The effects of whole-body vibration on the gross motor function, balance, and gait of children with cerebral palsy

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Abstract

Purpose The aim of this study was to determine the effect of Whole-Body Vibration on gross motor function and balance, gait of children with cerebral palsy.

Methods The Design is ABA design of single-subject experimental design. This study participate 2 subjects for 7 years old who were diagnosed children with spastic cerebral palsy. Baseline(A) and Baseline(A') phases were received not WBV, Intervention(B) phase provided with 30 minutes WBV in 10 session. All subjects were measured with the Gross Motor Function Measure(GMFM-66), Pediatric Balance Scale(PBS), One leg standing, Gait analysis in session and at follow-up.

Results The results showed that the subjects increased GMFM-66 score and remained in the assessment after the intervention. But the subject 2 was decrease again after baseline(A'). PBS of both subjects increased until after intervention but decreased during baseline(A'). In the one leg standing, both subjects increased after the baseline(A). Especially, the sessions exceeding the two standard deviation in the intervention process were 5 times and 8 times, respectively. The gait symmetry index of both subjects increased after intervention.

Conclusion WBV was effective in improving gross motor and balance, gait in children with cerebral palsy.

Key words Whole-Body Vibration, Cerebral Palsy, Gross Motor Function, Balance, Gait

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I. Introduction

Cerebral palsy is a non-progressive disease accompanied by difficulties in movement and postural control.[1] Activity is compromised by poor movement and postural development, as well as problems with sensation, perception, behavior, and secondary musculoskeletal development.[2] Cerebral palsy is one of the most common causes of physical impairment in childhood.[3] Such children exhibit higher-level sensory impairments and muscle tension than do their peers. They find it difficult to control their muscles, compromising the ability to exercise.[4] Several researchers have found that muscle strength in such children is related to motor function.[5),6),7] Various physical therapies improve latent motor ability and ameliorate the secondary problems.[8] The interventions include task-oriented exercises,[9] progressive resistance exercises,[10] virtual reality training,[11] treadmill work, weight-training machines (tilting tables),[12] and whole-body vibration (WBV).[3),13),14),15] Saquetto et al. (2015) found that WBV was associated with functional improvements in children with cerebral palsy, enhancing flexibility, posture control, balance, and coordination.[16] WBV is a form of neuromuscular training that uses vibration to stimulate points critical in terms of balance maintenance (thus, points exhibiting vibration reflexes; abbreviated TVRs).[17] When vibrations of a floor are transmitted throughout the body, these vibrations stimulate both the spine and the appendages, transmitting contraction commands to the spinal cord, enhancing muscle response rates and aiding movement by activating the nervous system. In addition, many exercises seek to mobilize (excite) the Golgi tendon organ.[18] Although many studies have explored the effects of whole-body vibration on subjects with various conditions, few works on children with cerebral palsy have appeared; it is difficult to determine if the initial effects persist. Here, we suggest that whole-body vibration benefits children with cerebral palsy. We sought to improve function using an appropriate intervention.

II. Materials and Methods

1. Subjects

We studied two children diagnosed with cerebral palsy in S hospital of Suwon City, Gyeonggi-do, South Korea; both were undergoing rehabilitation. Their parents gave written informed consent. The general characteristics of the subjects are in Table 1. The study period ran from March 5, 2018 to May 30, 2018, thus for about 3 months.

Table 1. General characteristics of the subjects

Subject	Gender	Age (years)	Weight (kg)	Height (cm)	Diagnosis	GMFCS (level)
1	Male	7	33	127	Rt. hemipleia	1
2	Male	7	27	122	Diplegia	1

2. Methods

1) Procedure and intervention

We used the single-subject, ABA research design. Baseline (phase A) and later phase (phase A’) data were each collected 5 times in the absence of vibration; interventional (phase B) data were collected 10 times. The whole-body vibrator was a Galileo Med-S model (Novotec Medical GmbH, Pforzheim, Germany) delivering alternating sinusoidal oscillations at 1–27 Hz at an amplitude of 0 ± 3.9 mm. Both subjects bent their knees by about 30° when on the footboard and bent their hips and ankles slightly with the feet about 20 cm apart. Vibration was applied in blocks of 6 min (two 3-min sessions with a rest of 1–2 min between sessions; five sequences in total over 30 min). Over the sessions, the vibrational frequency was gradually increased by 0.5 Hz (within the range 11–18 Hz) as tolerated by the children, who wore waist belts to protect against falls. If a child complained of fatigue or dizziness, exercise was immediately paused for 1–2 min.

Figure 1. Galileo Med S

3. Measurements

1) Gross Motor Function

We used a Gross Motor Function Measure (the GMFM-66) appropriate for children with cerebral palsy aged 0–18 years. The five assessment panels feature 66 items, thus fewer than the GMFM-88; scores can be obtained without evaluating all items. In addition, responses are ranked in terms of difficulty; functional ability is readily assessed.[19) The scores for each item ranged from 0 (failure) to 3 (complete success); the test–retest reliability was 0.99.[20] In other studies, the test–retest reliability was 0.97 and the interlaboratory reliability 0.98.[21] All scores were estimated using Gross Motor Ability Estimator (GMAE) software and were calculated at baseline, before, and twice after intervention (four assessments in all).

2) Balance

The Pediatric Balance Scale (PBS) was used to analyze changes in balance. The 14 items of the revised Berg Balance Scale include the time taken to maintain a sitting posture, the quality of the posture per se, and the ability to maintain head posture for 30 s (less than the time of the original Scale). Each test was attempted up to three times; the scores ranged from 0 to 4 and four assessments were conducted (as described above). The attributes required to stably perform independent activities at school, at home, and in the community include competence in terms of balance when sitting, writing, stretching, turning, and climbing stairs. The intra-rater and inter-rater correlation coefficients attained 0.99.[22] Also, the maximum duration of one-leg standing on the more affected side was measured[23]; this is an important measure of postural control.[24]

3) Gait

A G-sensor (BTS Bioengineering S.p.A., Milan, Italy) was used to measure walking/gait parameters and shaking. Walking cadence, average speed, walking period, and the walking and standing positions were measured by reference to changes in the center-of-gravity (at the L4-5 level) accelerations on the x-, y-, and z-axes, using an accelerometer and a gyroscope. All data were analyzed using G-studio software.[25] We also evaluated walking symmetry by representing leg accelerations during gait as curves[26]; we compared the two curves using the following formula.

$$\text{Symmetric Index} = \{(\text{corr}^\dagger + 1) \times 100\}/2$$

†corr : cross correlation coefficient of the parameter

Complete overlap of the two curves corresponds to a score of 100. The children walked back and forth for 8 m at a natural speed[27]; four assessments were performed (as described above).

Figure 2. G-SENSOR

4. Statistics analysis

The baseline and test data are presented as graphs with descriptive statistics; averages (with two standard deviations) were compared between the baseline and test periods. Our analyses of changes afforded by intervention were thus sensitive.[28)] Any data that lay outside the mean ± two standard deviations was considered significant.[29)]

III. Results

1. Gross Motor Function

The major outcomes are listed in Table 2. The initial baseline score of subject 1 was 82.99%, and this was maintained at the pre-test assessment. After 10 whole-body vibration exercises, the score improved to 86.52% and was maintained after the post-test. The initial baseline score of subject 2 was 77.46% and was maintained at the pre-test. After intervention, the score increased to 78.82%, but decreased after the post-test.

Table 2. Variations of GMFM-66 **(unit: %)**

	baseline 1	Pre-test	Post-test	baseline 2
Subject 1	82.99	82.99	86.52	86.52
Subject 2	77.46	77.46	78.28	75.34

2. Balance

The baseline PBS score of subject 1 was 47 and was maintained on the pre-test assessment. After 10 interventions, the score improved to 53, but fell to 50 after post-test. The baseline PBS score of subject 2 was 47 and was maintained on the pre-test assessment. After intervention, the score improved to 51, but, after the post-test, decreased to 50.

Table 3. Variations of PBS **(unit: score)**

	baseline 1	Pre-test	Post-test	baseline 2
Subject 1	47	47	53	50
Subject 2	47	47	51	50

The baseline one-leg-standing time of subject 1 was 1.83 ± 0.35 s, and that after intervention B 2.49 ± 0.15 s; the later phase A' score increased to 2.62 ± 0.08 s. During intervention, the scores on 5 of 10 sessions exceeded the baseline mean ± two standard deviation. The baseline one-leg-standing time of subject 2 was 1.69 ± 0.25 s, which rose to 2.43 ± 0.22 s during intervention, and then to 2.57 ± 0.06 s during follow-up. During intervention, the scores of 8 of 10 sessions exceeded the baseline value ± two standard deviations.

Table 4. Variations of one leg standing **(unit: second)**

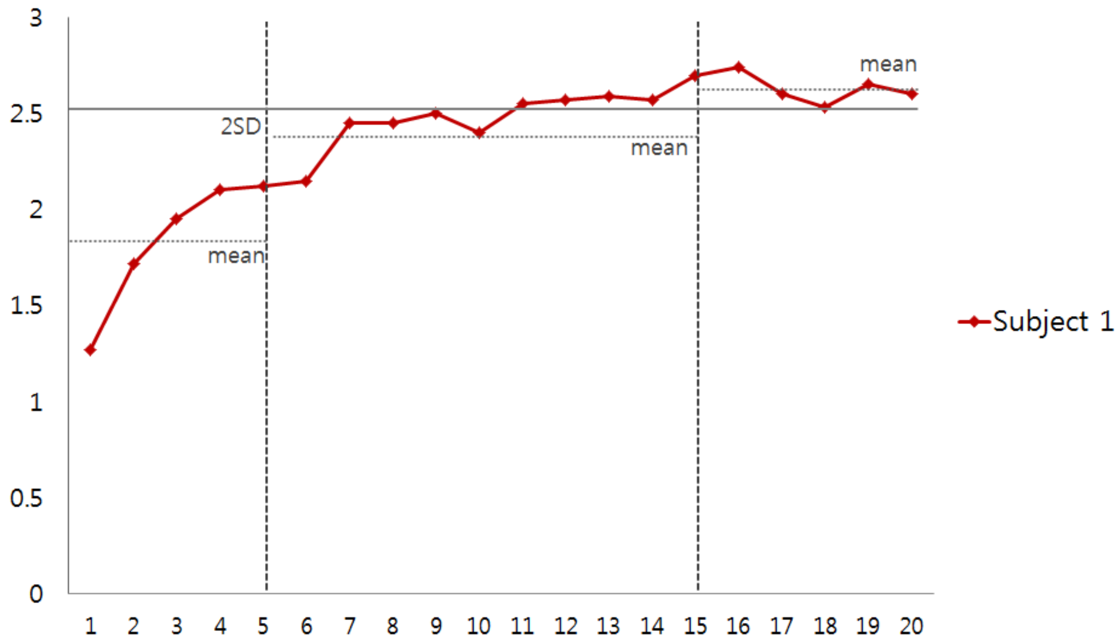
	Baseline A	Intervention B	Baseline A'
Subject 1	1.83±0.35	2.49±0.15	2.62±0.08
Subject 2	1.69±0.25	2.43±0.22	2.57±0.06

3. Gait

The symmetry index of subject 1 increased from 83% prior to whole-body vibration to 86.9% after intervention and to 89.5% after the post-test. The symmetry index of subject 2 increased from 94% before intervention to 98.5% after intervention and 99.3% after the post-test.

Table 5. Variations of symmetry index **(unit: %)**

	baseline 1	Pre-test	Post-test	baseline 2
Subject 1	81.3	83	86.9	89.5
Subject 2	92.7	94	98.5	99.3



M±SD: mean±standard deviation Figure 3. Change of one leg standing in session(subject 1)

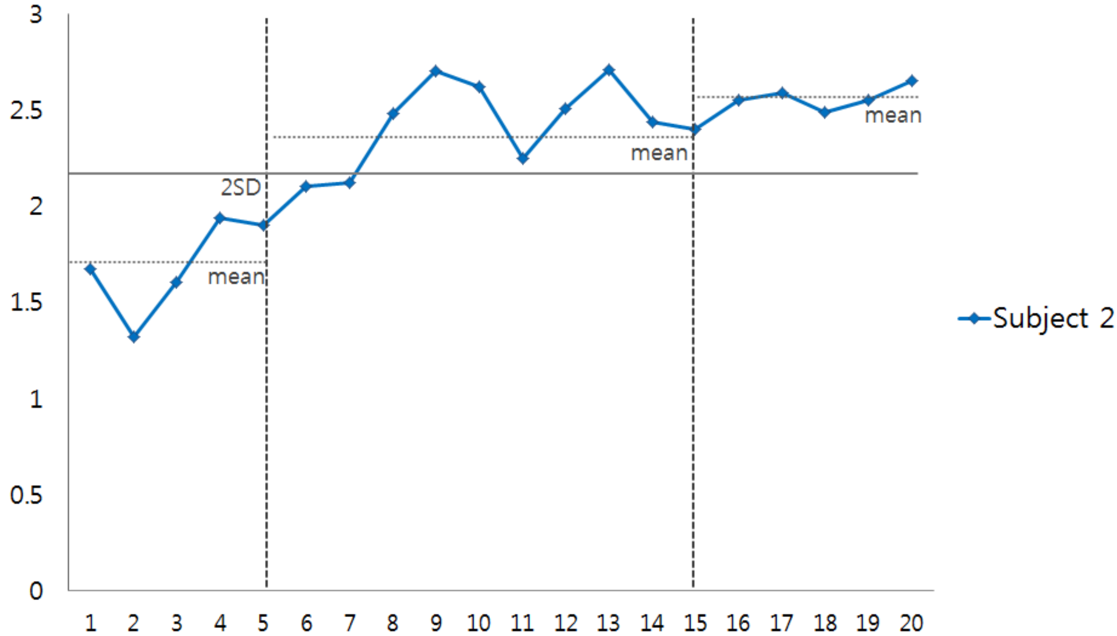


Figure 4. Change of one leg standing in session(subject 2)

IV. Discussion

Whole-body vibration exercises have been used to treat various diseases and have been effective in children with cerebral palsy. [15,30,31,32] Here, we investigated the effect of such exercises on the gross motor function, balance, and gait of two children with cerebral palsy. A gross motor function measure (GMFM) is often used to assess functional activity in such children.[15,31,33,34] Ibrahim et al. (2014) reported significant improvements in the GMFM D and E domains of a whole-body vibration group (both $p < 0.05$). Our results suggest that such exercise may improve sensory function and exercise performance. We used the GMFM-66 to assess motor function. For subject 1, the score of 82.99% pre- test improved to 86.52% after intervention and was maintained after the post-test. Thus, whole-body vibration transmitted through the feet when standing may stimulate the senses and induce muscle contractions, improving and maintaining function.[14] For subject 2, the score of 77.46% pre-test increased slightly to 78.28% after intervention, but then decreased to 75.34% after the post-test. In relation to the foregoing Cheng (2015) showed that the duration of any effect was as short as 3 days, and the systematic review of Novak (2013) revealed a universal therapeutic effect for children with cerebral palsy, although analysis was difficult.[35] In addition, the feelings and general condition of children during assessment may compromise cooperation.

Children with cerebral palsy lack stability and balance because of muscle weakness, abnormal muscle tension, and difficulties in exercising.[36] Kown et al. (2011) reported that the equilibrium of such children was 41.7 PBS points prior to horse-riding but 45.8 points after riding ($p = 0.004$).[37] Ahlborg et al. (2006) found that 8 weeks of whole-body vibration training for children with cerebral palsy significantly improved both dynamic balance and vestibular function.[13] Here, we assessed balance using the one- way PBS. In subject 1, 6 points of improvement were evident after intervention, but balance decreased after the post-test. In subject 2, an improvement of 4 points was evident after intervention, but, again, a decrease was apparent after the post-test. During intervention, the PBS scores increased, attributable to symmetrical weight support via uniform crossover vibration, and improvements in lower-limb sensation and strength. However, the score reductions evident after the post-test suggest that any effect of stimulation may be short term.[38,39] In particular, there has been a report that difficulty may arise due to the low degree of control ankle joint contributing to balance ability. [40,41]

One leg standing improved after 5 of 10 sessions for subject 1, and after 8 of 10 sessions for subject 2. Liao et al. (2001) suggested that one-step tests usefully evaluated and predicted postural stability.[42] Whole-body vibration improved adjustments in various directions, and postural stability (especially when moving). The walking ability of children with cerebral palsy is the area most in need of attention. Lee & Chon (2013) reported significant improvement in walking speed, walking cycle, and ankle angle when whole-body vibration was used to improve the ability to control the lower extremities.[30] Here, we evaluated left-/right-side differences using a symmetry index to quantify the extent to which the curves of the two sides were similar; leg accelerations during gait were represented as curves. The pre-test score of subject 1 was 83%, which became 86.9% after intervention and 89.5% after the post-test. For subject 2, the figures were 94%, 98.5%, and 99.3%; little difference was evident between the right and left sides. Body-weight shifting and the ability to symmetrically support weight by the anterior and posterior lower limb regions directly affect functional gait and improve after whole-body vibrational training.[15),31)] We also found that pre-postural training induced active weight- shifting and improved postural control and walking ability. In addition, muscle weakness may limit anti-gravity motion and activity,[43)] but whole-body vibration exercise may help improve function.

The limitations of our study include the fact that it is difficult to generalize our results because of the small numbers of participants and interventions and absence of control group; it was also difficult to control for variables that might affect our results. In addition, subject enthusiasm (in terms of participation), concentration, and emotional and physical commitments were all poor.

V. Conclusion

We explored the effects of whole-body vibration on the gross motor function, balance, and gait of two children with cerebral palsy (thus exhibiting hemiplegia and bilateral paralysis) using an ABA study design. The initial score of subject 1 was 82.99%, which improved to 86.52% after intervention, and then remained unchanged. The initial score of subject 2 was 77.46%, which increased to 78.82% after intervention, but then decreased after the post-test. The initial PBS score of subject 1 was 47 and improved to 53 after intervention, but then decreased to 50. The initial PBS score of subject 2 was 47 and improved to 51 after intervention, but then decreased to 50 after the post-test. In the one-leg-standing test, the baseline A value was 1.83 ± 0.35 s, and the intervention B value 2.49 ± 0.15 s. The later phase A’ increased to 2.62 ± 0.08 s. In addition, during intervention, the scores of 5 of 10 sessions exceeded the mean ± two standard deviations of the baseline value. The baseline A one-leg-stand time was 1.69 ± 0.25 s, the interventional value 2.43 ± 0.22 s, and the post-test value 2.57 ± 0.06 s (thus slightly greater). During intervention, the scores of 8 out of 10 intervention sessions exceeded the baseline value ± two standard deviations. For subject 1, gait symmetry index increased from 83% prior to intervention to 86.9% after intervention and 89.5% after the post-test; the figures for subject 2 were 94, 98.5, and 99.3%, respectively. Our work suggests that long-term interventional studies with many more subjects are needed.

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