Effect of Whole Body Vibration versus Suspension Therapy on Balance and Functional Capacity in Children with Diplegic Cerebral Palsy

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Abstract : Objectives: To compare between the effect of whole body vibration training and suspension therapy on balance and functional capacity in children with diplegic cerebral palsy.

Subjects and methods: Thirty diplegic cerebral palsied children from both sexes were enrolled in this study, ranging in age from 7 to 9 years. They were assigned randomly into two groups of equal numbers. Study group I received whole body vibration training and study group II received suspension therapy via spider cage. In addition to the same designed physical therapy program was given to both groups. Stability indices and functional capacity were evaluated by using 6-minute walk test and Biodex stability system respectively before and after six successive months of treatment. Results: Significant improvement was observed in both groups when comparing their pre and post treatment mean values of all measuring variables. Also, significant differences were recorded in all measuring variables when comparing the post treatment results of both groups in favor of the study group II. Conclusion: Whole body vibration and suspension therapy training are effective additional tools in rehabilitation of diplegic cerebral palsied children with decreased balance and functional capacity in favor of the suspension therapy.

Key words : Whole body vibration, suspension therapy, Balance, Functional capacity, Diplegic Cerebral Palsy

Introduction

Cerebral palsy is a group of motor disorders resulting from a non-progressive injury during early brain development leading to impairments of movement and posture¹. Spastic diplegia, represents the most common form of CP in which lower extremities are more affected than upper extremities and is most frequently


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accompanied by a wide range of ambulatory outcomes. Gait disturbances, impaired balance, and frequent falls are common problems in CP children. Causes of balance disorders include decreased muscle strength, range of movement, motor coordination, sensory organization, cognition, multisensory integration and abnormal muscle tone contribute to balance disturbances at different levels. It had been proved that there were abnormalities in the functioning of the vestibular apparatus of individuals with CP as the peripheral vestibular system was affected. Balance control in children with spastic diplegic CP is mostly affected due to impaired development of neural motor control mechanisms in addition to musculoskeletal abnormalities. The goal of most therapy programs is to maintain the affected extremity in the best possible aligned position to avoid overstretching soft tissue, edema, and pain. Through the exercise program and use of weight-bearing techniques. A method for muscle strengthening is whole-body vibration (WBV). A study showed that WBV therapy was superior to a low intensity resistance training program in improving isometric and dynamic muscle strength in middle aged and older women. Whole-body vibration is practiced on a vibrating platform on which the user is standing in a static position or moving in dynamic movements. Balance control is important for competence in the performance of most functional skills, helping children to recover from unexpected balance disturbances, either due to slips and trips or to self-induced instability when making a movement that brings them toward the edge of their limit of stability. The WBV is considered as a moving surface, so, the children needed to spend more time with both feet on the surface than when they walked over ground. The researches should be conducted to look at the long term effects of the WBV on the child’s ability to negotiate obstacles in their pathway while maintaining the dynamic balance because the parents suggest that children with CP are more prone to fall when encountering obstacles in their environment. Suspension therapy is an innovative and effective modality for treatment. It can be combined with conventional physical therapy methods and can be successfully combined with most of rehabilitation and sport equipment to give postural stability while promoting independence with security which significantly improves balance and coordination of the body and the performance of the vestibular system; also, it allows more full use of the patient’s strength and abilities. Biodex Stability System (BSS) enables objective assessment of balance. Functional ability was determined by means of six minute walk test (6MWT). The 6MWT is a sub-maximal test of aerobic capacity, in which the subjects walk as far as possible in 6 minutes (min.) around a pre-measured distance. It is a useful assessment tool for children with chronic conditions affecting the musculoskeletal system, because walking is a part of their everyday life. This test can present an indirect assessment of someone’s capacity during activities of daily living, and it can be used to follow-up evolution during treatment and to measure walking ability and baseline cardiovascular function of people with disease or low levels of fitness. The test has been validated in several populations, including patients CP. Therefore, the present study was conducted to compare between the effects of The WBV training and suspension therapy on balance and functional capacity in children with diplegic CP.

Materials and Methods

Thirty children with diplegic CP from both genders were enrolled in this study via National Institute for Neuro-Motor System and out-patient clinic of faculty of physical therapy, Cairo University. Their ages ranged from 7 to 9 years (with average age 7.11±0.56 and 7.52 ±0.63). Selecting the age from 8 to 10 years may be attributed to the fact that, patients with CP between 7 and 14 years show defect in agility and balance tasks. Children at 7–10 years of age are able to resolve a sensory conflict to maintain balance and appropriately utilize the vestibular system as a reference and postural control is essentially adult like.

The children were selected with inclusion criteria, including children who had sufficient cognition and were able to understand commands given to them. No history of previous surgery on the lower limbs or Botulinum injections of the lower limb muscles within the preceding 6 months. The degree of spasticity was 1 to 2 according to Modified Ashworth Scale; having level II on Gross Motor Functional Classification Scale (GMFCS). They had mild to moderate dynamic deformity. All the subjects were using AFOs on regular basis. They were able to walk independently at least 10 meters without the use of walking aids but with crouch gait. The strength of quadriceps, hamstring and calf muscles is at least grade 3 according to Kendall et al.

Children who had one or more of the following criteria were excluded from the study: vision or hearing loss, cardiac anomalies, athetotic type, previous history of fracture and subluxation.

The children were classified randomly into two groups of equal number: study group I included 15 children (7 boys and 8 girls) received WBV training and study group II included 15 children (8 boys and 7 girls) received suspension therapy. In addition, the two groups received the same designed exercise program.
This work was carried out in accordance with the code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. Parents of the children signed a consent form prior to participation as well as acceptance of the Ethical Committee of Cairo University was taken. All the procedures involved for evaluation and treatment, purpose of the study, potential risks and benefits were explained to all parents.

**Randomization**

Forty children were assessed for eligibility. Nine children were excluded as they did not meet the inclusion criteria and one child was excluded as his parents refused to participate in the study. Following the baseline measurements, randomization process was performed using closed envelopes. The authors prepared 30 closed envelopes with each envelope containing a card labeled with either study group I or study group II. Finally, each child was asked to draw a closed envelope that contained whether he/she was allocated to the study group I or II. The study design is shown as a flow chart in Figure 1.

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**Figure 1. Flow chart showing the experimental design of the study**
Materials and Methods

a- Preliminary evaluation:

**Gross Motor Function Measure (GMFM–88)**

The children’s motor functions were measured by the Gross Motor Function Measure (GMFM–88)\textsuperscript{26}. The GMFM–88 is a criterion reference tool that is designed to measure changes in gross motor function over time in children with motor impairment and has been validated for sensitivity to changes in children with CP\textsuperscript{27}. It includes 5 dimensions: (1) lying and rolling (17 items), (2) sitting (20 items), (3) crawling and kneeling (14 items), (4) standing (13 items), and (5) walking, running, and jumping (24 items)\textsuperscript{28}. Scores for each dimension were expressed as percentage of the maximum score for that dimension.

b. Balance evaluation and Six Minute Walk Test

A familiarity session was conducted prior to the test session to all the children to ensure their comfort with the research team and to be aware of the different test steps the Biodex instrument system and 6MWT

**Balance evaluation**

The BSS consisted of support handle and a display screen in front of the child that can be adjusted according to the height of each child. The screen provides visual feedback about the degree of tilting, that the child should maintain the cursor in the center of the screen to obtain a good score of balance. Dynamic limit of stability on stability level 8 was performed. Moreover, level 8 represents the most stable and high resistance level of the platform, as high test-retest reliability for the BSS was reported when using high resistance levels\textsuperscript{29}. When the child was centered on the platform, heels coordinates and feet angles and introduced to the system. The platform advanced to an unstable state, then the child was instructed to focus on the visually feedback screen directly in front of him/her while attempting to maintain the cursor in the middle of the bulls eye on the screen. Duration of the test was 30 seconds (sec.). The result was displayed on the screen at the end of each test including overall stability index, antero-posterior stability index, and medio-lateral stability index. The mean of the three repetitions was determined. The high values mean that the child had balance difficulty\textsuperscript{30}.

**Six Minute Walk Test**

Children were allowed to walk on an unobstructed, rectangular pathway following the guidelines of the American Thoracic Society which was conducted by the authors. The walking course distance of 20 meters (m) between turning points was used. To ensure safety and to measure the exact distance walked in 6 min., the therapist followed closely with a stopwatch. Each child was instructed to cover as many laps of the course as possible in 6 min. without running\textsuperscript{31}.

**Treatment protocol**

Each treatment was conducted for 1 hour/three times per week for six successive months. Each group received exercises program for balance and posture control for 30 min/hour/three times per week for six successive months. In addition, the children in the study group I received WBV training and study group II received suspension therapy for 30 min/three times per week for six successive months. A familiarity session was conducted prior to the treatment protocol to all the children. On this session, participants practiced WBV and exercises within spider cage to ensure their comfort with the research team and treatment protocol.

**Whole body vibration**

A commercially available WBV device (Vibraflex Home Edition II®, Orthometrix Inc, and White Plains, NY) was used. The treatment schedule was adapted from published observational studies\textsuperscript{32,33}. Each WBV session consisted of the following schedule: (3 min of WBV) – (3 min rest) – (3 min of WBV) – (3 min rest) – (3 min of WBV) of WBV. So, the duration of each treatment session was about 9 min. The session was terminated if the child complained of fatigue or pain. The child stood on the board with both feet touching the vibration plate. The peak-to-peak displacement, to which the feet are exposed, can be increased with increasing the distance of the feet from the center line of the vibrating board. Three positions are indicated on the vibrating board, marked as ‘1’, ‘2’ and ‘3’, which correspond to peak to-peak displacements of 2 mm, 4 mm and 6 mm. The feet were placed at an equal distance from the center of the board. The children wore shoes during the
WBV sessions to have a more stable position on the vibration plate. The child was initially attached to the tilt table with two straps, one at the level of the pelvis and the other on the level of the knees. The initial tilt angle was set to 35 degrees. The goal for the subsequent sessions was to increase the angle of the tilt table and to eventually perform the WBV without a tilt table, using a WBV device placed on the ground. The speed of the progress toward this goal depended on the child’s ability to maintain an upright posture under the conditions of WBV. The first treatment sessions were performed using a vibration frequency of 12 Hz, with the middle toe of each foot placed 5.5 cm from the neutral axis of the vibration plate (indicated as position ‘1’ on the WBV device). The peak acceleration exerted by vibration increased with the frequency and the amplitude of the vibration. Therefore, higher frequency and higher amplitude are likely to elicit higher musculoskeletal force. The goal was to increase the vibration frequency to 18 Hz (in steps of 0.5 Hz every two treatment sessions) and the peak-to-peak displacement to 4 mm (as determined for the middle toe of each foot). The frequency was increased only if the child felt comfortable with the setting. Once the frequency of 18 Hz was reached, the feet were gradually placed wider apart until they were vertically below the hip joint. These target settings corresponded to a peak acceleration of approximately 2.6 g and were based on our previous experience from a small observational study which indicated that these settings are usually well tolerated by children with Down syndrome. Thus, the middle toe of each foot was eventually placed between 8 cm and 11 cm from the neutral axis of the vibration plate, depending on the width of the child’s pelvis. Whether using the tilt table or the ground-based WBV system, the children flexed their knees and hips between 10 and 45 degrees (to prevent the vibration from extending up to the head). Guided by the study physiotherapist, the children shifted their weight from side to side or increased and decreased the knee and hip angle. Other exercises included weight shift with rotation of the trunk, and alternate flexion and extension of knees. Postural correction was encouraged through visual feedback (by performing the treatment in front of a mirror) and through the therapist’s verbal cueing.

Suspension therapy via spider cage

A designed physical therapy program inside the spider cage was applied. Each child was placed in standing position in the center of the cage. The child was hooked up in the spider cage by means of a belt around his/her waist which was fixed by Velcro straps. The belt attached to the cage by elastic cords. The elastic cords were applied in a spider shape. This suspension system “spider cage” provides horizontal and vertical suspension as a support, assistance, or even resistance during training. Different types of exercises were applied according to the level of the cords.

1. **Cords beside:** The cords connection to the cage was at the same level of the cords connection to the belt so that the whole weight of the body fell on the lower limbs to give a chance for full weight bearing. The cords should be elastic enough to allow the child to re-adjust him/herself and to develop his/her own control. At first, tension of the cords was adjusted to be equal to each other which enabled the child to assume upright position. Then, the tension of cords was decreased gradually. Whereas, the tension of the front and back cords was interchangeably decreased while repeating the same exercises. Different exercises to improve balance from different positions were applied including: kneeling, half kneeling, kneel-walking, stoops and recover, standing weight shift, squatting from standing position (squat balance), kicking ball, throwing ball, stepping, jumping in place, jumping abroad, standing on one foot and standing on balance board.

2. **Full suspension:** the level of the cords connection to the cage was above the level of the cords connection to the belt in which the child was fully suspended (the child’s feet were off the ground). This type of suspension was used as vestibular stimulation, to provide body awareness and to promote or develop postural reflexes (protective extension reactions, righting or equilibrium reactions). The therapist pulled the child backward, allowing him/her to swing forward and backward through space until he/she stopped, also up and down, and side to side movements were allowed. Each child was asked to keep his/her balance, while he/she was moved through space.

Duration of each exercise was 1–2 min with a time of rest (1–2 min) in between exercises.

In addition, each child in both groups underwent individually the same designed exercises program. The program included the following:

- Stretching exercises for the tight muscles
- Strengthening exercises for the antispastic muscles
- Balancing exercises in standing
- gait training
Data analysis

The collected data of the functional capacity and stability indices of both groups were statistically analyzed. Descriptive statistics were done in the form of mean and standard deviation (SD) to all measuring variables in addition to the age, weight and height. Paired t-test was conducted for comparing pre and post treatment mean values in each group. Unpaired t-test was conducted to compare pre and post treatment mean values of all measuring variables between both groups. The level of significance for all statistical tests was set at \( p < 0.05 \). All statistical analysis was conducted through SPSS (Statistical Package for Social Sciences, version 20). The percentage of improvement was calculated according to:

\[
\text{Percentage of improvement} = \frac{\text{post} - \text{pre}}{\text{pre}} \times 100
\]

Results

Subjects’ characteristics

Table 1, presented the mean± SD of age, weight and height of both study groups. There were no significant differences between both groups in the mean age, weight and height (\( P > 0.05 \)).

<table>
<thead>
<tr>
<th></th>
<th>Group I (n=15)</th>
<th>Group II (n=15)</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>7.11±0.56</td>
<td>7.52±0.63</td>
<td>1.88</td>
<td>0.07</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>27.06±3.79</td>
<td>27.86±4.43</td>
<td>0.53</td>
<td>0.59</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>115.12±4.59</td>
<td>117.33±6.85</td>
<td>1.04</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Data are expressed as mean (SD)  kg: Kilogram  cm: Centimeter  \( P \)-value: level of significance

Stability indices

The obtained results revealed no significant differences when comparing the pre-treatment mean values of the two groups (\( P > 0.05 \)). Statistically significant differences were recorded when comparing pre and post-treatment mean values (\( P<0.05 \)) in the form of significant reduction in all stability indices of both groups except non-significant differences in medio-lateral stability index (\( P>0.05 \)) in group I. There were significant differences when comparing the post treatment results of both groups in all measuring variables in favor of group II, as presented in table 2.

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overall SI</td>
<td>A/P SI</td>
</tr>
<tr>
<td>Pre</td>
<td>1.91 ±0.23</td>
<td>1.58 ±0.29</td>
</tr>
<tr>
<td>Post</td>
<td>1.64 ±0.26</td>
<td>1.38 ±0.20</td>
</tr>
<tr>
<td>t-value</td>
<td>-3.012</td>
<td>-2.199</td>
</tr>
<tr>
<td>p-value</td>
<td>0.0054*</td>
<td>0.0363*</td>
</tr>
</tbody>
</table>

Data are expressed as mean (SD)  SI: Stability index  A/P: Antero-posterior  M/L: Medio-lateral  \( P \)-value: Level of significance* Significant at \( P<0.05 \)
Table 3: Six minute walk test of both groups

<table>
<thead>
<tr>
<th></th>
<th>Group I (meter)</th>
<th>Group II (meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>298 ±8.34</td>
<td>295.57 ± 9.30</td>
</tr>
<tr>
<td>Post</td>
<td>330 ±7.45</td>
<td>350.32 ±10.75</td>
</tr>
<tr>
<td>% of improvement</td>
<td>10.74%</td>
<td>18.52%</td>
</tr>
<tr>
<td>t-test</td>
<td>11.08</td>
<td>14.92</td>
</tr>
<tr>
<td>p-value</td>
<td>0.0001*</td>
<td>0.0001*</td>
</tr>
</tbody>
</table>

Data are expressed as mean (SD)  P-value: level of significance %: percentage

* Significant at P< 0.05

Six- minute walk test

The obtained results revealed no significant differences when comparing the pre-treatment mean values of the two groups (P> 0.05). Significant improvement was observed in both groups, when comparing their pre and post-treatment mean values (P< 0.05). While significant difference was observed when comparing the post-treatment results of both groups (P< 0.05) in favor of group I. These are presented in table 3.

Discussion

Measures that improve mobility in children with CP potentially could result in substantial savings for health care systems. Meta-analysis found that abnormalities of gait or balance were the most consistent predictors of future falls. The clinical implication of this study was to compare between the effects of WBV and suspension therapy on balance and functional capacity of children with spastic diplegic CP. Both methods are effective additional tools to the rehabilitation program in favor of the suspension therapy with high recommendation for using suspension therapy.

Significant improvement in the mean values of all measuring variables was recorded in both groups except non-significant improvement in mediolateral stability index of the group received the WBV was recorded. This improvement could be attributed to the combined effect of a designed exercise program and sensory stimulation through WBV or suspension therapy which worked at a multi-system level: the visual, proprioceptive, and vestibular inputs leading to muscle tone modulation that encouraged the appearance of normal motor response, improved the sensorimotor integrative process and enhanced the relationship between the sensory and motor system.

The improvement in the mean values of stability indices of the study group received suspension therapy could be explained by Stillman who stated that proprioceptive awareness of postures and movements is most required during the learning of new skills. With slower movements, the proprioceptive system can monitor and adjust the movements as it occurs. This system is able to trigger immediate, rapid and precisely-tailored compensatory muscular contractions reflexively in response to unexpected changes in external or internal forces; for example as required during standing balance. Keen reported that training with the use of spider cage helped the patient firstly to overcome the gravitational effect on their static, dynamic patterns and secondarily to modulate the muscle tone, which helped in keeping the body from collapsing. McCollum and Leen added that spider cage provided more stabilization to the child which minimized the displacement of center of pressure (COP) under each foot, so keeping the COP near the middle. In addition to that, it helped the child to keep small amplitude of COP motion and decrease postural sway which reflected a good balance control and tended to achieve quiet stance. Suspension therapy for children with hemiparetic CP is an excellent supplement to regularly scheduled physical therapy intervention for the purpose of improving degree of stability in those patients.

It was observed that functional ability level of children in both groups was improved. These results were consistent with the findings of the American Thoracic Society which emphasized that several factors may be contributed to functional improvement as increased stride length because of improved ROM; improved muscular endurance; improved cardiopulmonary efficiency; improved circulation and improved biomechanical loading on the joints resulting in a more comfortable and efficient gait. Behavioral and psychological factors
such as increased confidence, improved body image, and decreased fear of movement or injury could also result in improvement in functional walking\textsuperscript{44}.

Significant difference was observed when comparing the post-treatment results of the two groups in favor of the study group II. These results might be attributed to the effect of spider cage on improving the function of vestibular system. Stimulation of vestibular response provided by spider cage stimulates otolith organs through linear displacement. These findings come in agreement with \textbf{Senior}\textsuperscript{45} who stated that the effect of suspension therapy in the development of equilibrium reaction to maintain and regain balance during standing pattern. This can be achieved primarily from vestibular input and secondary from proprioception and vision. If the speed or magnitude of displacement of the child’s center of gravity is too great, vestibular, proprioception and vision (equilibrium reaction) will help to regain balance in such cases. This treatment gives postural stability while promoting independence with security which significantly improves balance, coordination of the body and the performance of the vestibule system.

This study has some limitations including, only one kind of CP with relatively small sample size which limit the generalizability of the findings. Second, the short duration of the study to detect whether the effects of the suspension therapy or WBV were maintained and whether there were any longer term outcomes after terminating the program. Therefore, future studies can extend the duration of the study to help determine the long term sustainability of the program with a larger sample size and different kinds of CP.

\textbf{Conclusion}

From the obtained results of the current study, it can be concluded that the WBV and suspension therapy are effective additional tools to the rehabilitation program for children with spastic diplegic CP with decreased balance and functional capacity in favor of the suspension therapy with high recommendation for using suspension therapy.

\textbf{Acknowledgments}

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\textbf{References}


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