EFFECT OF WHOLE BODY VIBRATION ON QUADRICEPS MUSCLE PERFORMANCE IN HEMIPARETIC CHILDREN

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ABSTRACT

Background: Hemiplegic children present with weakness and motor skill deficits on one side of the body. Muscle performance elements are strength, power and endurance which are affected in all cases of hemiplegia.the aim of this study is to determine the effect of whole body vibration (WBV)on quadriceps muscle performance in hemiparetic children. **Methods:** Forty hemiparetic children were selected from the outpatient clinic of the Faculty of physical therapy, Cairo University and private clinics. The children were grade 1to1+ according to modified ashwarth scale and their ages ranged from 4to8 years, They were assigned into two groups of equal numbers study and control groups. The control group received selected physical therapy program and study group received the same selected program as control group plus vibration programboth groups received treatment 3 times/week for two successive months, Lafayette device was used to asses quadriceps muscle strength, six minute walk test (6MWT) was used to asses endurance and vertical jump test was used to asses average power. **Results:** There were no significant differences in Quadriceps force, 6MWT and average power between both groups pre-treatment ($p > 0.05$). Comparison between the control and study groups post treatment revealed that there were significant increase in Quadriceps force, 6MWT and average power in the study group compared with that of the control group ($p < 0.05$). **Conclusion:** the study indicates that WBV has beneficial effect on quadriceps muscle performance, so its highly recommended in physical therapy treatment program.

Keywords: cerebral palsy, whole body vibration, muscle performance, quadriceps, children.

Introduction

Cerebral palsy (CP) is a disorder of the development of movement and posture, causing activity limitations attributed to non-progressive disturbances of the fetus or infant brain that may also affect sensation, perception, cognition, communication, and behaviour[(1)].

Children with CP have reduced muscle strength and aerobic fitness, which may impact their ability to perform activities such as standing, walking, running and to participate in everyday life[(2)].

Hemiparesis refers to weakness involving one side of the body. Hemiplegia is the most severe form, caused by injury of the central nervous system[(3)].Hemiplegia is defined as involvement of ipsilateral upper and lower limbs, with the upper limb more severely affected than the lower limb, hand function being most affected. A focal lesion is likely to be the cause of hemiplegia[(4)]. The hemiplegic forms, characterized by a clinical pattern of unilateral motor and sensory impairment, constitute the most frequent expression of CP (more than 38% of cases) and the second in term of prevalence after diplegia, in premature infants (around 20% of cases)[(5)]

Muscle performance is the capacity of muscle to do work, the key elements of muscle performance are strength, power and endurance,Muscular strength is the ability of a muscle or muscle group to exert force to overcome the most resistance in one effort, Power is defined as the amount of work performed per unit of time, Muscular endurance is the ability of a muscle or muscle group to exert force to overcome a resistance many times[(6)].

The ability to improve muscle strength is the keystone on which vibration training is built. Previous studies revealed thatWBV is now a rapidly developing method used to increase muscle strength in clinical condition[(7)].

Quadriceps muscle performance is important for ambulation, increased activation of the quadriceps immediately preceding initial contact can reduce the potential for heel strike occurrence[(8)]. Reduced quadriceps strength relative to body mass is predictive of disease development There is a significant correlation between quadriceps strength and walking speed[(9).]

Methods

The study was approved by the ethical committee of the Faculty of Physical Therapy, Cairo University, Egypt NO:P.T.REC/012/001766.

The study was a quasi-experimental design.

Subjects:

Forty hemiparetic children of both sexes participated in this study. This sample was selected from outpatient clinic of Faculty Of Physical Therapy, Cairo University, The National Institute of neuromotor system and Private physical therapy clinics in Cairo, Giza and Qalyubia governorate.

The age of participated children ranged from 4 to 8 years, spasticity range from grade 1to 1+ according to modified Ashwarthscale[(10)], Their height were 1 meter or more[(11)]to be able to stand on WBV device and their hands grasping the hand rails, Able to stand alone and walk even with abnormal gait pattern, Able to follow simple verbal commands or instructions included in both test and training. All children with Visual or auditory problems, Fixed deformity or contractures in the lower extremity or history of epilepsy were excluded.

A written consent from children's parents was obtained before starting the study.

The sample was divided into two groups of equal number, control group(A) and study group(B) each group composed of twenty children. **Control group (A):** twenty children received selected physical therapy program designed for these patients while **Study group (B):** twenty children received the same selected physical therapy program designed to control group in addition to sessions of whole body vibration.

Both groups received the treatment program 3times /week for two successive months, one hour each session.

Materials

Lafayette Hand Held Dynamometer

The lafayette Manual Muscle Testing (MMT) system is an ergonomic hand –held device for objectively quantifying muscle strength.

For Vertical jump test (VJT)the needed tools are:

- Fixed chart on wall

- Tape measurement
- Marker
- Weight scale

For Six minute walk test (6MWT)the needed tools are:

- Stop watch.
- Chair.
- Tape measurement.
- Calculator.

Whole body vibration device (Vegamax fitness VG300A,made in china): was used for the treatment of the study group

Physical therapy tools: were used in the treatment of both groups are:Mat, ball, rolls, wedge, sitting chair, stand bar, balance board.

Procedures:

For evaluation:

Quadriceps muscle performance including Strength, power and endurance was assessed inall children in both groups (A&B) before and after 2 successive months of treatment.

A) Quadriceps muscle strength was measured by usingLafayette hand held dynamometer,The child was seated on chair with 90 degree hip flexion and 90 degree knee flexion, the Lafayette device in therapist hand was placed above patient's ankle joint on tibial shaft to measure quadriceps muscle strength while the child extend his leg.

B) Quadriceps power was assessed by using vertical jump test,Put chart on wall with tape measure attached to the chart, ask the patient to stand in front to chart where his/her shoulder just next to chart, ask him/her to raise his/her arm and put hand on chart and therapist make a mark. Then ask the patient to jump and touch the chart and the therapist make a mark, measure the distance between the two marks to determine the vertical jump height (VJH).

   Vertical jump height for all participants in the study was measured to be used in muscle power estimation equation, in this study we use Lewis Formula[(12)]

Average Power (Watts) = √ 4.9 x body mass (kg) x √ vertical jump hieght (m) x 9.81. This formula only estimates average power.

C) Quadriceps endurance was evaluated by using (6MWT) according to the guidelines of the American thoracic society[13], all Participants in both groups were allowed to walk on a 20 meter unobstructed, rectangular pathway.The starting point was detected and asking the child to walk the whole pathway for 6minutes, the therapist followed him/her closely with a stopwatch in order to ensure safety and to measure the exact distance walked in 6minutes.He/She was instructed to cover as many laps of the course as possible in 6minutes without running. A chair was placed each 5 meters distance in case of the child need rest, while the time was not stopped.

For treatment

Twenty CP children with hemiparesis in control group received a selective physical therapy program for one hour, three times / week which include:

- Stretching exercise to maintain the length and elastic properties of the muscles which are liable to tightness especially Achilles tendon , hamstring ,hip flexor and adductor (for lower extremity) -shoulder internal rotator ,elbow and wrist flexor ,pronator ,ulnar deviator (for upper extremity)[14].
- Facilitation of trunk control to improve postural control and balance.
- Strength training to hip flexor, knee extensor, ankle dorsi flexor.
- Facilitation of righting and equilibrium reactions to improve postural mechanisms via variety of exercises applied on ball and balance board through tilting from different positions in forward, backward and sideways[15].
- Facilitation of righting or rising reactions:
    - This reaction as described by**Grover,2001**[16] is part of postural reactions which is an essential component of postural control. This reaction gives the child the ability to change position as well as returning to original position, this training was done by encouraging the child to raise from:
    - Lying (prone or supine) to standing
    - Sitting to standing
    - Quadruped to kneeling to standing

- Facilitation of equilibrium reactions:
    - The exercises as described by **Kamm etal., 2001[17]** were conducted from different positions as sitting on ball, roll and from standing on balance board in different directions, responses of the children were:
    - Equilibrium and righting reactions for trunk control.
    - Abduction and extension of the arm and leg on raised side.
    - Protection and extension on lowered side.
- Facilitation of protective reaction by applying fast and large amplitude of stimulus to train saving reactions from sitting on ball or from standing by pushing the child to enhance the child to take protective steps either forward, backward or sideways to regain balance[18]
- Facilitation of single limb support
    - Hand weight bearing exercises and approximation to improve hand function, also facilitation of reaching, grasping and release according to the child abilities[19].
- Facilitation of balance from kneeling on mat and on balance board
- Facilitation of postural fixation and counterpoising through standing in different positions as described by **Sussman,2002[20]:**
    - Stand on one limb
    - Step standing
    - Walk standing
    - Stand on balance board
    - Kick and throwing ball from standing
    - Stoop and recover from different directions
- Facilitation of gait training, these exercises were done in closed environment like between parallel bars then in open environment without assistance the therapist stood behind or beside the child for assistance or guidance[21]
    - Walking between parallel bars forward, backward and sideway.
    - Walking on different floor surfaces(on mat, on floor, on carpet).
    - Walking in narrow base like balance beam or stepper.
    - Walkingin an open environment by placing obstacles across walking track.
    - Walkingin zigzagpathway.

Twenty CP children with hemiparesis in study group received the same designedphysical therapy program that was given to the control group in addition to WBV session. The whole body vibration programme involved exercises on vibrating platform. This platform vibrates horizontally at frequency ranged from (10-25) HZ[22]. The treatment programme consists of two successive months, three days per week. The program composed of number of positions as stand in erect position, stand on one leg and stand facing hand rails according toHeshametal.[11]

The duration of each position was2 minutes first month and increased to be 3 minutes second month. Rest period between each position was one minute in first month, half a minute in second month. The platform vibrates horizontally at a frequency range from (10 -25) HZ. The duration of the vibration exposure was 10 minutes. Manual mode was selected for maximum efficiency of exercising and to prevent accommodation the frequency increased gradually from 10 HZ to 15 HZ to20 HZ to 25 HZ,time was automatically set by device and the device automatically stopped after 10 minutes.

Statistical analysis

Descriptive statistics and unpaired t-test were conducted for comparison of subject characteristics between both groups. Chi- squared test was used for comparison of sex and affected side distribution between groups. Normal distribution of data was checked using the Shapiro-Wilk test. Levene's test for homogeneity of variances was conducted to ensure the homogeneity between groups.Unpaired t-test was conducted to compare the mean values of Quadriceps force, 6MWT and average power between the control and study groups. Paired t-test was conducted for comparison between pre and post treatment measurements in each group. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 22 for windows (IBM SPSS, Chicago, IL, USA).

Results

Subject characteristics was demonstrated intable (1), the mean ± SD of age, weight and height of the control and study groups. There was no significant differences between both groups in the subject characteristics ($p > 0.05$). Also, there was no significant difference in sex and affected side distribution between groups ($p > 0.05$).

Table (1): Comparison of subject characteristics between the control and study groups:

	Control group	Study group	t- value	P-value

	Mean ± SD	**Mean ± SD**		
Age (years)	5.85 ± 1.46	6.05 ± 1.5	-0.42	0.67
Weight (kg)	19 ± 6.31	18.95 ± 3.76	0.03	0.97
Height (cm)	111.4 ± 11.94	110.6 ± 8.31	0.24	0.8
Sex				
Boys	10	8	(χ^2= 0.4)	0.52
Girls	10	12		
Affected side				
Right	9	12	(χ^2= 0.9)	0.34
Left	11	8		

SD, Standard deviation; χ^2, Chi squared value; p value, Probability value

Effect of treatment on Quadriceps force, 6MWT and average power:

- Within group comparison:

There was a significant increase in Quadriceps force, 6MWT and average power post treatment in the control and study groups compared with that pre treatment ($p < 0.001$). The percent of increase in Quadriceps force, 6MWT and average power in the control group were 23.96, 13.53 and 14.18% respectively; and that of the study group were 52.34, 26.91 and 55.48% respectively as shown in table (2)

- Between groups comparison:

There was no significant difference in Quadriceps force, 6MWT and average power between both groups pre-treatment ($p > 0.05$). Comparison between the control and study groups post treatment revealed a significant increase in Quadriceps force, 6MWT and average power of the study group compared with that of the control group ($p < 0.05$), as shown in table (2)

Table (2): Mean Quadriceps force, 6MWT and average power pre and post treatment of the control and study groups:

	Control group	Study group		
	Mean ± SD	**Mean ± SD**	**t- value**	**p value**
Quadriceps force (lb)				
Pre	4.09 ± 1.85	4.26 ± 1.44	-0.33	0.74
Post	5.07 ± 1.88	6.49 ± 1.64	-2.25	0.01*
% of change	23.96	52.34		
t- value	-11.91	-16.97		
	p = 0.001*	***p = 0.001****		
6MWT (m)				
Pre	189.85 ± 45.73	196.95 ± 35.11	-0.55	0.58
Post	215.55 ± 51	249.95 ± 42.11	-2.32	0.02*
% of change	13.53	26.91		
t- value	-11.28	-18.25		
	p = 0.001*	***p = 0.001****		
Average power (Watts)				
Pre	114.59 ± 56.08	111.78 ± 38.54	0.18	0.85
Post	130.85 ± 59.88	173.8 ± 44.15	-2.85	0.01*
% of change	14.18	55.48		
t- value	-9.83	-18.65		
	p = 0.001*	***p = 0.001****		

SD, Standard deviation; p value, Probability value; *, Significant6MWT,six minute walk test

Discussion

There has been limited research on the effects of WBV exercise in treatment of CP children. According to our knowledgethis is the first study that has evaluated the effects of WBV on quadriceps muscle performance in hemiparetic children. The main finding of this study was that mean quadriceps force value was consistently greaterfollowing 10 minutes of WBV at 10-25 HZ three times /week for 2 successive months .

The aim of this study was to compare changes in quadriceps performance (strength, power and endurance) after 2 months of intervention with WBV and we observed that WBV was feasible and appeared to be safe in children with hemiparesis.

In the present study, the results revealed significant improvement in quadriceps muscle force of the WBV group which comes in agreement with the results of **Delecluse et al.**[23]who concluded that WBV can produce reflexive muscle contraction and an increase of strength of knee extensors.

The results of the current study showed that a significant improvement in vertical jump height of the WBV group which comes in agreement with the result of **Bosco et al**. [24]who

reported the effect of a 10-day training program of a daily of vertical sinusoidal vibrations at a frequency of 26 Hz. They found a significant improvement in the jumping performance

Walking a distance of 6 min was significantly increased in the WBV group. This comes in agreement with a study where the average walking speed in the 10-min walking test was increased in CP patients who received vibration therapy[25].

The latter studies reported increased isometric leg extension strength [26], power and jump height[27] following a single training session and also after10 days of training[28]. Isometric knee extensor strength did not improve following 4 months of WBV training[29]. Others have found positive effects of vibration training on muscle force[30-32].

It is well known that the input of proprioceptive pathways is used in the production of force during isometric contractions. By using WBV, the vibratory stimulus is highly activatingthe deep sensory receptors and their pathways resulting in reflexive muscle contractions. The increase in isometric strength after 8 weeks of intervention of deep sensory stimulation may result from an efficient facilitation of the positive proprioceptive feedback loop in the generation of isometric force.[33]

Time of vibration training in this study was 10 minutes which had a benificial effect on quadriceps muscle performance in hemiparetic children, while a previous study shows that a brief 30-second exposure to WBV transiently improves knee muscle performance in persons with multiple sclerosis[34].

The exact mechanism by which the explosive power training can enhance neuromuscular activation is not known, but there are several possible explanations which could cause this enhancement.Strength and power training may also increase the ability of motor units to fire briefly at very high rates, which may induce an increase in the rate of force development even if the peak force does not necessarily increase [35]. Whole body vibration-induced improvements in muscle performance have been suggested to be similar (and occur via similar pathways) to those after several weeks of resistance training [24]. During a whole body vibration loading, skeletal muscles undergo small changes in muscle length, most likely since mechanical vibration is able to induce a tonic excitatory influence on the muscles exposed to it [36]. In other words, vibration elicits a response called “tonic vibration reflex,” including activation of muscle spindles, mediation of the neural signals by 1a afferents, and finally, activation of muscle fibers via large-

motor neurons. The tonic vibration reflex is also able to cause an increase in recruitment of the motor units through activation of muscle spindles and polysynaptic pathways [(37)].

In this study, neurogenic enhancement or changes in the morphological structure of the muscles could not be assessed directly because the study protocol included neither EMG recordings nor muscle biopsies. However, on the basis of the evidence mentioned above, it is likely that the givenwhole body vibration training elicited neural adaptation. This was also supported by the results of the study; i.e., the quickly and clearly enhanced jump height suggested that neural adaptation did occur in response to the vibrationintervention. In addition, the lower-limb extension strength increased only after 2 months of vibration, thus also referring to neural potentiation. Further improvement in the extension strength might have required a greater change in the training stimulus[(29)].

Therefore, whole body vibration exercise may be efficient training stimulus for Children. So, Future studies should focus on comparing the performance-enhancing effects of whole body vibration to conventional resistance training.

Conclusion

This study revealed that WBV was effective in enhancing quadriceps muscle performance and recommended for the treatment ofhemiparetic children.

Conflict of interest

There were no conflicts of interest associated with this publication and there was no financial support for this work that could have influenced its outcome.

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