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The Immediate Effect of Whole Body Vibration on Spasticity in Children with Spastic Cerebral Palsy

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Abstract: *Background*: The purpose of this study is to evaluate the immediate effect of whole body vibration on the spasticity of the soleus muscle in children with spastic cerebral palsy. Fifteen children with spastic hemiplegia of age range from 4-6 years were taken as the sample of this study from the outpatient clinic of the faculty of Physical Therapy Cairo University. All the children were level (I and II) according to the gross motor function classification and degree of spasticity was (1 and 1+) on Modified Ashwarth Scale. The soleus muscle was assessed for spasticity by measuring the Hoffman reflex of muscle response using electromyography. All children were assessed for spasticity before receiving 20 minutes of whole body vibration at 20 Hz and immediately post WBV, 30 minutes post and the final reassessment 1 hour post application. *Results*: Showed a significant decrease in H/M ratio immediate and at 30 min post treatment compared with pretreatment (p = 0.001) while there was no significant difference in H/M ratio between pretreatment and 1 hour post treatment. *Conclusion*: whole body vibration has a significant immediate effect on spasticity within an hour after application in children with hemiplegic spastic cerebral palsy, so it is recommended using it before physical therapy session to increase the rehabilitation effect.

Key words: Children Withspastic Hemiplegia・Immediate Effect・Spasticity・Whole Body Vibration・H/M Ratio

INTRODUCTION

Spastic cerebral palsy (CP) is considered the most common type of CP. Up to 80% of all individuals with cerebral palsy suffer from some degree of spasticity. The degree of spasticity can vary from mild muscle stiffness to severe, painful and uncontrollable muscle spasms [1]. Spastic cerebral palsy is divided according to Miller [2], into spastic diplegia which is bilateral lower extremity involvement, spastic hemiplegia where the upper and lower extremity of one side is involved and spastic triplegia where there is an involvement of three extremities (typically both lower and one upper extremity), spastic double hemiplegia is four extremity involvements with more severe spasticity of the upper extremities than lower extremities and finally spastic quadriplegia / tetraplegia where all four extremities are involved.

Approximately 80% of preterm infants who manifest motor abnormalities have spastic diplegia whereas 17% of them have spastic hemiplegia [3]. Spastic hemiplegic children have different impairments in sensory function, perception, neuromuscular, postural control and range of motion which contribute to motor dysfunction that influences the child gross motor function and quality of life [4]. Most children have significant weakness in the trunk and spasticity of the extremities [5].

Spasticity is classically defined as an increase of the velocity dependent stretch reflex [6], it is considered the most problem affecting the motor control development and movement in children with spastic cerebral palsy.

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Because spastic CP is the most common type of CP in preterm and term infants, reducing spasticity is an important goal in the management of these children [7]. The goals of spasticity management are to improve flexibility and movement ability [8].

H-reflex (HR) is usually used to study the excitability of spinal motor circuitry. Upper neuron syndrome features like spasticity are associated with HR alterations and different patterns of HR abnormalities have been reported [6].

Physical therapy interventions have an effective role in the rehabilitation of children with spastic cerebral palsy [9]. In recent years, whole body vibration (WBV) training has become one of the methods for muscle tone modulation that is increasingly used in a variety of clinical situations [10]. It is considered a training method where the whole body of an individual is exposed to low frequency, low amplitude mechanical stimuli via a vibrating platform and this vibration stimulates the muscle spindle [11]. It influences the Ia afferent fibers of the muscle spindle, which inhibit the monosynaptic reflex and therefore causing the spasticity to be directly reduced and the H- reflex to be significantly decreased [7].

WBV training causes muscle contractions that occur in order to absorb the vibration produced by the device, the activity of these muscles can be analyzed by measuring the electromyographic (EMG) signal which showed that the lower leg muscles were the segment with the greatest stimulation during WBV training, as the signal reached 5- 50% of maximum voluntary contraction [12].

Some previous researches studied the persistence of the effect of WBV on spasticity in children with CP on 8 weeks training period and on 3 months of WBV training period, it was reported that the two training periods of WBV with physiotherapy reduced spasticity and improved motor function more effectively than physiotherapy alone [13, 14]. From our knowledge, there was a very few researches that study the immediate effect of whole body vibration on spasticity which actually needs to be studied to determine how long the persistence of its effect and how much it effects spasticity and thus, knowing the optimal time for applying physical therapy intervention whilst the effect of WBV in children with spastic cerebral palsy is at its maximum.

MATERIAL AND METHODS

Participants: This is a prospective intervention study that included fifteen children with hemiplegic cerebral palsy from both sexes of age range 4 to 6 years old. Subjects were selected from the outpatient clinic of the Faculty of Physical Therapy, Cairo University which they were assessed, diagnosed and received a regular physical therapy program of three sessions per week. All subjects were selected to be at level 1 and 11 on the Gross Motor Function Classification System and with a degree of spasticity ranged from 1 and 1+ according to the Modified Ashwarth Scale [15]. All children were cooperative and were able to follow and comprehend instructions. Subjects with fixed contractures, deformities or any surgical intervention in less than a year or had any hearing, visual, cardiac problems or recent fractures were excluded from this study.

Instrumentation: For assessment: Electromyography (Toennies EMG Training -A devision of Erich Jaeger neuroscreen plus EMG unit Gmbh, Wurzburg. March 1998) and neurosoft software were used to assess Hoffman reflex to muscle response (H/M) ratio. For treatment: Whole body vibration was conducted using a calibrated device (Mega Fox, China), which provides side to-side, alternating vertical, sinusoidal vibration.

Procedure: All children were first assessed for spasticity using the H/M ratio, the affected lower limb was measured then they stood over a mark on the platform base of the oscillating board of the whole body vibration device barefoot with a 30 degree semi flexed knee [14], the child holds on or not according to his abilities, the frequency of the vibration is calibrated to 20 HZ for ten minutes then, they were asked to rest for one minute and climb back on to the device for another ten minutes of vibration [7], after that they were reassessed for spasticity using the electromyography to record the immediate effect of the low frequency vibration on spasticity of the soleus muscle and the measures were repeated again after 30 minutes and again after one hour with no activity and complete rest in between.

Electromyography Application: The children were assessed in a prone position where the ankle was well supported and the foot was outside the plinth, the skin of the attachment site of the electrodes was lightly rubbed with an abrasive paste and cleaned with alcohol. Surface electrodes were placed based on Weiss *et al.* [16] which is also supported by the Surface Electromyography for the Non-Invasive Assessment of Muscles Project SENIAM [17], an active electrode positioned on the middle of the muscles belly (soleus muscle) and a reference electrode over the Achilles tendon. The electrical stimulation of the posterior tibial nerve was in the popliteal fossa. The amplification changed to 0.2 mV/div., the stimulation intensity started from 0 and then increased gradually until the H wave appears, replaced by F-waves and a maximal motor amplitude. The stimulation was repeated on this level to demonstrate the stability in latency and appearance of the H-reflex then, the H/M ratio calculated by the neuro EMG from Neurosoft© software.

Study Design and Statistical Analysis: The study was designed as within subject study. T-test were carried out for comparison of the mean age between groups. Chi- squared test was carried out for comparison of sex distribution between groups. Mann-Whitney test was used for comparison of spasticity grade and GMFCS levels between groups. Friedman test was carried out for comparison of H/M ratio between pretreatment, immediate post treatment, 30 minute post treatment and 1 hour post treatment in each group and was followed by Wilcoxon Signed Ranks test for pairwise comparison. H/M ratio was compared between groups by Mann-Whitney U test. The level of significance for all statistical tests was set at $p < 0.05$. The level of significance for all statistical tests was set at $p < 0.05$. All Statistical measures were performed through the statistical package for social sciences (SPSS) program version 25 for windows.

RESULTS

As presented in subject's flow chart (Figure 1), 15 children with hemiplegic spastic cerebral palsy enrolled and all of them completed the study measurement protocol and their data were analyzed; their demographic (age & gender) and clinical characteristics (spasticity grades & GMFCS levels)

Subject Characteristics: The mean age of children with hemiplegia was 5.13±0.91 years with minimum and maximum values of 4 and 6 years respectively (Table 2).

Gender Distribution: The gender distribution of children with hemiplegia revealed that there were 9 (60%) girls and 6 (40%) boys (Table 3).

Spasticity Grades Distribution: The spasticity grade distribution of children with hemiplegia revealed that there were 8 (53%) children were with spasticity grade I and 7 (47%) children with spasticity grade II (Table 4).

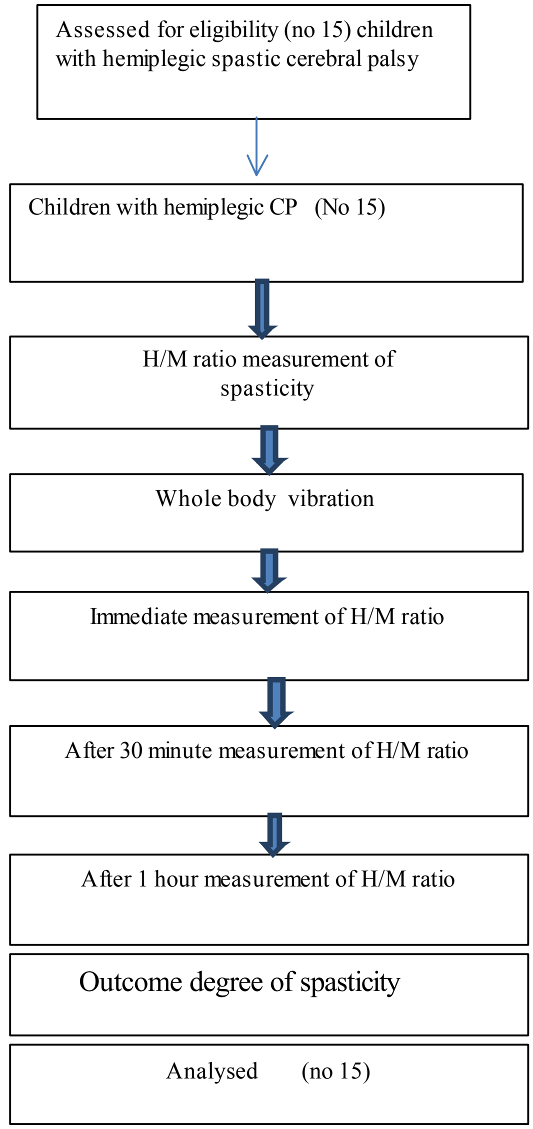

Fig. 1: Subject's flow chart

Table 2: Descriptive statistics for the age:

Age (years)	$\bar{x}$±SD	Minimum	Maximum	Range
Hemiplegia	5.13±0.91	4	6	2

Table 3: The frequency distribution of gender:

	Gender distribution	
	Girls	Boys
Hemiplegia	9 (60%)	6 (40%)

Table 4: The frequency distribution of spasticity grade:

	Spasticity grades	
	Grade I	Grade II
Hemiplegia	8 (53%)	7 (47%)

Table 5: The frequency distribution of GMFM levels:

	GMFM levels	
	Level I	Level II
Hemiplegia	8 (53%)	7 (47%)

Table 6: Comparison of H/M ratio between pre treatment, immediate post treatment, 30 min post treatment and 1 hour post treatment of the children with hemiplegia

H/M ratio						
Pre treatment	Immediate post treatment	30 min post treatment	1 hour post treatment	F- value	p- value	Sig $\bar{x}$±SD
29.6±9.96	23.96±8.62	24.17±8.56	29.04±9.97	29	0.0001	S

Multiple comparison (Bonferroni test)

	MD	% of change	p- value	Sig
PretreatmentVs. Immediate post treatment	5.64	19.05	0.0001	S
PretreatmentVs. 30 min post treatment	5.43	18.34	0.001	S
Pre treatmentVs 1 hour post treatment	0.56	1.89	0.13	NS
Immediate post treatment Vs 30 min post treatment	-0.21	0.88	1	NS
Immediate post treatment Vs 1 hour post treatment	-5.08	21.2	0.0001	S
30 min post treatment Vs 1 hour post treatment	-4.87	20.15	0.001	S

$\bar{x}$: Mean SD: Standard deviation MD: Mean difference
p value: Probability value S: Significant NS: Non significant

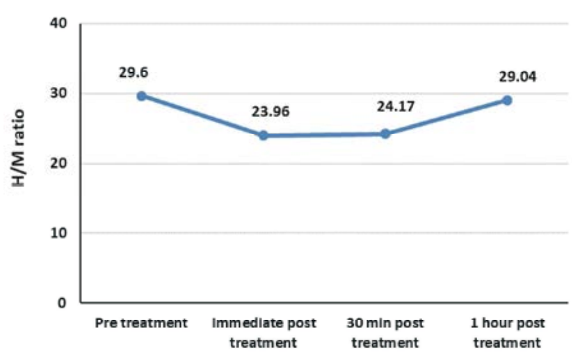

Fig. 2: Mean H/M ratio pre treatment, immediate post treatment, 30 min post treatment and 1 hour post treatment of the of the children with hemiplegia.

GMFM Distribution: The GMFM distribution of children with hemiplegia revealed that there were 8 (53%) children were with GMFM level I and 7 (47%) children with level II (Table 5).

Hoffman Reflex of Muscle Response (H/M Ratio): There was a significant increase in H/M ratio at pre treatment compared with that at immediate and 30 min post treatment ($p < 0.001$), while there was no significant difference between pre treatment and 1 hour post treatment ($p > 0.05$). There was no significant difference between immediate post treatment and 30 min post treatment ($p > 0.05$); however, there was a significant decrease in H/M ratio immediate post treatment compared with that at 1 hour post treatment($p < 0.001$) and significant decrease at 30 min compared with that at 1 hour post treatment ($p < 0.001$). (Table 6)

DISCUSSION

This study was conducted to evaluate the anti-spastic immediate effect of one session of whole body vibration and for how long that effect recovered on ankle planter flexor in children with spastic hemiplegic cerebral palsy. Whole body vibration was applied on all children included in this study while standing with a semi flexed knee supported on a vibrating platform which produces vibrations that according to Park *et al*. [7] who stated that spasticity reduced directly after beginning muscle contractions by stimulating alpha motor neurons and muscle spindles which stimulate Ia afferent fibers of the muscle spindle leading to inhibition of the monosynaptic reflex and therefore, the Hmax/Mmax ratio of the H reflex is significantly decreased, together with clinical spasticity associated with the hypersensitive muscle stretch reflex.

Selecting the optimal frequency of whole body vibration application in children with spastic cerebral palsy is critically important. A study by Yong-Gu Han *et al.* [18] proved that frequency 18 to 20-Hz which was more effective than that with 12- and 26-Hz frequency as, higher wave frequency lead children with spasticity to feel significant fatigue and the muscle will need a long time to recovers, in addition using wave with low frequency is unlikely to induce muscle strength and functional improvement in children with cerebral palsy. Spasticity is currently evaluated by clinical scales which are generally rapidly administered; however, the evidence provided by clinical measures of spasticity has been shown to be limited, therefore surface EMG is the standardized approach for evaluating the spastic lower limb [19]. Different methods were used to measure the spasticity for example, the modified Ashoworth scale, modified Tardieu scale [20], H-reflex (Hofmann reflex) is the most commonly used electrophysiological method in evaluating spasticity [21]. The recent study of Krause *et al.* [22] usedelectromyographyto detect the soleus muscle stretch-reflex response after the application of whole body vibration on 44 children with CP.

The current study was applied to benefit from the immediate effect of whole body vibration in reducing spasticity during the physical therapy session and to include it in the treatment program of the children with spastic cerebral palsy. The results of this study proved reduced spasticity in the calf muscle as a result of decreased H-reflex of the soleus muscle in children with spastic hemiplegic CP immediately after WBV application and its effect continued until 30 minutes then recovered when compared with pretreatment baseline. It is possible that the vibration -induced inhibitory influences may have an immediate onset, resulting in a later within-session reduction in spasticity (observed in the immediate post-WBV test). Theoretically, the long-term persistence of these inhibitory influences resulted in overall spasticity reduction, this finding was confirmed by Park *et al*. [7] who measured the immediate effect of WBV on spasticity in 17 spastic cerebral palsy children and found that spasticity was reduced immediately after a single session of WBV and this improvement lasted for 1-2 hours, but Lanitia [23] found that data from weekly test session suggests that following a session of WBV the reduction in quadriceps spasticity is greater following a delay of 15 minutes.

In children with spastic cerebral palsy, there are multiple consequences of poor communication between the brain and spinal cord resulting in loss of descending modulation of the spinal reflex arc which in turn results in spastic hypertonia with reflex hyper excitability and loss of motor control [24-26]. Hyper excitability of spinal reflexes and a decrease of inhibition of reflex activity are associated with spasticity [27, 28] so, the current study, investigated the neurophysiological consequences following WBV in regard to spinal excitability: all children in both study groups displayed a reduced reflex activity of the soleus muscle which is the closest muscle to the vibration platform and thus it mostly affected by the WBV stimulus [29]. The improvement of spasticity directly post WBV in this study may be attributed to the effect of the vibration on the receptor organs and the reduction of the sensitivity of primary or secondary muscle spindle endings [30]. As well, the integration of muscle spindle input is changed, which is illustrated by changes of Ia afferent transmission and thus by decreasing Ia afferent sensory input, spinal excitability might become comparable to that existing in healthy subjects, all previously leading to decreased stretch reflex and thus, spasticity would reduce [31]. A reduction of stretch reflex sensitivity improves voluntary muscle activation, because the muscle does not over react to small stretch loads [32].

The findings of this study came in agreement with the study results of Ahlborg *et al.* [33] who illustrated improvements in muscle strength and reduction of spasticity of the knee extensor muscles after WBVin adults with spastic diplegia due to cerebral palsy. Also Tupimai *et al*. [34] found a reduction in spasticity in the Modified Ashworth Scale (MAS) measurement of the hip adductor, quadriceps, hamstrings and soleus muscle of the stronger leg as well as the soleus of the weaker leg after passive muscle stretching (PMS) combined with the application of oscillating WBV in 12 children with spastic CP (GMFCS levels I-III) in comparison to PMS alone.

Finally, whole body vibration is a fairly new technique that has proved its significance in decreasing the spasticity in children with spastic cerebral palsy which is very important as, lower extremity spasticity frequently interferes with function and mobility in individuals with clinical deficits as spinal cord injuries and cerebral palsy [35].

The main difficulty of the present study was to maintain stabilization and support of the young participants while securing the electrodes on each child and application for obtaining accurate results during the assessment. As a result, effects were controlled by the study design and test-rest reliability. Moreover, repeated evaluation of the children may be boring and somewhat exhausting, this was minimized by watching different cartons or movies during the application process. The immediate effects of WBV in this study cannot be generalized and information about the acute maintenance of the present modulations needs to be studied in future research. Therefore, measuring the vibratory effects on spasticity during the described protocols can solely be discussed on the basis of evidence described in the literature.

CONCLUSION

In conclusion, a study protocol of 20 minutes session of 20 hz of whole body vibration was effective in reducing the spasticity of ankle planter flexor immediately after application and that effect recovered within whole one hour which is more than beneficial for the physical therapy session following the vibration to come out with better results, without any pain and with minimal effort unlike other methods of inhibiting spasticity in children with hemiplegic cerebral palsy. It was suggested that, WBV may be useful prior to motor rehabilitation interventions to enhance the effects of training.

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