

EFFECT OF WHOLE-BODY VIBRATION ON SPASTIC DIPLEGIC CHILDREN

Mohamed Ali Elshafey¹, Mohamed Serag Eldein Mahgoub Mostafa², Mohamed mohamed Tharwat³, Emad Makram Ghattas⁴, Ragab Kamal Elnaggar⁵

¹Assistant Professor, Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Cairo University, Egypt

²Assistant Professor Basic Sciences Department -Faculty of Physical Therapy– Cairo University and Heliopolis University for sustainable development, Egypt.

³lecturer of Physical Therapy, Department of Physical Therapy for internal medicine and neurology, Faculty of Physical Therapy Heliopolis University for sustainable development, Egypt.

⁴lecturer of Physical Therapy department for integumentary, Faculty of Physical Therapy Deraya University, Egypt.

⁵Assistant Professor Department of Physical Therapy for Pediatrics – Faculty of Physical Therapy – Cairo University and department of Physical Therapy and Health Rehabilitation, College of Applied Medical Sciences, Prince Sattam bin Abdulaziz University, Al-Kharj, Saudi Arabia

ABSTRACT

Background: Spastic diplegic children suffer from spasticity, muscle tightness and limitation of range of motion impeding their functional abilities and gait.

purpose: To evaluate the immediate effect of low frequency whole-body vibration on spasticity, popliteal angle, and gait kinematics in spastic diplegic children.

Methods: Study was carried out on forty spastic diplegic children their age ranged from 4 to 6 years old they were selected from the outpatient clinic of the Faculty of Physical Therapy Cairo University, they had level I and II according to the gross motor function classification system and had grade of I and I+ spasticity according to modified Ashworth scale, Hoffman reflex (H/M) was used to assess spasticity, 2- in-1 Digital Angle Ruler used to assess the popliteal angle range and Tekscan Software was utilized to evaluate gait kinematics.

Results: there is significant decreases in spasticity and popliteal angle immediately after application of whole-body vibration associated with significant improvement of kinematics gait parameters ($P < 0.001$).

Conclusion: Low frequency whole body vibration is an effective modality for spastic cerebral palsied children it reduced spasticity and improves range of motion and kinematic gait parameters.

Key words: Whole body vibration; Spastic diplegic; Gait analysis; H/M ratio.

1. INTRODUCTION

Spastic children are the most common type of cerebral palsy (CP) accounting for approximately 70%–80% of all children [1]. Spastic diplegic children accounts about 30-40 % of CP children, spastic diplegia accounts 70% to 80% of preterm infants with CP [2].

Spasticity is a muscular response increased with velocity when the muscle is stretched passively. Spastic diplegic children had muscular stiffness in the affected limbs causing limitation of movements [3], lower extremities are more affected than upper extremities in spastic diplegic children [4,5].

Diplegic children had lumbar lordosis, anterior pelvic tilt, hip adduction and internal rotation, knee flexion, toe in and equinovalgus foot deformity. Diplegic children walk with abnormal adapted gait pattern as equinus, jumping, crouched, scissoring and stiff knee gait pattern [6].

Diplegic children had flexed and internal rotated hips, semi flexed knees with planter flexed ankles. The upper limbs pattern delayed up to three or four years of age, it includes shoulder internal rotation, elbows flexion, wrists and fingers flexion, and adducted opposed thumbs [7].

Diplegic children had poor motor control, abnormal muscle contracture and abnormal muscular co contraction affecting the selective motor control and voluntary excursion of movement and function pattern. Diplegic children had weakness in posture reaction and mechanisms leading to poor balance and movement strategy [8].

Whole body vibration (WBV) is Mechanical oscillation generates force that acts on the body with different amplitudes and frequencies [9], was introduced to decrease muscle weakness and loss bone density in cosmonauts because lack gravity in the [10]. Whole body vibration improves balance, bone mineral density and stimulate muscle spindles and Golgi tendon organ thus reducing muscle spasticity [11]. Whole body vibration modulate muscle tone [12], stimulate proprioceptive reflex, reduce pain [13], and had warm-up effect reducing risk of soft tissue [14].

To date, limited research investigated the immediate effect of low frequency WBV on lower extremity spasticity and ambulation in spastic diplegic children [15]. The current study aimed to determine the effectiveness of low frequency WBV on lower extremity spasticity, popliteal angle range and kinematics gait parameters in spastic diplegic children.

2. Materials and Methods

Study design

The design of the study was prospective intervention study. Informed consent was obtained from all the participants caregivers the study was approved by the ethical committee of the faculty of physical therapy of Cairo university (P.T. RECC/012/001846).

Participants

Forty spastic diplegic children were selected from the outpatient clinic of Faculty of Physical Therapy Cairo University, their age ranged from four to six years they had level I and II according to Gross Motor Function Classification System and Spasticity grade 1 and 1⁺ according to Modified Ashworth Scale, they can understand order and follow instruction. Children were excluded if they had visual or auditory problems, uncontrolled convulsions, fixed contractures and deformities, surgical intervention less than one year and Children injected by BOTOX within four months.

Materials

Modified Ashworth scale: to measure the grade of spasticity of the selected children [16]. Gross motor function classification system Expanded and Revised version to measure function activities level of the selected children [17]. 2- in-1 Digital Angle Ruler (Made in china). EMG Neuropac S1, Model DI 90B, SN 00030, made in Japan to measure H/M ratio

and Tekscan's walkway pressure assessment (Tekscan Inc., Boston, USA) system – Tekscan to measure gait kinematics [18]. Whole body vibrator (vegamax fitness VG300A, made in china).

Procedure

Spasticity, popliteal angle and gait kinematics were assessed before and immediately after application of whole body vibration, the child lies in a prone position to measure H/M ratio firstly by EMG from the soleus muscle then changes his position to supine to evaluate the popliteal angle by 2- in-1 Digital Angle Ruler, then gait kinematics were evaluated by Tekscan Software. All children received whole body vibration for twenty minutes, the vibration protocol was 20 Hz with 2 mm vertical displacement with children in a semi-squat position on the platform to focus energy on the lower extremities [19].

1- Hoffmann reflex of soleus muscle: The soleus H-reflex, is obtained by anodal stimulation of the posterior tibial nerve at the popliteal fossa, stimulation starts with Small intensities to record H- response then with higher intensities to record M- response [20].

2- The popliteal angle was measured by 2- in-1 Digital Angle Ruler from supine position with hip flexed to right angle [21].

3- Tekscan's walkway pressure assessment system used to measure step length, step width, foot angle, walking speed and time. The child was instructed to walk over the walkway for two or three times till the child became adapted with the apparatus then the data recorded. The data then were displayed and exported in spread sheet form.

Data Analysis: The statistical analyses were performed by the statistical package of social sciences (SPSS) version 20. Descriptive statistics (mean and standard deviation) were computed for all data. The paired t - test was applied for comparison within the group.

3. Results

I- General characteristics of the subjects

The mean age of children was 5.33 ± 0.82 years. The gender distribution of children revealed that there were 21 (52.5%) girls and 19 (47.5%) boys. The spasticity grade distribution of children revealed that there were 18 (45%) children were with spasticity grade I and 22 (55%) children with spasticity grade II. The GMFM distribution of children revealed that there were 23(57.5%) children were with GMFM level I and 17 (42.5%) children with level II.

II. Effect of application of WBV on H/M ratio

as shown in table (1) there was a significant decrease in H/M ratio in comparison of the pre and immediate post application of WBV ($p = 0.0001$) The mean difference was 8.84 and the percent of change was 28.84%.

III. Effect of application of WBV on popliteal angle

as shown in table (1) there was significant decrease popliteal angle in comparison of pre and immediate post application of WBV ($p = 0.0001$). The mean difference was 10.2 degrees, and the percent of change was 25.04%.

Table 1. Comparison of H/M ratio and popliteal angle between pre and immediate post application of WBV

H/M ratio		t- value	P- value	Sig
$\bar{X} \pm SD$				
Pretreatment	Immediate post treatment			
30.65 ± 5.84	21.81 ± 6.51	41.52	0.0001	S
Popliteal angle (degrees)		t- value	P- value	Sig
$\bar{X} \pm SD$				
Pretreatment	Immediate post treatment			
37.53 ± 6.45	28.43 ± 6.19	32.75	0.0001	S

IV- Comparison between pre and immediate post application of WBV of spatial parameters

There was a significant increase in step length immediately post application of WBV compared with pre application of WBV (p = 0.0001). The mean difference was 5.05 cm, and the percent of change was 26.64%. There was a significant increase in step width immediately post application of WBV as compared with pre application of WBV (p = 0.002). The mean difference was -0.92 cm, and the percent of change was 14.39%. There was a significant increase in foot angle immediately post application of WBV as compared with pre application of WBV (p = 0.0001). The mean difference was -4.84 degrees, and the percent of change was 31.02% as shown in table (2).

Table 2. Comparison between pre and immediate post application of WBV of spatial parameters

Spatial parameters	Pre	immediate Post	MD	% of change	t- value	p- value	Sig
	$\bar{X} \pm SD$	$\bar{X} \pm SD$					
step length (cm)	18.95 ± 4.65	24 ± 4.82	5.05	26.64	-6.33	0.0001	S
step width (cm)	6.39 ± 1.69	7.31 ± 1.02	-0.92	14.39	-3.92	0.002	S
foot angle (degree)	15.6 ± 7.34	20.44 ± 3.62	-4.84	31.02	-5.97	0.0001	S

\bar{X} : Mean MD : Mean difference p value : Probability value
SD : Standard deviation t value : Paired t value S : Significant

V- Comparison between pre and immediate post application of WBV of temporal parameters

There was a significant increase in cadence immediately post application of WBV as compared with pre application of WBV (p = 0.001). The mean difference was 7.39 cm, and the percent of change was 9.71%. There was a significant increase in gait velocity

immediately post application of WBV as compared with pre application of WBV ($p = 0.001$). The mean difference was 6.6 cm/sec, and the percent of change was 16.76 as shown in table (3).

Table 3. Comparison between pre and immediate post application of WBV of temporal parameters.

Temporal parameters	Pre	immediate Post	MD	% of change	t-value	p-value	Sig
	$\bar{X} \pm SD$	$\bar{X} \pm SD$					
Cadence (steps/min)	76.09 ± 9.16	83.48 ± 8.54	-7.39	9.71	-8.01	0.001	S
Gait velocity (cm/sec)	39.36 ± 14.7	45.96 ± 12.53	-6.6	16.76	-7.7	0.001	S

\bar{X} : Mean

MD: Mean difference

p value: Probability value

SD: Standard deviation

t value: Paired t value

S: Significant

NS: Non-significant

4. DISCUSSION

Whole body vibration is a commonly used method in pediatric rehabilitation centers for physical disabled children as it is useful in treatment of spastic children, with minimal cost as appose to the more expensive ways used to inhibit spasticity and had long term effect but there is limited research studying its immediate effect on low frequency WBV on spastic children, as spasticity impedes function in spastic CP children and affects their quality of life, low frequency WBV used as method than increase voluntary control and damp spasticity. The effect of low frequency WBV may last for an hour.

Whole body vibration applied with the children standing with semi flexed knee on a vibrating platform to increase the force effectiveness with frequency of 20 Hz, this comes in agreement with **Yong-Gu Han et al., (2019)** who reported that WBV with 18 to 20-Hz was more effective as higher frequencies make the children feels fatigue and requires a long time for the muscle recovers and lower frequency don't improves muscle strength or function abilities [22].

The result of our studies showed immediately reduction of spasticity of the calf muscle, increase the range of the popliteal angle and improve step length, step width, foot angle, walking speed this comes in agreement with **Chunung et al., (2017)** who reported that stimulating alpha motor neurons influencing the Ia afferent fibers of the muscle spindle and reduce spasticity by which inhibit the monosynaptic reflex [23].

These findings comes in agreement with **Tupimai et al., (2016)** who reported reduction in spasticity of hip adductor, quadriceps, hamstrings, and soleus muscle measured by Modified Ashworth Scale after WBV application for 12 children with spastic CP with GMFCS levels I-III [24].

There is significant reduction of H/M ratio after application of low frequency WBV for 20 minutes and this comes in agreement with **Krause et al., (2015)** who found an immediate reduction in the musculus soleus stretch-reflex response after applying whole body vibration on 44 children with CP [25], this also comes in agreement with, **Ahlborg et al., (2006)** who reported that WBV in spastic diplegia adults improved in muscle strength and

reduced spasticity of the knee extensor muscles[26], this also comes in agreement with **Sean A et al., (2015)** Who reported that whole body vibration provides symptomatic relief for CP children and it may improve spasticity, muscle strength and coordination [27].

Whole body vibration induced excitatory influences continue for a short time after the WBV, resulting in a transient increase in spasticity followed by induced inhibitory influences resulting in reduction of spasticity. Whole body vibration reduced spasticity so the children are more free and relaxed allowing them to execute more effective tasks so there is improvement in the popliteal angle and kinematics gait parameters this comes in agreement with **Lanitia L.Ness (2009)** who reported that reduction in quadriceps spasticity after WBV is greater after 15 minutes of application than 5 minutes of application [28]. Also, our results agree with **Hsin-Yi et al., 2015** who suggested that an 8-week WBV intervention normalized muscle tone, improved active joint range and enhanced ambulatory performance in children with cerebral palsy for at least 3 days [29].

Whole body vibration stimulates muscle spindle, tendon organs, Pacinian, and Meissner corpuscles [30], WBV stimulates proprioceptive receptors specially the muscle spindles which could initiate stretch reflexes, resulting in the activation of α motor neurons and causes muscle contraction, WBV could also improve postural stability due to its positive effects on muscle strength, synchronization of the motor units firing and improved co-contraction of synergist muscles, that might bring about better balance control strategies in patients [31].

5. Conclusion

Low frequency whole body vibration is an effective modality for spastic cerebral palsied children it reduced spasticity and improves range of motion and kinematic gait parameters.

Recommendations

- Using whole body vibration on other cases than cerebral palsy.
- Using whole body vibration for different age groups.
- Matching different age groups on the training program of vibratory stimulation for different cases.
- Using whole body vibration for other cases with different spasticity and functional levels.
- Increasing application time of whole-body vibration.

AUTHORS' CONTRIBUTION

We are five authors for this work, and we did all requirement to accomplish this work, there is no other researchers participate in this work.

Competing interests:

We did not receive any financial support from any institution or company it is our project and we insured all expenses. No competing interests

Source of funding: self-funding.

6. References

1. Berker N and Yalçın S. The help guide to cerebral palsy, General concepts, associated problems. **Istanbul, Turkey. Global HELP 2010;19:5–14.**
2. Tong-Wai R., Wester R. and Shevel M. 'A clinical and etiologic profile of spastic diplegia'. **Elsevier Science, 2006; 34, (3), 212–218.**
3. Van Den Noort J. C., Scholets V. A., Becher J. G. & Harlaar J. Evaluation of the catch in spasticity assessment in children with cerebral palsy. **Archives of physical medicine and rehabilitation. 2010; 91, 615-623**
4. Ju Y., Hwang I., Cherng R. Postural adjustment of children with spastic diplegic cerebral palsy during seated hand reaching in different directions. **Arch Phys Med Rehabil. 2012; 93:471–479.**
5. Butti N., Montirosso R., Giusti L., Piccinini L., Borgatti R., & Urgesi C. Early brain damage affects body schema and person perception abilities in children and adolescents with spastic diplegia. **Neural Plasticity 2019:1-17.**
6. Tecklin J. Pediatric Physical Therapy, 5th edition, Philadelphia: **Lippincott Williams & Wilkins.wolter kluwer 2014**
7. Bax and Brown J.K.The spectrum of disorders known as cerebral palsy, 2nd edition, London: **Mac Keith Press. 2004**
8. Marjorie H and Anne SC. postural dysfunction during standing and walking in children with cerebral palsy: what are the underlying problems and what new therapies might improve balance? **Neural Plast. 2005; 12(2-3): 211-219.**
9. Mostafa S. Ali, Ahmed S. Awad, and Mohamed I. Elassal. The effect of two therapeutic interventions on balance in children with spastic cerebral palsy: A comparative study. **J Taibah Univ Med Sci. 2019 Aug; 14(4): 350–356.** doi: [10.1016/j.jtumed.2019.05.005](https://doi.org/10.1016/j.jtumed.2019.05.005)
10. Marin PJ and Rhea MR. "Effects of vibration training on muscle power: a meta-analysis". **J Strength Cond Res. 2010 Mar;24(3):871-878.**
11. Myung-Sook Ko, Yon Ju Sim, Do Hyun Kim, Hye-Seon Jeon. Effects of 3 Weeks of Whole-Body Vibration Training on Joint Position Sense, Balance, and Gait in Children with Cerebral Palsy: A Randomized Controlled Study. **Physiotherapy Canada. January 2016.68(2):1-7.**
12. Rogan S., Hilfiker R, Herren K., Radlinger L. & De Bruin E. D. Effects of whole-body vibration on postural control in elderly: a systematic review and meta-analysis. **BMC geriatrics. 2011; 11, 72.**
13. Banky M, Ryan HK, Clark R, Olver J, Williams G. Do clinical tests of spasticity accurately reflect muscle function during walking: a systematic review. **Brain Inj 2017; 31(4): 440-55.**
14. Seo HG, Oh PM, Leigh JH, Chun C, Park C, Kim CH. Effect of focal muscle vibration on calf muscle spasticity: a proof-of concept study. **PM&R: J Injury Func Rehabil 2016; 8(11): 1083-1089.**
15. Ruck J, Chabot G, Rauch F. Vibration treatment in cerebral palsy: A randomized controlled pilot study. **J Musculoskelet Neuronal Interact. 2010;10(1):77-83.**
16. Bohannon RW and Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. **Phys Ther. 1987;67(2):206-207.**
17. Towns M, Rosenbaum P, Palisano R, Virginia F W. Should the Gross Motor Function Classification System be used for children who do not have cerebral palsy? **Developmental Medicine & Child Neurology.2017;60(2) 147-154**

18. Coda A., Carline T. and Santos D. Repeatability and reproducibility of the Tekscan HR-Walkway system in healthy children'. **The foot**,2014; **3**, p. **1**.
19. Park Y J, Wook S, and Lee H S. Comparison of the Effectiveness of Whole-Body Vibration in Stroke Patients: A Meta-Analysis. **BioMed Research International**. 2018; **5083634**
20. Burke D. Clinical uses of H reflexes of upper and lower limb muscles. *Clin Neurophysiol Pract*. 2016; **7**; **1:9-17**.
21. Sabine R Ten Berge, Jan P.K. Halbertsma, Patrick G.M. Maathuis , Nienke P Verheij Msc , Pieter U Dijkstra , Karel G.B. Maathuis. Reliability of Popliteal Angle Measurement. **Journal of Pediatric Orthopaedics**. October 2007.**27(6):648-652**
22. Yong-Gu Han, Soon-Won Lee, Chang-Kyo Yun. The immediate influence of various whole-body vibration frequency on balance and walking ability in children with cerebral palsy: a pilot study. **J Exerc Rehabil**. 2019;**15**, **4**, **597-602**.
23. Park C, Park E S, Choi J Y, Cho Y and wook D. Immediate Effect of a Single Session of Whole-Body Vibration on Spasticity in Children with Cerebral Palsy. **Ann Rehabil Med** 2017;**41(2):273-78**.
24. Tupimai T, Peungsuwan P, Prasertnoo J, Yamauchi J. Effect of combining passive muscle stretching and whole-body vibration on spasticity and physical performance of children and adolescents with cerebral palsy. **J Phys Ther Sci**. 2016;**28(1):7-13**.
25. Anne Krause, Schönau E, Ibrahim Duran, Ramona Ritzmann, Kathrin Freyler, Albert Gollhofer, et.al. Acute Adaptations of Spasticity-Related Impairments after Whole Body Vibration - Effects on Stretch Reflex Responses, Voluntary Muscle Activation and Mobility. **Conference: Black Forest Forum for Musculoskeletal InteractionsAt: Bad Liebenzell**. 2015.
26. Lotta Ahlborg, Christina Andersson, Per Julin. Whole-body vibration training compared with resistance training: Effect on spasticity, muscle strength and motor performance in adults with cerebral palsy. **Journal of Rehabilitation Medicine**, 2006; **38(5):302-8**.
27. Sean A. Duquette, Anthony M. Guiliano, and David J. Starmer. Whole body vibration and cerebral palsy: a systematic review. **J Can Chiropr Assoc**. 2015; **59(3): 245–52**.
28. Lanitia L. Ness, and Edelle C. Field-Fote. Effect of whole-body vibration on quadriceps spasticity in individuals with spastic hypertonia due to spinal cord injury. **Restorative Neurology and Neuroscience** 2009; **27,623–33**
29. Hsin-Yi Kathy Cheng, Yu-Chun Yu, Alice May-Kuen Wong, Yung-Shen Tsai, Yan-Ying Ju. Effects of an eight-week whole body vibration on lower extremity muscle tone and function in children with cerebral palsy. **Res Dev Disabil**, 2015;**38:256-61**.
30. Costantino C, Petraglia F, Sabetta L and Giumelli R. Effects of Single or Multiple Sessions of Whole-Body Vibration in Stroke: Is There Any Evidence to Support the Clinical Use in Rehabilitation. **Rehabil Res Pract**. 2018; **8491859**.
31. Abbasi E, Kahrizi S, Razi M, and Faghihzadeh S. The effect of whole-body vibration training on the lower extremity muscles' electromyographic activities in patients with knee osteoarthritis. **Med J Islam Repub Iran**. 2017; **31: 107**.