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CASE REPORT

EFFECT OF VIBRATION ON UPPER LIMB SPASTICITY AND FUNCTION IN CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY

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ARTICLE INFO ABSTRACT

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Key words:
CP-Cerebral Palsy, QUEST-Quality of Upper Extremity Skill Test, MMAS-Modified Modified Asworth's Scale, PRT-Pediatric Reach Test, Vibration.

Introduction: Children with cerebral palsy hemiparesis commonly have spasticity in upper limb especially in elbow and wrist flexors, limiting reaching, grasping, object manipulation, play and self-care etc. The aim of present study was to examine weather upper limb vibration therapy is effective or not to reduce spasticity and improve upper limb function in hemiplegic cerebral palsy children.
Method: 32 children were randomly assigned to conventional and experimental groups. Spasticity was measured by modified modified ashworth scale, reaching was measured by pediatric reach test, and quality of upper extremity skill testwas used for upper limb function. Conventional Group was treated by weight bearing exercise and multi direction reaching, while experimental group was given upper limb vibration in addition to multi direction reaching for 6 weeks, 5 days/ week.
Statistical analysis: Data was analysed using Mann Whitney U test by taking the change of score from pre to post. To find out the difference between the groups for changed score of modified modified ashworth scale and quality of upper extremity skill test. ANOVA was used for paediatric reach test.
Results: Results of the study showed that both the conventional and experimental groups improved their upper limb function from pre to post test measurement. However the experimental group showed better changes as compared to the conventional group.
Conclusion: Upper limb vibration with conventional physiotherapy brings about more improvement in spasticity, reaching and quality of upper limb than conventional physiotherapy alone in children with hemiplegic cerebral palsy.

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INTRODUCTION

Cerebral palsy is defined as a group of non-progressive but often changing motor impairments due to lesions of the central nervous system (CNS) in the early stages of development. [1] The causative event has to occur in early childhood, usually defined as less than 2 years of age. [2] Cerebral Palsy is the most common chronic disability of childhood today and spastic CP is one of the most common types (80%). [3]

Rosen MG *et al*. (1992) described Cerebral palsy is a commonest physical disability of childhood occurring in 2.0 to 2.5 per 1000 live birth as reported from Western Australia, Sweden, U.K. and United States. [4] However, in India the incidence is as 1 per 300 live births. [5] Hemiplegia is a form of spastic Cerebral Palsy (CP) in which one arm and leg on either the right or left side of the body is affected. It is the most common syndrome in children born at term and is second in frequency only to spastic diplegia among preterm infants. It is seen in 56 % of term infants and 17 % of pre term infants. [6] The upper limb is usually more severely involved than lower one. This limits reaching, grasping and object manipulation, interfering also with exploration, play, and self-care. [7]As the motor system relies heavily on deep sensory stimulation, recent studies have investigated the effect of vibration stimuli. Studies show efficacy of WBV in reducing spasticity, improving strength, balance, ankle dorsiflexion angle and gait parameters in post stroke and spinal cord injury patients improving posture and balance in patients with Parkinson's disease and multiple sclerosis. [8-12] Although research suggests a positive influence of vibration on motor performance in individuals with neurological disorders, there are very limited numbers of studies in children with cerebral palsy (CP).

A few Studies Have Shown Improvement in Children with CP

- ✓ Spasticity ↓ (MAS/MMAS and Isokinetic dynamometer) [13]
- ✓ Strength of muscles↑ (hand held dynamometer) [14]
- ✓ Motor function ↑ (GMFM and GMFCS) [15]
- ✓ Increase of the activation and the co- activation of biceps and triceps[16]

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- ✓ Vibrations Increase Bone Mass and Muscle Strength in Upper Limbs [17]
- ✓ Vibration therapy decreases spasticity and improve motor performance in children with CP [18]
- ✓ Reduce flexors spasticity and improve functions in the rehabilitation of upper limb spasticity [19]
- ✓ Focal muscle vibration on triceps brachii muscle can reduce the spasticity for both elbow and wrist joint muscles [20]

Tonic Vibration Reflex

Contraction of a muscle subjected to vibration. The vibrating stimuli stretch the muscles, which activate TVR by vibratory activation of muscle spindles which transmit the signal through the CNS to the muscles involved. [21]

30–100 Hz → Activation of receptors (Skin, tendons, muscle spindles) → Spinal cord through afferent nerve fibers →Activation of monosynaptic and polysynaptic reflex arcs → Contraction of muscle.

Static weight Bearing and Reaching Activities also Influence the Upper Limb Function, Some Studies Shown Improvement

- ✓ Static weight bearing is believed to reduce spasticity by inhibiting motor neuron excitability through prolonged stretch and compression on the muscle spindles, Golgi tendon organs, cutaneous receptors, and joint receptors. [22]
- ✓ For the upper extremities (UEs), usually weight is born directly through the hands or forearms in various positions, such as prone with arms in extension or side sitting with support on an extended arm. [23]
- ✓ Static weight bearing exercises improve bone growth and mineral density. [24]
- ✓ Practice of reaching tasks or task oriented reaching improves upper limb reaching as well as upper extremity function. [25]
- ✓ Reaching practice on a task enhance the quality of reaching movements of the affected arm in children with spastic hemiparesis. [26]
- ✓ Schneiberg S *et al*. (2010) found that trunk restraint promoted greater improvement in upper limb movement quality for reaches to targets closely located. [27]

METHODOLOGY

Study Design: A pre- test post- test experimental study design

Sample Size: 32 children randomly allocated to 2 Groups by chit picking

Group 1: Conventional therapy (n=16)
Group 2: Conventional therapy and upper limb vibration (n=16)

Study duration:6 weeks

Inclusion criteria: Children diagnosed as spastic hemiplegic cerebral palsy, children of either sex in the age group ranging from 3 to 8 years, children could understand and follow commands given by the therapist, comprehensive and cooperative.

Exclusion Criteria: Children with types of cerebral palsy other than spastic hemiplegia, history of convulsions /epilepsy, children with impaired cognitive function, any recent surgical procedure for correction of deformity, soft tissue release etc.

Procedure: Informed consent was obtained from parents of children who fulfilled inclusion and exclusion criteria and randomly assigned to Group 1 and Group 2. The dependant variables such as spasticity was measured by Modified Modified Ashworth Scale (MMAS, Reaching was measured by Pediatric Reach Test (PRT) and Upper limb skill was measured by Quality of upper extremity skill test (QUEST). Group 1 treated by conventional physiotherapy and Group 2 treated by conventional physiotherapy + upper limb vibration. Treatment was given 5 days / week for for 6 weeks.

Technique of Application of Wbv: Procedure was explained to the parents. Child was seated on stool with feet flat on floor , his/her affected hand placed on vibration platform with extended wrist and straight elbow for weight bearing and vibration was applied for 5 minutes. After 5 minutes subject was asked to reach for toys in different direction with affected upper extremity for 5 minutes. After 5 minutes again the timer was set on 5 minutes and the vibration switch was turned on to apply vibration. Then after that again 5 minutes reaching were given in different direction. This whole procedure was repeated 4 times, so total duration of treatment was 40 minutes/ session (20 minutes vibration, 20 minutes reaching).

Conventional Therapy: Child was seated on stool with feet flat on floor, his/her affected hand placed on stool platform for weight bearing, with extended wrist for 5 minutes. After 5 minutes subject was asked to reach for toys in different direction with affected upper extremity for 5 minutes. After 5 minutes again the upper extremity placed on stool for 5 minutes. After that again 5 minutes reaching in different direction. This whole procedure repeated 4 times so total duration of treatment was 40 minutes/ session (20 minutes weight bearing, 20 minutes reaching).

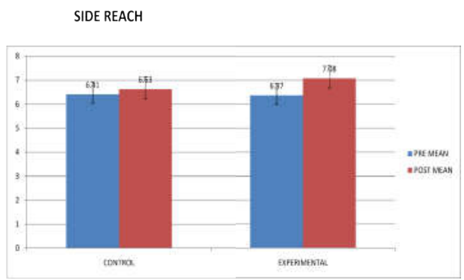
Data Collection

The dependant variables such as Spasticity, Reaching and Upper limb skill were measured by Modified Modified Ashworth Scale (MMAS) Pediatric Reach Test (PRT) and Quality of upper extremity skill test (QUEST) respectively prior to the interventiuons and after 6 weeks of therapeutic interventions.

Data Analysis

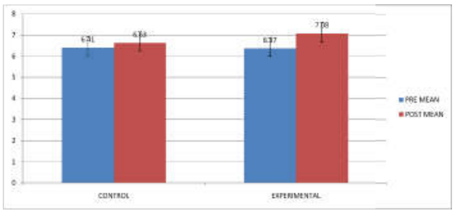
Data was analysed using Mann Whitney U test by taking the change of score from pre to post. To find out the difference between the groups for changed score of Modified modified ashworth scale and for quality of upper extremity skill test. Anova was used for paediatric reach test. An alpha level of 0.05 of significance was set for the tests. Analysis was performed using SPSS package 23 version.

RESULTS



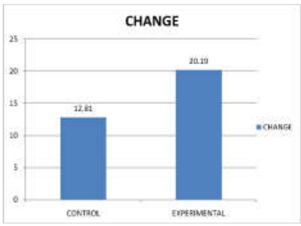
This graph indicates the change of side reach score between experimental and control group. The pre mean of experimental group is 6.37 and post mean 7.08 and pre mean of control group is 6.41 and post mean 6.63.

SIDE REACH



This graph indicates the change of side reach score between experimental and control group. The pre mean of experimental group is 6.37 and post mean 7.08 and pre mean of control group is 6.41 and post mean 6.63.

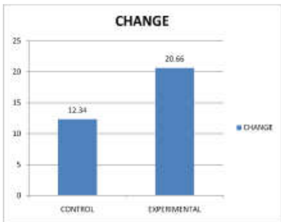
ELBOW FLEXORS SPASTICITY



Mann Whitney U test showed that Z score is -2.558, value of test is 69.00 with $p<0.011$, indicating a significant difference in change of scores between groups.

This graph indicates the change of MMAS score elbow flexors between experimental and control group by Mann Whitney U test. The mean rank of experimental group is 20.19 and control group is 12.81.

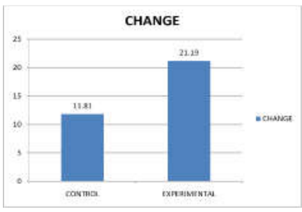
WRIST FLEXOR SPASTICITY



Mann Whitney U test showed that Z score is -2.862, value of test is 61.500 with $p<0.004$, indicating a significant difference in change of scores between groups.

This graph indicates the change of MMAS score of wrist flexors between experimental and control group by Mann Whitney U test. The mean rank of experimental group is 20.66 and control group is 12.34.

QUEST



Mann Whitney U test showed that Z score is -2.835, value of test is 53 with $p<0.005$, indicating a significant difference in change of scores between groups.

This graph indicates the change in Quest score between experimental and control groups by Mann Whitney U test. It shows the mean rank experimental group is 21.19 and control group is 11.81.

DISCUSSION

32 children were randomly assigned to group 1 which was conventional (n=16, male: 8, female: 8, mean age: 55, 81 months, SD 13.19 months) and group 2 which was experimental (n=16, male: 8, female: 8, mean age: 54.18 months, SD 15.61 months).

Overall results of the study show that after 6 weeks of intervention on hemiplegic cerebral palsy children, both groups showed significant improvement in spasticity, reaching and in upper limb function. Improvement in spasticity as measured by MMAS (elbow flexor and wrist flexors) and reaching measured by PRT score; and upper limb function measured by QUEST was significantly more in the experimental group as compared to conventional group.

Spasticity

The experimental and conventional groups showed a reduction of 20.19 and 12.81 ranks respectively in elbow flexors spasticity, a reduction of 20.66 and 12.34 ranks respectively in wrist flexors spasticity as measured by MMAS, which was significant with time.

The reduction in spasticity in the conventional group can be attributed to inhibitory pressure which dampens muscle tone during the conventional exercises. Pressure from prolonged weight bearing on hand dampens elbow flexor and pressure over hand dampens wrist flexor tone. Also, Slow, maintained stretch on hand by in weight bearing position at maximum available lengthened range activates Golgi tendon organs and inhibits muscle tone due largely to peripheral reflex effects (stretch-protection reflex). [28] By sustained muscle stretch, spastic muscle hypertonus has been diminished and late EMG-potentials are reduced or have disappeared completely. [29] There is positive evidence supporting the immediate effects of stretching. [30] There is evidence supporting the effectiveness of weight-bearing exercises for reduction in spasticity in children with cerebral palsy. [22]

The reduction in spasticity in the experimental group can be primarily attributed to the effect of vibration activating presynaptic Ia inhibition. [31] The presynaptic inhibition of the Ia spindle afferents from soleus muscle by vibration have been investigated by Desmedt JE*et al*. (1978). [32] Muscle vibration progressively recruits single motor units according to the motor neuron size principle through polysynaptic proprioceptive pathways. However, the presynaptic inhibition of Ia spindle afferents simultaneously induced by the vibration works in reverse on the same rank order of motor neurons of the wrist flexor and biceps spinal pool, thereby limiting the polysynaptic recruitment of units in the tonic vibration reflex while depressing the autogenic phasic proprioceptive reflexes. These mechanisms elucidate the so-called vibration paradox and extend the size principle of Henneman to presynaptic inhibitory effects.

H and tendon reflexes are inhibited by locally applied vibration while simultaneously eliciting the TVR, an effect attributed to presynaptic inhibition as predominantly monosynaptic reflexes are affected. [33-35] Other presynaptic mechanisms such as homosynapticpostactivation depression (the phenomenon of a reduced transmitter release from previously activated fibres), cannot be eliminated. [36]

Katusić A *et al*. (2013) conducted a randomized conventionalled trial using Modified Ashworth Scale (MMAS) and gross motor function as assessed by Gross Motor Function Measurement (GMFM-88) as outcomes measures. Therapeutic intervention was conducted twice a week during 3 months (12 weeks). They concluded that vibration therapy may decrease spasticity and improve motor performance in children with CP. [37]

Caliandro P*et al*. (2012) investigated effects of focal muscle vibration (3 consecutive days, 30 min/day with fixed frequency of 100 Hz, <0.5 mm amplitude) on spasticity due to cerebral palsy in children and found that spasticity ameliorated with a 40% reduction of the MAS value and a 7.7% improvement of the ankle ROM at T1 (24 hours afterwards). Similar results were observed in T2 (30 days afterwards) and T3 (12 weeks afterwards), thus suggesting long-lasting effects of the treatment. [38]

In a study conducted byNoma T*et al*. (2009)**,** post stroke subjects showed significant and potentially durable improvements in MAS score ($p < 0.01$), F-wave parameters ($p < 0.01$) and motor-function parameters ($p < 0.05$). The MAS score and F-wave parameters remained significantly below the baseline 30 minutes after stimulation. They concluded that the application of vibratory stimuli is an effective non-pharmacological anti-spastic treatment that could facilitate stroke rehabilitation. [39]

The significantly better reduction in spasticity in the experimental group can be primarily attributed to the effect of vibration activating presynaptic Ia inhibition that decreases spasticity and prolonged weight bearing that could lead to sustained stretching which dampens elbow flexor and pressure over hand dampens wrist flexor tone. [28, 31]

Tupimai T*et al*. (2016) suggested that the combined treatment of muscle stretching and vibration had better effects than stretching 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 stretching alone. After the 6-week intervention, the combined treatment significantly decreased the scores of the MAS when compared to stretching alone. [40]

Reaching

Improvement in front reaching was 0.68 (9.31%) and 0.22 (3.21%) for experimental and conventional group respectively, which is significant with time. Improvement in side reaching was .70 (9.88%) and .21 (3.16%) for experimental and conventional group respectively, which is significant with time.

The prime factor for improvement in reaching in the conventional group could be due to decrease in spasticity as a result of weight bearing and multidirectional reaching.

Practice of functional activities like reaching in various directions while sitting upright have the potential to train aspects of muscle performance such as coordination, strength, endurance, physical conditioning as well as motor learning as reaching tasks resembled items of PRT. [41] Since the exercises simulated the multidirectional movement and context of movement, neuromuscular organization to movement occurs. [42] Thus, this can be transformed as an improved performance on PRT score. Schneiberg S*et al*. (2010) found in their study that functional reaching in mutidirection improves reaching, increase degree of elbow extension and increase shoulder flexion and abduction. [43]

In experimental group vibration reduces spasticity in elbow and wrist flexion that could lead to increase elbow and wrist extension and improve reaching distance. Repeated reaching improves motor learing and child got adapted permanent improvement. [38]

Feldman R (1998) has proposed that the nervous system generates movements by combining independent efferent conventional inputs with afferent inputs from vestibular, visual, and proprioceptive receptors. This forms the actual frame of reference (FR) of the body and its surrounding external space. The FR changes its orientation (voluntary movement) when the values that constitute the original FR change (efferent and afferent inputs). [44]

The author gave an example that a toddler's ability to stand can only be acquired when the ability to form a united FR by integrating all intrinsic (body) and extrinsic (space) information is completed. Feldman's (1998) theory of FR is similar to Schmidt's theory of motor schema (1975). [45] Schmidt's schema theory state that motor learning is improved with varied practice, which in his concept would generate more diversified motor programs. Both FR and Schema theory state that a movement skill is acquired though accumulating sensory and motor experience. The literature available in motor development and the abnormal neurophysiological findings thus support the notion that motor compensations in children with CP are not simply just maladaptive behaviors, but that they can also be the result of a maladaptive plasticity. [46-47]

Reaching improved significantly in experimental group than conventional group, it could be due to both group received weight bearing and reaching exercises but experimental group received additional vibration therapy in weight bearing position.

Weight bearing (WB) is assumed to prevent tightness or contracture of soft tissues and restore the length of muscles by prolonged stretching. WB is believed to reduce spasticity by inhibiting motor neuron excitability through prolonged stretch and compression on the muscle spindles, Golgi tendon organs, cutaneous receptors, and joint receptors. There also are claims that WB exercises improve bone growth and mineral density. Particularly for those children with limited mobility, the exercises are said to stimulate antigravity muscle strength and endurance. WB through the UEs is thought to reduce muscle tone in the affected hand and improve hand function. [22]

In stroke patient there was improvement in reaching through whole body vibration this could be due to decrease in spasticity through the effect of whole body. [48]

Segmental vibration in stroke patients also improved reaching kinematics this could be due to the ability of segmental vibration to act on plastic remodeling of central nervous system. [49]

Quest

Mann Whitney U test shows significant improvement between the two groups with $p< 0.004$, Mean rank 21.19 in experimental group and 11.81 in conventional group.

The QUEST score was used to evaluate the upper limb function in hemiplegic cerebral palsy children in this study. Only one component of QUEST i.e.; dissociated movements of bilateral upper extremity were evaluated. Both the groups received similar reaching exercises in multi direction. Reaching exercise was repeated minimum 20 minutes and given 5 days/week for 6 weeks in the department of physiotherapy. So this much repetition could help in creating motor learning in both the groups. [41] Motor learning theory suggests that, procedural learning develops slowly through repetitions of an act over many trials, and it is expressed through improved performance of the task it was practiced.

Improvement in conventional group which received reaching exercises alone could also be due to improved motor conventional and increased strength of upper limb. Multi direction exercise has also been linked to improve cortical reorganization. Animal studies can demonstrated that task oriented reaching training can restore function by using non affected part of the brain which are generally adjacent to the lesion and/or recruiting the supplementary areas of brain. Neural plastic changes have also been demonstrated in the human brain following stroke and task specific intervention. Jang SH *et al*. (2003) also noted decrease in the unaffected and increase in the affected primary sensory motor cortex activities along with functional recovery in stroke patients who received task oriented reaching exercises. [50] Classen J *et al*. (1988) using focal transcranial magnetic stimulation has shown that task oriented reaching exercises in comparison to traditional stroke rehabilitation, yields long lasting cortical reorganization specific to the area being used. [51] Both Karni A *et al*. (1995) using functional magnetic resonance imaging (FMRI) and Classen J *et al*. (1988) using task oriented reaching exercises, reported a slowly evolving, long term, experience dependent reorganization of the adult primary motor cortex after daily practice of task oriented motor activities. [51-52]

The Underlying Mechanism of Upper Limb Function Training

The more practice and repetition are key components of training which lead to more sensory input, feedback and permanent changes as new strategies and motor plan produced lead to learning a new skill or restore the lost skill.

The nervous system provide the

1. Sensory processing for perception of body orientation in space provided by visual, vestibular, and somato-sensory systems.
2. Sensory-motor integration essential for linking sensation to motor responses (centrally programmed postural adjustments that precede voluntary movement).
3. Mechanism of new motor strategy

Information coming from periphery reached to the spinal cord through spinal nerves, information coming from head and neck reached to brainstem through cranial nerves. All the previous information reached to the thalamus to be sensitized then to the post-central gyrus to be localized. Perception, cognition, new sensory strategy will be produced by sensory areas which lead to increase of efficiency of synapses. After that information reach to cerebellum and basal ganglion to be smoothening and prevention of excessive activity, then reach to pre-central gyrus to produce permanent changes and new motor behaviour.

Which mean learning of new skill then formation of motor command via tracts to final common pathway (alpha and gamma MN) to perform new behavior of skills or reacquisition of skills. Despite the development of indices designed to assess the function of the hand's grip strength assessment remains the cornerstone of most longitudinal studies designed to show functional change in the hand.

The significant improvement of upper limb function in the experimental group than conventional group can be primarily attributed to the effect of vibration, weight bearing and reaching activities. Some studies have shown that vibration decreases the spasticity of patients with stroke, spinal cord injury and multiple sclerosis. A vibration intervention decreases spasticity and improves walking speed, muscle strength and gross motor function without any side effects in adults with CP. [40]

Focal muscle vibratory stimuli have been used in different muscle group of the upper limb there were improved upper limb function and reduction in spasticity this could be due to proprioceptive facilitation and improve motor conventional. [53]

SWB exercises helpful in reducing spasticity, increasing bone mineral density and improving hand function in the UE in children with CP. [24]

Repetitive task training involves the repeated practice of functional tasks is thought to reduce muscle weakness and to form the physiological basis of motor learning. [54]

Repeated training of reaching and function of upper limb in cerebral palsy children improved the quest score it could be due to improves motor learning. Ali SSM *et al*. (2016) improves upper limb function. [55]

All the participants found the upper limb vibration session enjoyable, similar to as reported by Delecluse C *et al*. (2005).[56] Almost all of the participants reported they would again like to receive the vibration training if offered. No adverse effects of upper limb vibration were identified during the study like several previous studies. [56-64]

CONCLUSION

Upper limb vibration with conventional physiotherapy brings about more improvement in spasticity, reaching and quality of upper limb than conventional physiotherapy alone in children with hemiplegic cerebral palsy.

Limitations

Study sample was small and carry over effect of the study has not been studied.

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