eccentric-concentric contraction of the surrounding muscles of each joint [10]. In this study, the TUG test, used to confirm dynamic balance, showed improvement in the post-intervention evaluation, but follow-up evaluation was not performed. The decrease in muscle tone of the ankle plantarflexors and the activity of the TA seemed to have an important effect on changing the gait pattern in the present study. Dickin et al. (2013) [64] applied vertical WBV training in adults with hemiplegic cerebral palsy, and reported significant improvement in the active range of motion of the ankle, step velocity, and stride length. During walking, the voluntary control of the affected side ankle provided adequate stability when weight was shifted between left and right; thus, stride length became longer and gait velocity was improved. The results of this study also showed that velocity and cadence of gait were increased, while single-leg support time, double-leg support time, and left toe deviation remained decreased until follow-up evaluation. Dingwell and Cavanagh (2001) [65] reported that patients with reduced or deficient ankle proprioceptors displayed compensatory movements for postural control, while Damiano et al. (2013) [66] reported that this problem reduced the quality of gait, shown by decreased velocity and stride. In this regard, the subject of this study showed compensatory gait pattern due to long-term damage to the proprioceptors. However, the proprioceptors of the lower extremity were improved following horizontal WBV training, restoring the ability to move the joint with less rigidity [67]. As a result, horizontal WBV training may improve sensorimotor, stability and mobility of the foot, as shown by a reduced single-leg and double-leg support time, with increased velocity and cadence per minute. The present study has several limitations. First, the results of a case report for a 10-year-old boy cannot be extrapolated to the general population. Thus, further research is necessary to examine the effect of horizontal WBV training in a large patient population. Second, horizontal WBV training was combined with conventional physical therapy for ethical reasons; therefore, it is not clear whether the improvement observed was solely due to the horizontal WBV training. Further studies must be performed to address these limitations.

Conclusions

The purpose of this study was to investigate the effects of WBV training in the horizontal direction on muscle tone, muscle activity, balance, and gait in a child with diplegic cerebral palsy. The results of this study suggest that WBV training in the horizontal direction improved muscle tone and activity in the trunk and lower extremity, as well as balance and gait, in a child with diplegic cerebral palsy. However, this study has limitations, as there was only 1 subject and because conventional physical therapy and horizontal vibration training were performed together. Therefore, it is necessary to examine the effect of WBV training in a horizontal direction on children with cerebral palsy in a future high-quality study.

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