



Original Article

Effect of combining passive muscle stretching and whole body vibration on spasticity and physical performance of children and adolescents with cerebral palsy

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Abstract. [Purpose] This study evaluated the immediate and short-term effects of a combination of prolonged passive muscle stretching (PMS) and whole body vibration (WBV) on the spasticity, strength and balance of children and adolescents with cerebral palsy. [Subjects and Methods] A randomized two-period crossover trial was designed. Twelve subjects with cerebral palsy aged 10.6 ± 2.4 years received both PMS alone as a control group (CG) and a combination of PMS and WBV as an experimental group (EG). After random allocation to the trial schedules of either EG-CG or CG-EG, CG received prolonged PMS while standing on a tilt-table for 40 minutes/day, and EG received prolonged PMS for 30 minutes, followed by 10 minutes WBV. Both CG and EG received the treatment 5 days/week for 6 weeks. [Results] Immediately after one treatment, EG resulted in better improvement in scores on the Modified Ashworth Scale than CG. After the 6-week intervention, EG also showed significantly decreased scores on the Modified Ashworth Scale compared to CG. Both CG and EG showed significantly reduced the performance times in the five times sit to stand test, and EG also showed significantly increased scores on the pediatric balance scale. [Conclusion] This study showed that 6 weeks of combined prolonged PMS and WBV had beneficial effects on the spasticity, muscle strength and balance of children and adolescents with CP.

Key words: Modified Ashworth Scale, Five times sit to stand test, Cerebral palsy

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INTRODUCTION

Muscle dysfunction of the leg is very common in children with spastic diplegia cerebral palsy (CP)¹⁾. Spasticity causes muscle stiffness and weakness, and decreases daily functional activities including standing and walking²⁾. Passive muscle stretching is a common physical therapy for decreasing the spasticity of children and adults with CP spasticity. It has been reported that prolonged passive muscle stretching improves the range of movements and reduces spasticity³⁾. Prolonged passive muscle stretching while standing on a tilt-table decreases the resistance to passive ankle joint movements in children with CP⁴⁾. Therefore, it has been suggested as a treatment technique for children and adults with CP. Whole body vibration has also been proposed as a treatment for children and adults with spastic CP. It is simply applied while subjects stand on an oscillating platform. Some studies have shown that whole body vibration decreases the spasticity of patients with stroke,

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spinal cord injury and multiple sclerosis⁵⁻⁷). A whole body vibration intervention decreases spasticity and improves walking speed, muscle strength and gross motor function without any side effects in adults with CP⁷). Because both muscle stretching and vibration have underlying treatment efficacy in the alleviation of spasticity, and promote muscle function in adults with CP, a therapeutic program combining passive muscle stretching and whole body vibration may show better treatment effects in children and adolescents with spastic CP. However, no study has yet combined passive muscle stretching with whole body vibration for children and adolescents with spastic CP. Therefore, the aim of this study was to investigate the effect of combining passive muscle stretching and whole body vibration on the spasticity, functional strength and balance of children and adolescents with spastic CP.

SUBJECTS AND METHODS

Twelve children and adolescents with spastic CP aged 6–18 years (age, 10.58 ± 2.35 years; height, 127.25 ± 9.72 cm; body mass, 26.48 ± 7.95 kg; mean \pm SD) were recruited from Khon Kaen Special School. Subjects were classified for gross motor function at levels I, II and III according to the Gross Motor Function Classification System (GMFCS), and were included in the study when their Modified Ashworth Scale (MAS) scores were greater than or equal to 1. Exclusion criteria for this study: were receiving PMS more than 3 times/week; medical treatment for spasticity such as a drugs, botulinum toxin injection, or orthopedic surgery during the last six months; medical problems such as arthritis, congenital abnormality, cardiovascular or pulmonary diseases, or neuromuscular diseases; musculoskeletal disorders; or infectious disease. This study was approved by the local Ethics Committee for Human Research of Khon Kaen University. Parents of the children and the children read and signed an informed consent form before the start of the study.

The study was designed as a two-period cross-over trial in which all subjects received both, passive muscle stretching alone as a control group (CG), and a combination of passive muscle stretching and whole body vibration as an experimental group (EG), as shown in Fig. 1. Both treatment groups were evaluated for immediate effect (one treatment) and for short-term effect (6 weeks treatment). The sample size was calculated based on a primary Modified Ashworth Scale (MAS) outcome which was determined as the predicted value (the post-test value of MAS decreased 20%). The minimum requirement of subjects was 12. Sampling randomization was stratified according to the GMFCS from levels I to III, and ages of children (6 to <10 years), and adolescents (10–19 years). After the baseline assessment of all subjects, 12 children were randomly assigned to either EG-CG or CG-EG. In EG-CG, the number of subjects with GMFCS levels I, II and III was 1, 1 and 4, respectively, and 3 of the 6 subjects were under the age of 10 while in CG-EG, the number of subjects with GMFCS levels I, II and III was 1, 2 and 3, respectively and 2 of the 6 subjects were under the age of 10. The GMFCS levels and ages were

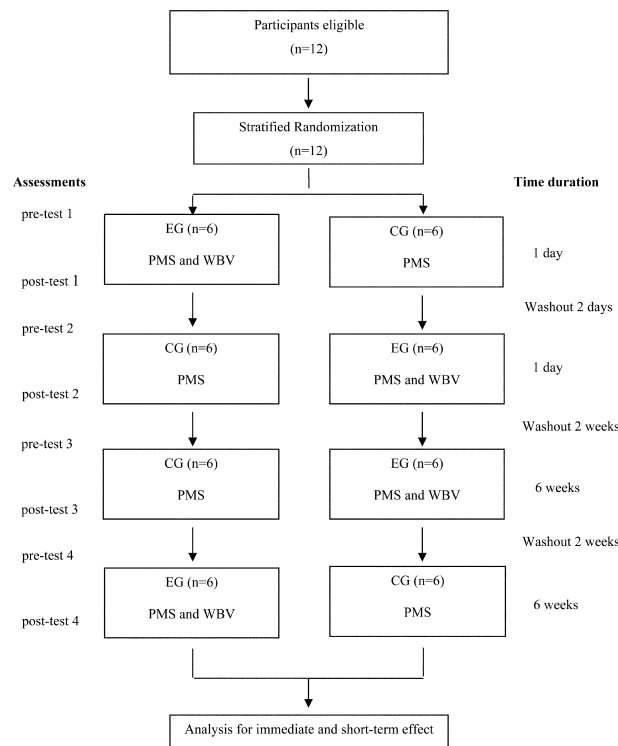


Fig. 1. The flow diagram of the randomized two-period crossover trial
CG: control group; EG: experimental group; PMS: passive muscle stretching; WBV: whole body vibration

similar in both groups and each group was crossed over at the end of each phase was so that each group received the same treatment. In phase 1, subjects were evaluated for outcome variables before and immediately after a one-time treatment and in phase 2, the procedure was repeated after group crossover. All subjects rested for 2 days for a washout between phases 1 and 2. After phase 2 had finished, subjects rested for the 2-day washout period, and in phase 3, all individuals continuously received treatment for 6 weeks. After phase 3, a washout period of 2 weeks was conducted before group crossover for phase 4. Pre-and post-treatment measurements were conducted in phases 3 and 4.

For CG, passive muscle stretching was performed while the subjects stood on a tilt table for 40 minutes per session. The table was tilted to 70–80 degrees relative to the horizontal plane, and two straps around the chest and knees helped to support the body. For EG, a combination of passive muscle stretching and whole body vibration was conducted. Whole body vibration was applied at 20 Hz on the oscillation platform (AIKO vibrator, ETF-001CG, Thailand). After passive muscle stretching for 30 minutes, a total of 10 minutes of one-minute vibration with one minute rest was performed while the subjects stood with equal weight-bearing on both feet. Subjects stood in a standardized foot position on the platform as recommended by the manufacturer with center of the platform located between the legs placed shoulder-width apart. The amplitude of vibration becomes larger when the feet are placed further from the center line. For safety reasons, some subjects held a handle-bar during the vibration. Both the CG and EG interventions were conducted for a total of 40 minutes treatment/day, 5 days/week for 6 weeks, in addition to the regular physiotherapy program at school of 1 session/week. Before and after the single treatments and the 6-week treatments, subjects were evaluated using the Modified Ashworth Scale (MAS), the five times sit-to-stand test (FTSST) and the pediatric balance scale (PBS).

The Modified Ashworth Scale (MAS) was a primary outcome. MAS is known as an essential clinical measure of muscle spasticity in people with neurological conditions⁸). The hip adductor, quadriceps, hamstrings, and soleus muscles were evaluated. The topographic distribution of impairment was determined as the leg with lower or higher spasticity which represented the weaker or stronger side, respectively. MAS scores were assigned numerical values for the evaluated MAS scores (0, 1, 2, 3, 4 and 5). A value of 0 indicates no increase in muscle tone; 1 (1 point) is a slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion when the affected part is moved in flexion or extension; 1+ (2 points) is a slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM (range of movement); 2 (3 points) is a more marked increase in muscle tone through most of the ROM, but the affected part is easily moved; 3 (4 points) is a considerable increase in muscle tone passivity, with movement difficult; 4 (5 points) is an affected part rigid in flexion or extension. MAS was assessed by the same evaluator throughout the experiment, and outcomes were tested for the intra-tester reliability.

The five times sit-to-stand test (FTSST) is a reliable tool for evaluating lower limb muscle strength and balance ability⁹). Subjects sat on a chair with their arms crossed over the chest, and they were asked to stand up and sit down again as quickly as possible five times without using arm support. The test began with the word “Go” and stopped when subjects sat after the fifth performance; the time was recorded.

The pediatric balance scale (PBS) is a modification of the Berg Balance Scale, which was developed for the evaluation of the balance ability of school-age children with mild to moderate motor impairments. PBS has been demonstrated to have good test-retest and inter-rater reliabilities¹⁰). There are 14 items and each item is scored on a five point ordinal scale from zero to four with a maximum score of 56 points. In order to demonstrate each task and give instruction, each child was allowed to practice each item once. If the child was unable to complete the task based on their inability to understand the directions, a second practice trial was allowed, and the best score was recorded¹¹). PBS took approximately 15 minutes to conduct, and if some children needed more time or felt fatigued during the test they were allowed to rest for a few minutes.

The distribution of the data was examined using the Shapiro-Wilk’s test to examine the assumption of normality. All results were not normally distributed. Non-parametric tests were used for all outcomes. The data are presented as the median and quartiles. The differences of variables within and between the groups were assessed with the Wilcoxon Signed-Ranks test and the Mann-Whitney U-test, respectively. Significance was accepted for values of $p < 0.05$.

RESULTS

Tables 1 and 2 summarize the pre-and post-intervention measurement values of CG and EG. In the immediate effect of EG, MAS scores significantly decreased in all muscles of the stronger side and the soleus of the weaker side. In the immediate effect of CG, MAS scores significantly decreased in the quadriceps, hamstrings and soleus muscles of the stronger side. In the comparison of the groups, only the MAS score of the soleus of the weaker side was significantly improved by EG. After the 6-week treatment, all the evaluated items significantly improved in EG, and the MAS scores of the hamstrings and soleus of the stronger side and FTSST improved in CG. In the comparison of the groups, the MAS scores of the quadriceps and hamstrings of both sides, and soleus of the stronger side were more significantly decreased by EG than by CG. No significant differences between the groups were found for FTSST, PBS and MAS of the hip adductors.

DISCUSSION

The results show the combined treatment of PMS and WBV had better effects than PMS alone on the spasticity of children

and adolescents with CP. Immediately after one treatment, the combined treatment showed better improvement in the scores of the MAS than PMS alone. After the 6-week intervention, the combined treatment significantly decreased the scores of the MAS when compared to PMS alone. Both treatments significantly reduced the children's performance times in the five times sit-to-stand test, while the combined treatment significantly increased the scores of the pediatric balance scale. Thus, the results suggest that a 6-week intervention of a combination of prolonged PMS and WBV may elicit beneficial effects for the spasticity and balance of patients with cerebral palsy.

Prolonged passive muscle stretching is a common treatment for people with spasticity CP. Sustained passive muscle stretching for a long duration improves the range of movements, and reduces the spasticity of muscles^{11, 12}. Passive muscle stretching activates Golgi tendon organs and inhibits the excitability of alpha motor neurons. Reduced motoneuronal excitability leads to an increase in the extensibility of soft tissues¹³. Current evidence supports the effectiveness of passive stretching of children with spastic CP, although the reduction in spasticity may not be linked with functional activities such as walking³. A combination of exercise, massage therapy and therapeutic supports is an effective treatment for the release of muscle stiffness, decrease of pain, and improvement of physical functions¹⁴⁻¹⁶. Also, dynamic stretching exercise improves

Table 1. Pre-and post-intervention evaluation items of the control and experimental groups

	Immediate effect				Short-term effect			
	Control group		Experimental group		Control group		Experimental group	
	Before	After	Before	After	Before	After	Before	After
MAS score								
Stronger								
Hip adductors	2 (1:3.75)	2 (1:2)	2 (1:3)	1 (1:2.75)*	2 (1:3)	2 (1:2.8)	2 (1:3)	1 (1:1)*
Quadriceps	2.5 (2:3)	1 (1:2)*	2.5 (2:3)	2 (1.25:2)*	3 (1.3:3)	2 (1.3:2.8)	3 (1.3:3)	1 (1:2)*
Hamstrings	2 (1:3)	1 (1:2)*	2 (1:3)	1 (1:1)*	2.5 (2:3)	2 (1.3:2.8)*	3 (2:3)	1 (1:1.8)**
Soleus	2 (1.25:4.75)	1.5 (1:3)*	2 (1.25:4.75)	1 (1:2)*	3 (1.3:5)	2 (1:4)*	3 (2:5)	1.5 (1:2.8)**
Weaker								
Hip adductors	2 (1:3.75)	1 (1:3)	2 (1:3.75)	1 (1:3)	1.5 (1:2.8)	1.5 (1:2.0)	1.5 (1:2.8)	1 (1:1)*
Quadriceps	2 (1:2.75)	2 (1:2)	2 (1:2.75)	1 (1:2)	2 (1:2)	2 (1:2)	2 (1:2)	1 (1:1.8)*
Hamstrings	1.5 (1:2.75)	1 (1:2)	1.5 (1:2.75)	1 (1:1)	1.5 (1:2)	2 (1:2.8)	1.5 (1:2)	1 (1:1)*
Soleus	2 (2:3.75)	1.5 (1:3.75)	2 (2:3.75)	1 (1:2.5)**	2.5 (1:4)	2 (1:3)	2 (1:3.8)	1 (1:2.8)*
FTSST (s)	16.59 (13.0:23.1)	17.28 (10.6:22.7)	16.93 (12.3:16.9)	11.96 (10.9:19.9)	13.34 (10.7:20.6)	10.14 (9.6:12.7)*	13.55 (11.8:21.9)	11.36 (8.1:13.4)**
PBS (score)	26.00 (7:42)	25.00 (7.5:42.25)	24.00 (8.5:42.25)	26.50 (10:42.25)	26.0 (7.3:45.8)	27.5 (8.5:42.0)	24.5 (8.5:42.0)	31.0 (10.0:44.3)*

Data are presented as median (quartile1:quartile3) for all outcomes. *p < 0.05, **p < 0.01

Table 2. Comparison of the median differences between the control and experimental groups

	Immediate effect		Short-term effect	
	Control group	Experimental group	Control group	Experimental group
MAS score				
Stronger				
Hip adductors	0 (-1.0 : 0)	0 (-1.0 : 0)	0 (-1 : 0.75)	-0.5 (-1 : 0)
Quadriceps	-1.0 (-1.75 : 0)	-1.0 (-1 : 0)	0 (-1 : 0)	-1.0 (-1 : -1)*
Hamstrings	-0.5 (-1.0 : 0)	-1.0 (-2.0 : 0)	-0.5 (-1 : 0)	-1.0 (-2 : -1)*
Soleus	0 (-1.0 : 0)	-1.0 (-2.0 : 0)	0 (-1 : 0)	-1.0 (-1.75 : -0.25)*
Weaker				
Hip adductors	0 (-0.75 : 0)	0 (-1.0 : 0)	0 (0 : 0)	0 (-1 : 0)
Quadriceps	0 (-0.75 : 0)	0 (-1.75 to 0)	0 (0 : 0)	-0.5 (-1 : 0)*
Hamstrings	0 (-1.0 : 0)	0 (-1.75 : 0)	0 (0 : 0.75)	-0.5 (-1 : 0)*
Soleus	0 (-1.0 : 0)	-1.0 (-1.75 : -0.25)*	0 (-1 : 0)	-1.0 (-1 : 0)
FTSST (s)	-1.18 (-3.0 : -1.6)	-2.61 (-5.3 : -1.1)	-3.28 (-6.70 : -0.51)	-4.46 (-8.09 : -2.41)
PBS (score)	0 (0 : 1)	0 (0 : 1)	0 (-2 : 2.75)	2.5 (0 : 4)

Data are presented as the median difference (quartile 1: quartile 3) for all outcomes. *p < 0.05

joint mobility¹⁷). Therefore, different therapeutic methods should be used to normalize muscle tone, maintain or increase soft-tissue extensibility, reduce contracture pain, and improve motor function¹⁸).

Whole body vibration improved the MAS score of the soleus on the weaker side. Oscillation of the ankle joints with a vibrator helps to induce release of a stiff ankle joint. During vibration, standing in a neutral ankle position with body weight bearing also stimulates the stretching of calf muscles. Whole body vibration decreases the spasticity of muscles and increases the gross motor function of subjects with CP^{7, 19}). Whole body vibration improved muscle strength and power movement similar to conventional resistance training in older women²⁰ and in adults with CP⁷). Whole body vibration is a mechanical stimulus characterized by an oscillatory motion. The muscle spindle senses a very small change in muscle length when a skeletal muscle perceives vibration. This information is transmitted to the fibers of group Ia or II, eventually reaching the spinal cord. In the spinal cord, the information serves as presynaptic inhibition through an interstitial cell and suppresses the alpha motor neurons^{21, 22}). The activation of these sensory receptors results in reflexive activation of motor units similar to the tonic vibration reflex²³). Whole body vibration can also improve the balance of stroke patients^{24, 25}). Whole body vibration improved the performance of multiple sclerosis patients in the Timed Up & Go Test²⁶). This improvement in physical balance after whole body vibration may be associated with improvement of leg muscle strength²⁷). The activation of proprioceptive spinal circuits can be induced by upright standing on a vibration platform. Because reflexes are related to the time-differential activation of spindles in muscles and tendons²⁸), the improvement in balance might be positively related to muscle strength and proprioception after vibration training. Whole body vibration may allow children and adolescents with CP to walk effectively with an improvement of balance. Similar to our results, previous research has shown that whole body vibration improves the muscle tone, strength, balance and mobility of children with CP^{29–31}); however, those studies used a vibration frequency with stepwise increment up to 18 Hz compared to the constant vibration frequency of 20 Hz used in the present study. Thus, future research should investigate the effect of different frequencies of vibration.

A limitation of this study was the small number of subjects and the absence of double-blinding of subjects and physiotherapists. With regard to adherence to treatment, all subjects enjoyed whole body vibration therapy and engaged in regular interaction with the physiotherapists. Therefore, whole body vibration should be added to the physiotherapy program. Although improvements in outcomes were found in this study, the optimal dose-response vibration was not clear. Thus, further studies should focus on the training protocol or whole body vibration that can provide the best results for children and adolescents with CP.

In conclusion, this present study showed that 6 weeks of combined passive muscle stretching and whole body vibration could decrease the spasticity and increase the muscle strength and balance of children and adolescents with CP. Whole body vibration could be an alternative additional treatment to passive muscle stretching for both clinical and home therapy programs for children and adolescents with CP.

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