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Original Article

Suit therapy versus whole-body vibration on bone mineral density in children with spastic diplegia

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Abstract

Objectives: Osteoporosis because of physical inactivity is one of the major complications associated with neuromuscular disorders. The study aimed to compare using Suit therapy and whole-body vibration in addition to selected physical therapy program to improve Bone Mineral Density in children with cerebral palsy of spastic diplegia. **Methods**: Forty-six patients were classified randomly into two equal groups. Patients in the group (A) engaged in a selected physical therapy program, also besides, suit therapy training program while those in the group (B) received the same selected physical therapy program received by group (A) in addition to the whole-body vibration training program. The treatment programs were conducted three times per week for twelve successive weeks. Measurements obtained included bone mineral density at the lumbar spine as well as at the femoral neck. These measures were recorded pre- and post-treatment. **Results**: There was a significant improvement in favor of the whole-body Vibration group. Bone mineral density improved significantly at both the lumbar spine (P=.038) and the femoral neck (P=.005) in the WBV group as compared to the Suit therapy group. **Conclusions**: Whole-body vibration is effective in improving Bone Mineral Density rather than Suit therapy in children with cerebral palsy of spastic diplegia.

Keywords: Bone Mineral Density, Diplegia, Suit Therapy, Whole-body Vibration

Introduction

Cerebral palsy (CP) involves several non-progressive disorders of posture and motor impairment. It is a common cause of disability in childhood. The disorder results from various insults to different areas within the developing nervous system, which explains the variability in clinical findings[1]. Spastic diplegia is the common term applied to the variation of spastic quadriparesis in which the lower limbs are more affected than the upper limbs[2].

In children with CP, the rate of bone mineral acquisition is diminished relative to normal; thus, the bone mineral density (BMD) and bone mineral content (BMC) are lower than age-matched normal values. With growth, BMD falls further below normal with increasing age. Poor mobility status predicts a low BMD in children with CP: 97% of non-ambulatory children older than 9 years with moderate-to-severe CP[3].

Therapeutic suits were first designed for cosmonauts in the late 1960s to create forces on the body for stabilizing the torso to allow for more fluent and coordinated movement of all limbs to counteract the adverse effects of zero gravity such as muscle atrophy and osteopenia[4,5].

These suits are assumed to create tension, thereby strengthening the muscles, and the deep pressure at the joints and provide additional proprioceptive information which enhances body awareness. Since receiving sensory cues during rehabilitation may improve postural control, the proponents of the suit therapy methods have claimed that, once the body and body segments are in proper alignment, intensive therapy with the suit enables re-education of the brain to recognize and form the correct movement of the muscles: The more correct proprioceptive input results in the more proper alignment[6,7].

Since Rubin et al., (2002) showed that low-magnitude high-frequency mechanical accelerations may produce a strong osteogenic response in animals[8] and humans[9], whole-body vibration (WBV) has become a topic of interest.

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Indeed, this marked increase in the use of WBV has led to the apparition of narrative[10-13], systematic[14,15], and also state-of science[16] reviews focusing on different aspects, outcomes, or populations within this exercise training modality.

WBV training uses high-frequency mechanical stimuli generated by a vibrating platform and transmitted through the body[17]. The platforms vary in the type of vibration produced (vertical or side-alternating) and the range of amplitudes and frequencies available[18]. The exact nature of the mechanism by which WBV training stimulates osteogenesis is still not certainly known[18].

Therefore, the main objective of this study was to compare using Suit therapy and whole-body vibration in addition to the selected physical therapy program to improve Bone Mineral Density in children with cerebral palsy of spastic diplegia.

Materials and methods

Study design

The current comparative study was conducted after approval by the local ethical committee of the Faculty of Physical Therapy, Cairo University. Ethical principles of the Declarations of Helsinki were followed. Based on study design; participants were randomly assigned into two equal groups. Signed informal consent was obtained from each participant's parents.

Sample size

Windows version of G-Power 3.1.9.4 software was used to determine sample size as follows: it was calculated by assuming, comparing the difference between two independent means: two tails, with an effect size of 1.1. Assuming α=0.05 and power of 95%, a sample size of 46 participants would be required and they were divided into two equal groups.

Participants

Participants were recruited from the outpatient clinic, Faculty of Physical Therapy, Cairo University. Forty-six children of both sexes with age ranged from 5 - 7 years were selected. Patients included in this study were diagnosed with cerebral palsy of spastic diplegia. The degree of spasticity was ranged between 1 and 1+ according to Modified Ashworth scale. Children were able to stand alone with heels on the ground without support. They were cognitively competent and able to understand and follow instructions.

Children with fixed deformities of upper and lower limbs were excluded including one who had significant perceptual, cognitive, visual, and auditory disorders.

The children were assigned into two groups of equal number, group (A), and group (B). Each group consisted of twenty-three participants. Study group (A) engaged in the suit therapy training program in addition to a selected physical therapy program. Children in group (B) engaged in the whole-body vibration program in addition to the same selected physical therapy program received by group (A). The treatment session lasted one and half hours with short breaks of around 10 minutes and was conducted three times per week for twelve successive weeks.

Evaluation Procedure

1. Dual Energy X-ray Absorptiometry (DXA):

Dual Energy X-ray Absorptiometry (DXA) scans are most commonly used to assess bone mineral density (BMD) of hips, lumbar spine, and total body through low radiation dose, low scanning time and great precision and accuracy.

The measuring system (Model: DP3, Lunar Corporation, Madison, WI, USA) is composed of three components. The central device consists of a padded platform and a mechanical arm like a scanner that emits a low dose X-ray on the measured area. The peripheral device which is portable to measure bone density on the periphery. The computer contains software for determining bone mineral density.

Measured variables were bone mineral density at the lumbar spine and the femoral neck in gram (gm) by measured area (cm^2).

Firstly, personal data including name, age, height, and weight were entered into the software. Each participant was asked to lie on the padded platform for few minutes while the mechanical device passed over the child without touching; as radiation was emitted through the exposed part related to either lumbar spine or neck of femur at the dominant side.

The image of the neck of the femur and lumbar spine received through the detector in the mechanical device was converted by the equipment. Quantity of the bone mineral density was analyzed and reported.

Treatment Procedure

1. Selected Physical Therapy Program:

This rehabilitative program was applied to both study groups. It included the facilitation of normal movement patterns. Inhibition of released primitive reflexes as well as facilitation of postural reactions including righting, equilibrium, and protective reactions were also included. Gait training was performed through closed and open environment protocols. Routine stretching exercises were applied for all participants.

2. Suit Therapy:

Following the selected physical therapy program and based on the facilitation of weight-bearing, selected exercises were applied to participants of group (A) while wearing the suit. These exercises included different progressions of standing with manual support, standing holding on, single-limb stance, and squatting on both lower limbs. The tension of bands was calculated before using the suit and this tension was calibrated every five sessions.

3. Whole-body vibration system (WVB):

The whole-body vibration system (Model: OMA-701A) was used for whole-body vibration training of group (B) through reciprocating horizontal displacements on the left and right side of a fulcrum (side alternating type). The automatic mode

Table 1. Demographic and Baseline characteristics.

Item		Group A	Group B
Age (year)	Mean±SD	5.13±0.74	5.0±0.84
Weight (Kg)		14.6±3.83	14.93±2.89
Height (meter)		0.97±0.09	0.99±0.1
Frequency distribution of gender	Boys	11	10
	Girls	12	13
Frequency distribution of spasticity grading according to Modified Ashworth Scale	1	10	9
	1+	13	14

Table 2. Comparing the mean values of Bone Mineral Density parameters in both groups.

BMD	Group	Pre	Post	p-value
Lumbar Spine	ST	0.381±0.06	0.387±0.04	0.188
	WBV	0.376±0.08	0.397±0.04	0.012
	p-value	0.45	0.038	
Femoral Neck	ST	0.422±0.08	0.43±0.06	0.373
	WBV	0.414±0.08	0.47±0.07	0.000
	p-value	0.288	0.005	

BMD: Bone Mineral Density, ST: Suit Therapy, WBV: Whole-body vibration.

was used as peak-to-peak displacement was ranged between 0mm = no amplitude and 3.9 mm = the maximal amplitude. This selected mode allowed adjustment of the output according to each child depending on the body size with a landmark at the second toe. The frequency was individually adjusted with a range of 5-25 Hz.

Following the selected physical therapy program and based on published related studies, that investigated children with neuromuscular disorders and bone fragility disorders; one WBV session is only 3×3 minutes long with 3 minutes rest in between. The three trails included standing in an erect position, squatting, and side-standing (facing handrail). Knee immobilizer was used to maintain knee during first as well as last trail while barefooted. The handrail of the device was used for support during all trails. All exercises were performed with a pad provided by the manufacturer. The session was ended by a period of cooling down. WBV session lasted for 20 min. long and conducted once daily thrice weekly for twelve successive weeks for a total of 36 sessions.

Statistical analysis

Data analyses were performed using Graph Pad Prism 8 for Windows. The collected data of demographic and other baseline characteristics were statistically treated to show the mean and standard deviation of measured parameters. Chi-square test and independent t-test were used to compare baseline characteristics between both groups.

Parametric statistical test in form of repeated measures 2-way analysis of variance (ANOVA) was performed to compare changes in bone mineral density measures according to applied rehabilitation programs. Tukey's multiple comparisons test was conducted following ANOVA when statistically significant differences between data collected before and after treatment within each group and between groups were found. P-value (<0.05) was considered statistically significant.

Results

Table 1 presents a summary of demographic and other baseline characteristics at entry including age, weight, height, frequency distribution of gender, and frequency distribution of spasticity grading according to Modified Ashworth Scale. There were no significant differences between both groups ($p>0.05$).

Comparing pre-treatment mean values between groups revealed no significant difference in all measured variables ($p>0.05$). No significant statistical difference was observed in bone mineral density when comparing pre- and post-treatment mean values of the suit therapy group (A) either at the lumbar spine or at the femoral neck of the dominant side, after application of the rehabilitation program (p>0.05). In contrast, significant statistical differences were observed in bone mineral density when comparing pre- and post-treatment mean values of whole-body vibration group (B) either at the lumbar spine or at the femoral neck of the dominant side, after application of the rehabilitation program (p<0.05). Comparing post-treatment mean values between groups revealed a significant difference in bone mineral density at both the lumbar spine and the femoral neck of the dominant side in favor of whole-body vibration Group (p<0.05) as shown in Table 2.

Discussion

Neurodevelopmental disorders especially CP interfere with posture and motor function. Most of these deficits include neuromuscular and musculoskeletal problems which may affect dramatically the growth and development of children with these deficits.

Koop and Green 1992, concluded that independent standing may be delayed up to 5 years because of inadequate hip flexion as well as hip adductors spasticity in children with diplegia[19]. Therefore, determining the age ranged between five and seven years.

Children with CP can have poorly calcified bones due to a developmental defect (e.g. hormone deficiency); nutritional inadequacy (poor feeding and oral motor dysfunction) may lead to inadequate caloric, protein, and calcium intake. All these factors are important determinate of bone mineral density or medical drug effect (e.g. anticonvulsants) Anticonvulsant medications and limited sunlight exposure may further cause low serum vitamin D levels and thus, the calcium content of bone may be decreased[20].

Insufficient use of weight-bearing activities may contribute to poor bone mineralization in children with CP. Duration of immobilization and some physical problems may cause a deficiency in bone mineralization, as a result, non-ambulatory children with CP often have a poor bone density (osteopenia) and many have bone fractures secondary to minor injuries. Fractures diminish the quality of life of the children and add to their care requirements[21].

Physical inactivity is considered as the main factor affecting bone growth due to moderate to severe functional limitations like diminished weight-bearing activities as well as abnormal muscular activities like abnormal patterns of co-contraction. As a result, low bone mineral density will develop in addition to inadequate nutrition, low vitamin D levels, and irregularities in skeletal maturation.

Currently, suit therapy has been added to physical therapy programs for children with CP as it focuses on improving sensory input through stimulation of deep sensation. Recently, Whole-body vibration (WBV) has been studied on different pathologies as its mechanism depends on promoting reflex contraction of whole-body muscles so, improving proprioceptive awareness. We tried in this current study to compare two different methods enhancing sensory input which are suit therapy and WBV on bone mineral density which already proved to be low in children with CP.

Dual-energy X-ray absorptiometry (DXA) is indispensable for clinical practice in osteoporosis. DXA is the reference method for measuring bone mineral density (BMD) at the lumbar spine and proximal femur[22]. Therefore, it was used in the current study and by a specialist in this field who wasn't blind about this study.

The results of the current study revealed changes in BMD in both groups. Significance was apparent only when comparing pre- and post-treatment results of group B and when comparing post-treatment results of both groups in favor of group B which was enrolled WBV.

The implementation of evidence into clinical practice and future research is of utmost importance. Suit therapies may be costly and time-consuming[23,24].

Due to the lack of definitive treatment for CP, it is not surprising that alternative approaches to management arise and attract the attention of parents of children with CP[25].

Children with sensory deficits and poor muscle strength including children with neuromotor developmental disorders can benefit from the use of suit therapies[7].

Important effects on low BMD have been observed in small and diverse cohorts of children with CP. It is unclear whether small sample sizes or variable treatment responses account for non-significant findings[26].

Improvements in BMD in children and adolescents with compromised bone mass have been found not only at the lower limbs but also at the lumbar spine and the whole body. Seven out of the nine studies included in a review that focused on this population[27] reported positive results at various sites. This is supported by the meta-analysis carried out by Slatkovska et al., (2010) which found significant improvements in trabecular volumetric BMD at both the tibia and the spine following WBV training. This review[28] suggested that the growing skeleton of children and adolescents may be more sensitive to WBV training than other populations.

Totosy de Zepetnek et al.[13] stated in their narrative review that the efficacy of WBV training is anabolic to trabecular and cortical bone among young adults and children with low BMD or physical impairments.

The advantages of the side-alternating WBV are the involuntary muscle stimulus and the low forces applied to the body. Spinal reflexes and muscle contractions are provoked through the side alternating vibration stimulus[29].

Stark et al.[30] Showed that WBV accompanied by other training methods (i.e., physiotherapy, resistance, and treadmill training) improved whole-body BMD and bone mineral content (BMC) in bilateral spastic CP children with higher expectation before 10 years of age.

However, this study had some limitations. Our study was limited to one type of cerebral palsy in addition to a limited range of age. This inclusive criterion developed to avoid variation in results.

Conclusions

We demonstrated that whole-body vibration is effective in improving Bone Mineral Density rather than Suit therapy in children with cerebral palsy of spastic diplegia.

Further future investigations are required on different types of cerebral palsy, larger sample, for a longer period, using different age groups as well as using different assessment tools.

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