Efficacy of Balance Training Program on Improvement of Knee Flexion Deformity in Spastic Diplegic Cerebral Palsied Children

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Abstract

Objective: The aim of this work was to show the effect of balance training program on improvement of motor control of knee joint, tightness of hamstring, gastrocnemius, gracillis and passive range of knee extension.

Methods: Thirty children were enrolled in this study and randomly assigned into two groups of equal number. Both groups had tightness of knee flexors, decreased extension ROM, all of the child can stand with support and all children who had surgical release of tightness were excluded from the study. Standard plastic goniometer was used to detect and follow knee extension from the point of flexion deformity, flexibility tests was used to detect hamstring, gastrocnemius and gracillis muscles flexibility in addition to tape measurement was used alternatively to measure distance between the heel to buttock at the point of extension limitation. These measurements were taken before initial treatment and after 12 weeks of treatment. The Group A (study group) include 15 spastic diplegic C.P. children who received a course of balance training program that include static and dynamic postural stability training plus traditional physiotherapy program. Group B (control group) include 15 spastic diplegic C.P. children who received a traditional physiotherapy program only. children parents in both groups were instructed to wear both knee immobilizers during standing and sleep. The children in group A were advised to perform balance training program as a home routine.

Results: Data analysis were available on 30 spastic diplegic C.P. children and there was insignificant difference in the variables related to age and sex ($p>0.05$). The mean value of knee flexion pre and post treatment showed highly statistical significant difference ($p<0.01$) for the right lower limb in group (A) also statistically significant difference ($p<0.05$) to the right lower limb in group (B). On the other hand there was a highly statistical significant difference of the (Lt) lower limb pre and post treatment in the study group ($p<.01$) while non significant difference to the (Lt) lower limb in the control group ($p>0.05$). The mean value of pre and post treatment revealed that distance between buttock and heel being highly statistically significant pronounced ($p<0.01$) in Rt and Lt side of study group than control one ($p<0.05$).

Conclusion: The use of balance training program plus traditional physiotherapy program are superior to traditional physiotherapy alone for all measurement that include knee mobility and hamstring, gastrocnemius and gracillis flexibility after 12 weeks follow up.

Key Words: Balance training – Knee flexion deformity – Spastic diplegia.

Introduction

SPASTIC diplegic cerebral palsy caused by brain damage in the outer layer of the brain and the cerebral cortex. Spastic diplegic cerebral palsy affects nearly 35 percent of C.P. children and is the most common form of cerebral palsy. Spastic diplegic cerebral palsy symptoms include increased tone or tension in a muscle, tightness of muscles and released pathological reflexes. All four limbs are affected both legs as well as mild affects in the arms are present. Proper treatment can correct toe walking and flexed knees deformity which are common attributes of spastic diplegia [1,2].

The spastic diplegia was known as Little’s disease for several years. Gradually, researchers determined that Little’s disease was spastic diplegia just one of the forms cerebral palsy can take. Diplegia means that both sides of body are affected by a form of paralysis; di is from the Greek for two and plegia is derived from the Greek for some form of paralysis. The term diparesis, which means mild affection in motor disorder [3,4].

There are four commonly identified automatic postural strategies (ankle, hip, suspensory strategies and anticipatory postural responses) muscles contractile patterns are from distal to proximal (gastrocnemius, hamstring, paraspinal muscles). This contraction appear whenever sway is small, slow, and near midline called ankle strategy. But when sway is large, fast and nearing the limit of stability,
muscles contractile patterns are from proximal to distal (abdominals, quadriceps, tibialis anterior) [5,6].

The most effective and efficient treatments will focus first on physical problems with the greatest impact on function and address more than one problem at a time. Training balance on an unstable surface contributes not only to use of visual and vestibular inputs but also (to the use of hip strategy, to increase lower extremity strength and to increase motor control on that type of surface) [7,8].

The spastic diplegic children when they want to walk they need some flexion of hips and knees. Therefore they start walking with both hips and knees in some degree of flexion, adduction and internal rotation. The weight is then taken on the medial border of the feet which results in a valgus deformity of their feet. He moves further forward by bending his trunk over his hips, his legs then follow, toes down first to prevent him falling forwards [9].

Spastic diplegic patients start walking with both hips and knees in some degree of flexion, adduction, internal rotation, the weight is then taken on the medial border of the feet which results in valgus deformity of the feet [4].

Hamstring muscle is functionally important hip extensors. Tightness of hamstring cause inability to perform hip extension lead to tightness of hip flexors lead to anterior pelvic tilting lead to hyper lordosis and forward trunk walking. Tightness of gastrocnemius and gracillis with hamstring lead to knee flexion deformity.

**Material and Methods**

Thirty children from both sexes with spastic diplegia were enrolled for this study. They had tightness in both hamstring and limitation in knee extension. Post operative released of hamstring were excluded, their age ranged from 4 to 7 years.

Children were randomly assigned into two groups of equal number.

**Group A (study group):** Includes 15 spastic diplegic C.P. children who received a course of balance training program that include static and dynamic postural stability training plus traditional physiotherapy program.

**Group B (control group):** Includes 15 spastic diplegic C.P. children who received a traditional physiotherapy program only.

All spastic diplegic children have to have the ability to stand with support, walk with assistance in flexion hip and knee and valgus of the foot.

**Assessment muscles flexibility:**

- From supine lying position the untested limb put in flexion position, tested limb put in flexion hip 90, flexion knee 90, then perform gradual knee extension to detect flexibility of hamstring. The tightness detected from (limitation in knee extension, resistance in knee extension and facial expression). Then perform to the other limb.

- From supine lying position, tested limb taken passively from extended knee to abduction hip (to test gracillis muscle), pillow under knee and from extended knee perform dorsiflexion (to test gastrocnemius muscle).

**Assessment of knee mobility:**

- By using standard plastic goniometer used to detect and follow passive range of knee extension from the point of flexion deformity. The child was placed in supine with thorax firmly strapped to the table to prevent body shift. Normally the knee extension is the starting position (zero degree) by using goniometer therapist measure improvement in knee flexion deformity pre and post treatment.

- Another method to detect limitation in extension, alternatively measure the heel to buttock distance in the point of extension limitation pre and post treatment. This can be a very accurate way of detecting small alterations in range and is useful for follow-up of knee flexion deformity and checking progress in treatment.

**Treatment procedure:**

The children were treated 3 times per week, each treatment session lasted 1 hour. The treatment program include:

**A- Traditional physiotherapy program which includes the following:**

- Faradic stimulation for anterior tibial group to triggering the mass flexion of lower limb so
inhibit the extensor spasticity with support ankle in dorsi-flexion to prevent cross electricity to reach calf muscles because these spastic muscles are more sensitive to electric stimulation than ankle dorsiflexor.

- Prolonged stretch to spastic muscles to gain relaxation via; at first quick stretch occur lead to stimulate gamma fibers lead to stimulate contractile part of intrafusal muscle fiber lead to stimulate non contractile part which include stretch receptors sending afferent signals to PHC. Then to AHC then to alpha motor neuron causing contraction of extra-fusal muscle fibers. At second step just one contraction or repeated contraction occurred stimulate GTO sending 1b afferent to PHC then to 1b inter neuron which reverse the stimulated signals into inhibitory signals inhibiting AHC (alpha motor neuron) then relax the extrafusal muscle fibers. Techniques used as prolonged stretch (positioning, night splint, reflex inhibiting pattern, Bobath technique) [10].

- Facilitation of anti-spastic muscles (tapping followed by movement, quick stretch, triggering mass flexion, biofeedback, weight bearing, clenching to toes, compression on bony prominence, rapping the muscle, approximation, TVR, irradiation to weak muscles by strong muscles, ice application for brief time) [11,12].

- Passive stretching to tight muscles (most common tight muscles are; tendo-acchilis muscles, hamstring, hip flexor and hip adductor). Concentration focused on hamstring, gastrocnemius and gracillis muscles because their tightness responsible on knee flexion deformity. It must be decent gentle gradual stretch not over stretch at all [10].

- Graduated active exercise for trunk muscles (abdominal, para-spinal, lateral flexors).

- Gait training using aids in closed environment using obstacles, side walking then by pass walking).

- Hot packs to improve circulation and relax muscle tension.

B- Balance training program:

This program was introduced to study group only which includes:

• Static balance training:
  - Ability to maintain posture in different position about 20 second.
  - Maintain quadruped position, kneeling, half kneeling, standing; standing with step forward, with large BOS then narrow BOS, shifting to one limb.

• Dynamic balance training:
  - Ability to control the body when the support surface is moving or when the body is moving on a stable surface.

Methods:

- Biodex stability system which produce perturbation in all directions.

- Medical ball to train automatic postural reactions (righting reaction training via sitting on ball and make tilting to body then the child right his head and thorax. Equilibrium reaction training via different positioning as prone on ball, supine on ball, quadruped on balance board, sitting on ball, kneeling with disturbance, half kneeling with disturbance, standing with disturbance, standing with step forward with disturbance, narrow BOS with disturbance, shifting with disturbance) all these produced motor response as raised side of body have equilibrium reaction and lowering side on the other side have protective reaction, axial parts have righting reactions.

• Perturbations in all positions:
  • Quadribed disturbance forward, backward, side-way then by raising one limb then disturbance as above then others, then both one upper limb and opposite lower limb with disturbance.
  • Kneeling and half kneeling in addition to disturbance in all directions sudden raising of one upper limb then release and other limb then both upper limbs.
  • Standing against wall, ball, stand bar, corner, manual support standing with disturbance in all direction then by narrowing BOS then disturbance then by shifting of one lower limb then disturbance then decrease the support by remove one hand from support then disturbance then by taking forward step then disturbance, then ask the child to push me and sudden release in all direction.
  • Changing positions, stooping and recovery exercises to facilitate balance training. The child backed to me in standing then by lowering foot of one limb below plinth ask the child to raise, ask him to do stoop and recovery, using of abdominal belt to perform change of position training [9].

Results

Data analysis were available on 30 spastic diplegic C.P. children. 15 subjects were randomized to traditional physiotherapy program plus balance training and the remaining 15 subjects were randomized to traditional program only. Demographic
data in (Table 4) revealed that $p$-value <0.05 for some variables, this means that has affected on the study at 5% level of significant. But, $p$-value >0.05 for age, group and sex, this means that all of them have not affected on the study at 5% level of significant.

**Knee flexion:**

A comparison of the pre and post treatment for the right lower limbs in both groups as shown in (Table 1) revealed that there is highly statistical significant difference ($p<0.01$) for the (Rt) knee flexion pre and post treatment of the study group (A) also statistically significant difference ($p<0.05$) to the right lower limb in group (B) (Table 1) and Fig. (1). On the other hand there is a highly statistical significant difference of the (Lt) knee flexion pre and post treatment in the study group ($p<0.01$) but non significant difference to the (Lt) knee flexion in the control group ($p>0.05$). The percentage of decreasing in knee flexion in the group A was -7.5% on Rt and -7% on the Lt in study group and -1.43 % on Rt and -2.1 % on Lt in group B as shown in (Table 3).

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**Distance between buttock and heel:**

A comparison of the pre and post treatment for the right knee flexion in both groups as shown in (Table 2) revealed that there is highly statistically significant difference ($p<0.01$) for the (Rt) knee flexion pre and post treatment of the study group (A) also statistically significant difference ($p<0.05$) to the right lower limb in group (B) [demonstrated Fig. (2)]. On the other hand there is a highly statistical significant difference of the (Lt) knee flexion pre and post treatment in the study group ($p<0.01$) and significant difference to the (Lt) knee flexion in the control group ($p<0.05$). The percentage of improvement in distance between buttoc and heel in the group A was 16.95% on Rt and 13.72% on the Lt in study group and 1.62% Rt and 2.36% on Lt in control group as shown in (Table 3).

Since $p$-value <0.05 for variables, this means that has affected on the study at 5% level of significant. But, $p$-value >0.05 for age, group and sex, this means that all of them have not affected on the study at 5% level of significant.

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**Table (1): The mean values of Knee flexion in degree.**

<table>
<thead>
<tr>
<th>Data</th>
<th>Group A</th>
<th>Group B</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Pre-rt</td>
<td>Post-rt</td>
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<tr>
<td>Mean</td>
<td>45.07</td>
<td>41.67</td>
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<tr>
<td>Standard deviation</td>
<td>3.24</td>
<td>3.13</td>
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<tr>
<td>Difference mean</td>
<td>3.4</td>
<td>3.13</td>
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<tr>
<td>$p$-value</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
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</table>

**Table (2): The mean values of distance between buttock and heel in cm.**

<table>
<thead>
<tr>
<th>Data</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-rt</td>
<td>Post-rt</td>
</tr>
<tr>
<td>Mean</td>
<td>27.86</td>
<td>32.5</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.68</td>
<td>1.72</td>
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<tr>
<td>Difference mean</td>
<td>4.67</td>
<td>3.86</td>
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<tr>
<td>$p$-value</td>
<td>&lt;0.01</td>
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**Table (3): Percentage of improvement of variables.**

<table>
<thead>
<tr>
<th>Side</th>
<th>Knee flexion</th>
<th>Distance between buttoc and heel</th>
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<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Rt</td>
<td>-7.5%</td>
<td>-1.43%</td>
</tr>
<tr>
<td>Lt</td>
<td>-7%</td>
<td>-2.1%</td>
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**Table (4): Demographic data (ANOVA).**

<table>
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<th>Source</th>
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<th>ss</th>
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<th>Adj ms</th>
<th>f</th>
<th>$p$-value</th>
<th>Test</th>
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<tbody>
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<td>12499.3</td>
<td>12499.3</td>
<td>12499.3</td>
<td>1076.8</td>
<td>0.0</td>
<td>Sig.</td>
</tr>
<tr>
<td>Age</td>
<td>1</td>
<td>2.8</td>
<td>5.2</td>
<td>5.2</td>
<td>0.49</td>
<td>0.484</td>
<td>No sig.</td>
</tr>
<tr>
<td>Sex</td>
<td>3</td>
<td>42.9</td>
<td>43.8</td>
<td>14.46</td>
<td>1.37</td>
<td>0.252</td>
<td>No sig.</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>0.14</td>
<td>0.707</td>
<td>No sig.</td>
</tr>
<tr>
<td>Error</td>
<td>233</td>
<td>2474.8</td>
<td>2474.8</td>
<td>10.6</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>239</td>
<td>15021.2</td>
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</table>
Discussion

A course of traditional physiotherapy program plus balance training were significantly more effective than traditional physiotherapy alone. Knee flexion was decreased by -7.5%, -7% in study group in comparison with control group which decreased by -1.43%, -2.1% and increase of the distances between buttock and heel by 16.95%-13.72% in study group while control group increased by 1.62-2.36%.

Underlying mechanism of balance training: Balance control requires the interaction of the nervous and musculoskeletal systems and contextual effects.

The nervous system provide the following:
1- Sensory processing for perception of body orientation in space provided by visual, vestibular, and somato-sensory systems.
2- Sensori-motor integration essential for linking sensation to motor responses (centrally programmed postural adjustments that precede voluntary movement).
3- Motor strategies for planning, programming and executing balance response. Information from peripheral receptors including visual, vestibular, and somato-sensory (proprioceptive including conscial which are joint receptors, unconsctial proprioceptors which are muscle spindle and GTO in addition to cutaneus receptors) to the cord and brain stem then be sensitzed by the thalamus then localizd by post central gyrus (sensory areas) to make three functions (perception of sensation, cognition, formation of sensory strategies) then reach to cerebellum and basal ganglion to prevent excessive activity, smoothening of information then to the precentral gyrus which perform permanent changes lead to motor strategies and long term memory of this skill.

Underlying mechanism of balance training:

Internal responses:
- Reflexly response via stretch reflex comprises the first response to external perturbation producing contraction of antigravity muscles to regain balance.
- Voluntary response produces highly variable motor output by reaching to nearby stable surface.
- Automatic postural reactions produce prevention from fallen down.

External responses:
- Ankle strategies produced by small disturbance (forward movement produce forward body sway shifting line of gravity backward produces contraction of paraspinial muscles, hamstring, calf muscles, backward movement produces backward body sway shifting line of gravity anterior produce contraction of abdominal, quadriceps, ant-tibial group.
- Weight shift strategies: This moves COG in a lateral plane primarily through activation of hip abductor and adductor muscles.
- Hip strategy: Produced by large and fast disturbance. Large rapid forward movement of board lead to backward sway shifting of line of gravity anterior leads to contraction of abdominal, quadriceps and ant-tibial muscles. Large backward movement leads to forward body sway shifting of COG backward produces contraction paraspinial, hamstring and calf muscles.
- **Step strategy**: Produced by large force perturbation leads to forward or backward step to increase BOS to regain balance control. In addition to the effect of balance training on motor control and strengthen of weak muscles, vestibular stimulation will trigger vestibule-spinal tract which affects on alpha motor neuron producing modulation of muscle tone, stimulates also the co-ordination of different parts of the body parts to learn the difficult and new situation to overcome it after that [14].

Heitkamp et al., [15] studied the gain in strength and muscular balance after balance training which was performed on instability training devices as rolling board and large rubber ball. Strength gain was similar for the flexors and extensors. Affected limbs improve after balance training greater than increase over the strength training group. The results indicate that balance training be effective for gain in muscle strength, equalization of muscular imbalances which may be achieved after balance training.

Goddard et al., [16] studied the effect of force platform feedback for standing balance training after stroke. There are no significant effects on laboratory postural sway indicators and clinical measure of functions at follow-up assessment. Force platform feedback improves stance symmetry but not sway in standing, clinical balance outcomes.

**Conclusion:**

Balance training with traditional physiotherapy program should be considered in tightness of muscles and limitation of ROM. The use of balance training program plus traditional physiotherapy program are superior to traditional physiotherapy alone for all measurements that include knee mobility and muscles flexibility after 12 weeks follow-up.

**References**