Efficacy of Trans-mastoidal Vestibular Galvanic Stimulation in Improvement Gait Performance and Upright Postural Stability in Hemiplegic CP Children

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Abstract

Objectives: This work was carried out to investigate the efficacy of galvanic vestibular stimulation in improving gait performance and upright postural stability in hemiplegic cerebral palsy children.

Method: Thirty children were enrolled in this study and randomly assigned into two groups; group A (galvanic vestibular stimulation plus vestibular training program), and group B (vestibular training program). Stride length and time, walking speed tests and modified Ashworth, pediatric balance scales were used to detect and follow the walking performance and upright postural stability. This measurement was taken before initial treatment and after 12 weeks of treatment. The children parents in both groups A and B were instructed to complete 3 hours of the home routine program.

Results: Data analysis was available on the 30 hemiplegic cerebral palsied children participated in the study. The difference between pre and post-treatment results was significant representative in stride length and time, spasticity changes and pediatric balance scores in study groups while insignificant improvement in control groups.

Conclusion: The combined vestibular training program and trans-mastoidal vestibular galvanic stimulation are suggested in improving walking performance and upright postural stability in a static and dynamic situation. So, this selective physiotherapy approach may be used as a strong choice for improving walking and balance abilities in hemiplegic CP children.

Keywords: Galvanic vestibular stimulation; Cerebral palsy; Walking performance

Introduction

Central nervous system lesion which occurs in cerebral palsy patients lead to impaired postural reaction mechanism, loss of reciprocal inhibition mechanism, muscle tone disturbance, impaired coordination mechanism and failure of posture stabilization. Poor balance mechanism is the direct source of the defective motor and functional skills acquisition and motor development delay [1-3]. Learning process through sensory feedback is the plasticity way for continuous modifications of neural connections. Environmental manipulation and external stimulation reshape the neural network patterns through synaptic competition mechanism with the greatest activated synaptic connections become the winner and gain the skill and the lowest activated become the loser. Throughout of life there is an alteration of the synapse’s functional characteristics according to the new experience and skills plus environmental elements and variant situations or occurring CNS lesion [4]. Brain plasticity can occur at every lifetime because the CNS is continually remodelling via synaptic reorganization. So vestibular restoration therapy relies on the active participation which produces anatomical and permanent changes in the synaptic network of the neural circuits which produce behavioral changes on the postural stability [5-10]. Utilization of vestibular galvanic electric stimulation on the mastoid process via placing of anode electrode on the mastoid process in the similar side of body sway and the cathode on the other side. This will activate Na⁺ channels opening lead to depolarization of vestibular afferent nerve which produce modulation of the afferent vestibular signals by raising firing rate of the vestibular
afferent on the cathode side and reducing the excitation degree on
the anodal side which leading to deviation of the posture toward
anodal side [11-13]. GVS has a positive effect on the balance
time required to perform walking in the calibrated distance.

**Intervention:** For all children, the treatment was handling three
times weekly, for 3 months. Each session persists for 90 minutes
(30 minutes vestibular galvanic electric stimulation for study group
plus 60 minutes for a vestibular training program for each group) in
a physical therapy room, in addition to 3 hours of the home regular
program, 7 days a week around the treatment duration.

**Both groups (A and B) received a vestibular training program, like the following:**

a) With the eyes closed: concentration on vestibular system
training through an unstable surface to isolate proprioceptors
and perform postural reaction training(righting + equilibrium+
protective reaction training) through medical balls and balance
board of different sizes.

b) With the eyes opened then closed slow then rapid
training. The child performs dynamic vestibular training forward to
the mirror by walking sideways with feet followed each other then
walk on one line then walk by passing foot to one another.

c) Static training to vestibular system by performing
proximal stabilization in a quadruped, kneeling, half kneeling
standing.

d) Proprioceptive training with vestibular training by
standing on one foot with eyes opened then closed.

e) Equal weight shift transfer by starting the big base of
support then gradual decrease of BOS without disturbance then
with disturbance-with eye opened then eye closed-with hand
support then without.

f) Step forward including or excluding disturbance, with
eyes opened then closed on different directions and surfaces.

g) Weight-bearing with upper extremity functional training
as hand skills training (from sitting- standing-kneeling) as grasping,
voluntary release, reaching hand manipulative skills, bilateral hand
use, and eye-hand coordination training.

h) Changing positions from non-weight bearing to weight
bearing and opposite and from static to dynamic and opposite.

i) Upside training anteroposterior movement and lateral
movement then rotatory movement.

j) Swing therapy anteroposterior movement and lateral
movement then rotatory movement.

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**Subjects**

30 children from the two sexes with hemiplegic C.P. children
were joined in this study, aged 5 to 10 years at a time of enrollment
due to the children in this age could participate in pediatric balance
scale graduations. Children could walk with assistance, On the
other hand, C.P. Children that run up against the involvement
rules were derived out if they had: preceding BoNT-A dose in the
L.L or U.L in the last 12 months or had surgical tendon or muscle
lengthening operation. Children were selected randomly to the
study group (A) taken vestibular galvanic electric stimulation plus
vestibular training approach while the control group (B) taken
vestibular training approach only. The individual-based vestibular
galvanic electric stimulation treatment sessions of 30 minutes were
conducted day after day for 3 months in a physiotherapy treatment
room after the vestibular training period for the group (A). Also,
children in the study group were subjected to home regular program
3 hours daily for the 3 months treatment period. The control group
(B) received a vestibular training program only.

**Outcome measurements**

**Gait speed test:** It was used to evaluate the walking speed
by determining 10 meters which evaluates functional vestibular
abilities. Measuring tape and stopwatch tools were needed to
measure the walking speed. Starting and finishing areas of one
meter were used to build up the maximum speed and decelerate of
the speed. The average of 3 trials results was recorded pre and post
treatment [28].

**Modified ashworth scale:** It was used to evaluate and follow
up the degree of muscle tone disturbance pre and post-treatment.

**Pediatric balance scale:** It was used to evaluate functional
balance abilities. It consists of 14 items each one is scored on a
5-point scale with zero scores indicate to the child cannot achieve
the task without assistance and 4 scores indicate to independence
in performing the ability.

The highest score is 56 points (the summation of the scores in
all items).
The experimental group (group A) received vestibular galvanic electric stimulation following: Vestibular galvanic electric stimulation is a noninvasive technique that sending a direct electric message to the vestibular receptors (3 semicircular ducts and the two otolith organs utricle and saccule) aiming for enhancement of gait performance. By locating a target to the child and starting point on a sheet and placed the anodal electrode on the mastoid process on the side of paralysis and the cathode on the other mastoid process. The elastic headbands stabilized the two stimulating electrodes. The physiotherapist asks the child to go with holding the child from his upper parts of the shoulder in the similar time of turning on the direct current with the intensity of 0.5 mA intensity with long latency more than 200 ms for 30 minutes. There is deviation of the posture on the anodal side till the child reaches to the target or the child could use a pediatric treadmill withholding of hand support and ask the child to slowly walk with the similar time of turning the apparatus on.

Results

Patients characteristics

Table 1 display the demographic and analytic traits of all patients. There were 13 boys (43.33%) and 17 girls (56.67%) and in term of right-hand dominance reported in 17 patients (56.67%), and also 13 patients (43.33%) were left-hand dominance. There was no representative change within both groups regarding age (p=0.4814), to sex (p=0.7240) and in term of hand dominance (p=0.4814).

Table 1: Patients charactaristics.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Study Group N=15</th>
<th>Control Group N=15</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>7.80±1.26</td>
<td>7.73±1.16</td>
<td>0.8816</td>
</tr>
<tr>
<td>Sex N%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>7 (46.67%)</td>
<td>(40%) 6</td>
<td>0.724</td>
</tr>
<tr>
<td>Girls</td>
<td>8 (53.33%)</td>
<td>9 (60%)</td>
<td></td>
</tr>
<tr>
<td>Hand dominance N%</td>
<td></td>
<td></td>
<td>0.4814</td>
</tr>
<tr>
<td>Right</td>
<td>9 (60%)</td>
<td>8 (53.33%)</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>6 (40%)</td>
<td>7 (46.67%)</td>
<td></td>
</tr>
</tbody>
</table>

Changes in stride length

Mean test scores and SD for both groups are demonstrated in Table 2. The mean record of stride length level in the two groups at (pre- and post-treatment levels) was worthless (p=0.05). The average improvement of stride length level tended to be extremely representative's improvement in the experimental group (3.433±0.961 versus 2.967±0.990, p=0.0005) while worthless representatives in the control group (3.100±0.828 versus 2.967±0.915, p=0.1038). The percentage of improvement of stride length level was (15.706%) in the study group compared to the (4.483%) in the control group.

Table 2: The average test of stride length level in both groups.

<table>
<thead>
<tr>
<th>Stride Length Level</th>
<th>Study Group Mean±SD</th>
<th>Control Group Mean±SD</th>
<th>P-value (Within Groups)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td>2.967±0.990</td>
<td>2.967±0.915</td>
<td>1</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>3.433±0.961</td>
<td>3.100±0.828</td>
<td>0.3176</td>
</tr>
<tr>
<td>Improvement%</td>
<td>15.71%</td>
<td>4.48%</td>
<td>0.0389</td>
</tr>
<tr>
<td>P-value (within groups)</td>
<td>0.0005</td>
<td>0.1038</td>
<td></td>
</tr>
</tbody>
</table>

Changes in walking velocity

Mean test scores and SD for both groups are demonstrated in Table 3. The mean record of walking velocity level in the two groups at (pre-treatment) was worthless (p=0.05) while the two groups had a representative’s improvement in walking velocity at post-treatment level (p<.05). The average improvement of walking velocity level tended to be extremely representative's improvement in the study group (6.93±0.7 versus 5.8±0.86, p=0.0001) while worthless representatives regarding control group (5.80±1.21 versus 5.67±1.29, p=0.1643). The percentage of improvement of walking velocity level was (19.48%) in the study group compared to the (2.29%) regarding the control group.

Table 3: The average test of walking velocity level in both groups.

<table>
<thead>
<tr>
<th>Walking Velocity Level</th>
<th>Study Group Mean±SD</th>
<th>Control Group Mean±SD</th>
<th>P-value (Within Groups)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td>5.8±0.86</td>
<td>5.67±1.29</td>
<td>0.7419</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>6.93±0.70</td>
<td>5.80±1.21</td>
<td>0.0039</td>
</tr>
<tr>
<td>Improvement%</td>
<td>19.48%</td>
<td>2.29%</td>
<td>0.0004</td>
</tr>
<tr>
<td>P-value (within groups)</td>
<td>0.0001</td>
<td>0.1643</td>
<td></td>
</tr>
</tbody>
</table>

Changes in pediatric scale

Mean test scores and SD for both groups are presented in Table 4. The mean record of pediatric scale score in the two groups at pre-treatment was worthless (p=0.05) while the two groups had a significant improvement in pediatric scale score post-treatment (p<.05). The average improvement of pediatric scale score
tended to be extremely representative’s improvement in the study group (41.80±1.32 versus 36.53±3.07, p=0.0001) than regarding control group (36.07±2.91 versus 36.53±2.72, p=0.0558). The percentage of improvement of pediatric scale score was (14.43%) in the study group compared to the (1.2%) regarding control group.

**Table 4:** The average test of pediatric scale score in both groups.

<table>
<thead>
<tr>
<th>Pediatric Scale Score</th>
<th>Study Group Mean±SD</th>
<th>Control Group Mean±SD</th>
<th>P-value (Within Groups)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td>36.53±3.07</td>
<td>36.53±2.72</td>
<td>0.3531</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>41.80±1.32</td>
<td>36.07±2.91</td>
<td>0.0001</td>
</tr>
<tr>
<td>Improvement%</td>
<td>14.43%</td>
<td>1.20%</td>
<td>0.3275</td>
</tr>
<tr>
<td>P-value (within groups)</td>
<td>0.0001</td>
<td>0.0558</td>
<td></td>
</tr>
</tbody>
</table>

**Changes in spasticity degree**

Mean test scores and SD for both groups are demonstrated in the Table 5. The mean record of spasticity degree level in the two groups at (pre-treatment) had significant improvement (p<0.05) while both groups had a worthless improvement in spasticity degree at post-treatment level (p>0.05). The average improvement of spasticity degree level tended to be extremely representative’s improvement in the study group. (1.47±0.52 versus 2.40±0.63, p=0.0001) while worthless regarding control group (1.53±0.52 versus 1.60±0.51, p= 0.3343). The percentage of improvement of spasticity degree level was (38.75%) in the study group compared to the (4.375%) regarding control group.

**Table 5:** The average test of spasticity degree level in both groups.

<table>
<thead>
<tr>
<th>Spasticity Degree Level</th>
<th>Study Group Mean±SD</th>
<th>Control Group Mean±SD</th>
<th>P-value (Within Groups)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td>2.40±0.63</td>
<td>1.60±0.51</td>
<td>0.0007</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>1.47±0.52</td>
<td>1.53±0.52</td>
<td>0.7263</td>
</tr>
<tr>
<td>Improvement%</td>
<td>38.75%</td>
<td>4.38%</td>
<td>0.0009</td>
</tr>
<tr>
<td>P-value (within groups)</td>
<td>0.0001</td>
<td>0.3343</td>
<td></td>
</tr>
</tbody>
</table>

**Changes in stride time**

Mean test scores and SD for both groups are demonstrated in Table 6. The mean record of stride time level in the two groups at (pre-and post-treatment level) was worthless (p>0.05). The average improvement of stride time level had a tendency to be extremely representatives improvement in the study group (11.07±1.91 versus 12.93±2.25, p=0.0002) than regarding control group (12.27±1.58 versus 12.47±1.55, p= 0.0824). The percentage of improvement of stride time level was (14.385%) in the study group compared to the (1.6%) regarding control group.

**Table 6:** The average test of stride time level in both groups.

<table>
<thead>
<tr>
<th>Stride Time Level</th>
<th>Study Group Mean±SD</th>
<th>Control Group Mean±SD</th>
<th>P-value (Within Groups)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td>12.93±2.25</td>
<td>12.47±1.55</td>
<td>0.514</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>11.07±1.91</td>
<td>12.27±1.58</td>
<td>0.071</td>
</tr>
<tr>
<td>Improvement%</td>
<td>14.39%</td>
<td>1.60%</td>
<td>0.0001</td>
</tr>
<tr>
<td>P-value (within groups)</td>
<td>0.0002</td>
<td>0.0824</td>
<td></td>
</tr>
</tbody>
</table>

**Discussion**

Utricle and saccule stimulation occur by placing galvanic stimulation on mastoid processes in which cathode on one side and anode on another side which lead to sway on the anodal side. The perception tilt sway occur toward the paralyzed side so the anode should be located on the mastoid process of the paralyzed side because it decreases the firing rates in vestibular afferent of anodal current this will cause shifting in subject perception sway(tilt) in a direction opposite to that turned in walking [13,31]. When a patient walks in a well-learned place he will have a pre-programmed strategy and neural motor circuits so when the patient makes a fast walking there is decrease in sway as a result of vestibular signals is less vital in fast walking as it depends on pre-programmed motor strategy and less of vestibular input while slow walking depends mainly on vestibular input so the sway in vestibular impairment is more in slowly walking than fast walking [32]. Patients with vestibular impairment make sway laterally, decrease walking speed and increase head movement as a compensatory mechanism [33]. Patients with unilateral vestibular impairment suffer from sway toward affected side [34]. The response of GVS is low when the patient is in standing but has a great effect during walking. This is an indicator that vestibular apparatus is very vital during walking more than during standing [35-40]. GVS could stimulate the semi-circular canal which evoked by angular acceleration and head velocity also could stimulate the static utricle and saccule which evoked by linear acceleration and head tilt [41-57]. The static and kinetic labyrinthine provide the CNS with successive sensory input about the linear and rotatory acceleration of the head which activates postural control during head movement via vestibulospinal and reticulospinal tracts [58]. GVS is an electric stimulation passed through application over mastoids producing modulation of the vestibular hair cells and their afferent activity [12,59]. GVS could decrease the abnormalities in walking performance especially in slow walking because the vestibular apparatus has a great role in postural stability in slow walking than in fast walking [60-64]; (Figure 1).
Figure 1: Underlying mechanisms of vestibular galvanic electric stimulation.

Because the vestibular apparatus is a nonlinear fundamentally, so the numbers of the neural network units increase the spread of stimulation producing large correct neural response due to more complicated neural network were involved in dynamic balance than in static balance which leads to improvement of stride length and time and walking velocity [65, 66]. The vestibular disorder clinical picture includes static symptoms which include vestibular nystagmus, head tilting, and body as a vestibulospinal sign, vertigo, perception sway and autonomic manifestations (nausea and vomiting) it needs short time for compensations to occur. Dynamic symptoms include impaired postural control and VOR deficits. It is poorly compensated and take a long of time [67]. The vestibular restoration therapy is aiming for learning acquisition process to deal with difficult circumstances and responses could be used in vertigo treatment [74-78]. Vestibular restoration therapy should concentrate on adaptation mechanism for gaining the dynamic vestibular skill sensory substitution play a vital role in recovery of vestibular impairment by increasing the sensory feedback during close and open eyes, disturbance stimulus through different positions and manipulating the surface (unstable-rough-smooth-rubbery), upside down training, proprioceptive training through static weight bearing and dynamic approximation plus a sense of weights to gain improvement of postural sway [73, 79, 80].
Conclusion

The combined vestibular training program and transmastoidal vestibular galvanic stimulation are suggested in improving walking performance and upright postural stability in a static and dynamic situation. So, this selective physiotherapy approach may be used as a strong choice for improving walking and balance abilities in hemiplegic C.P children.

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References


