Efficacy of Augmented Training Program for Hip Abductors in Stroke Patients

MOUSSA A. SHARAF, PhD.*; SAHAR M. ADEL, PhD.** and KHALED E. AYAD, PhD.***

The Departments of Physical Therapy for Neuromuscular Disorders and its Surgery, Faculty of Physical Therapy, Cairo University* & Basic Science, Faculty of Physical Therapy, Cairo University** and Musculoskeletal Disorders, Faculty of Physical Therapy, Cairo University***

Abstract

Background: Stroke patients are suffering from weakness of hip abductors that causes disturbance of balance and functional activities, in addition to, increasing the risk of fall. The main aims of this study were to evaluate the efficacy of a re-education program for rehabilitation of hip abductors on balance and some functional activities and to study its long-term effect on these activities as compared with traditional exercises.

Material and Methods: Forty stroke patients participated in the study. They were divided randomly into two equal groups. The study group received the re-education program in addition to traditional exercises while control group received traditional exercises only for successive eight weeks. Lateral reach test, timed up and go test, medio-lateral stability and the maximum angle of lateral sway of the trunk during standing from sitting were measured before treatment, after treatment and after another three months.

Results: There was significant difference between pre & post-treatment in both groups and significant difference between post-treatment & follow-up in the study group and non significant in the control group.

Conclusion: Proper re-education program for the hip abductors is very effective in the rehabilitation of stroke patients.

Key Words: Stroke – Balance – Medio-lateral stability – Hip abductors – Muscle re-education.

Introduction

BALANCE impairment is one of the most important impairments following stroke [1-4]. It increases fall risk [5-6]. Reduced balance is closely associated with low ambulatory level in chronic stroke patients and may be an important factor in loss of cardiovascular fitness [7]. The decreased ability to maintain static and dynamic balance after stroke could be related to the inability to select reliable sensory information (visual, vestibular and somatosensory systems) in order to produce the proper motor action necessary to maintain postural stability [8,9]. A positive correlation exists between balance impairments and decreased strength of the muscles of the lower limb [3,4,10,11].

As a result of dysfunction of the motor control [12] and delayed or diminished recruitment of lower limb muscles including the hip abductors [13,14], stroke patients suffer from weakness of hip abductors which results in lack of the ability to counteract the leaning by the trunk to the opposite side [15,16], difficulties during standing from sitting [17-20] and difficulties in standing and shifting weight [21-22], in addition to, difficulties during walking [16,23].

Weakness of hip abductors in stroke patients is potentially important contributor to lateral instability and associated with poorer physical performance [24-26]. This weakness causes increased incidence for falling [27,28] so, weakness of these muscles can be used as a predictor for future falling [29,30]. These falls can lead to high economic costs and social problems, as well as, pathological events (e.g. hip fractures), and additional declines in function and disability status [5,11,27,31].

Therefore, this study was conducted to evaluate the efficacy of augmented training program for hip abductors in stroke patients as compared with the traditional treatment program and also to evaluate the long-term effect of this program.

Subjects and Methods

Forty male stroke patients participated in this study. Patients were selected from the out-patient clinic, Faculty of Physical Therapy, Cairo Univer-
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Inclusion criteria:

Patients were medically stable. Degree of spasticity in the hip adductors of the affected side is 1+ or 2 according to Modified Ashworth’s Scale [32]. All patients had the ability to stand from sitting position and walk independently without assistance of external aids or orthosis. All patients were able to follow simple verbal commands and instructions.

Exclusion criteria:

- Patients with other neurological or orthopedic diseases that may affect balance and walking, as recurrent stroke, Parkinsonism, severe osteoarthritis, or rheumatoid arthritis.
- Patients with balance disorders due to other causes rather than stroke (e.g., inner ear, vestibular or cerebellar dysfunctions).
- Patients who had deep sensory loss, blindness or deafness.
- Patients who had deformities of the lower limbs.
- Patients with perceptual or cognitive disorders.
- Patients with visuospatial neglect.

Patients were randomly assigned into two equal groups; study group and control group. The investigator flipped a coin to determine whether the patient was in the study or control group.

- **Study group (Group A):** Included 20 patients, eleven patients were right sided stroke and the other nine were left sided. Five patients had hemorrhagic stroke and the other 15 had ischemic stroke.
- **Control group (Group B):** Included 20 patients, ten patients were right sided stroke and 10 were left sided. Four had hemorrhagic stroke and the other 16 had ischemic stroke.

The general characteristics of patients in both groups are shown in Table (1).

Procedures:

An informed consent was obtained from all patients before participation. The aims and procedures of the study were explained to each patient before participation.

A- Evaluative procedures:

Each step of the evaluative procedure was practiced three times to make the patient familiar with the procedures before starting recording.

All patients in both groups were subjected to the following assessment before starting treatment (pre-treatment), directly after treatment (post-treatment) and after three months following the end of the treatment (follow-up):

- **Lateral reach test (LRT) [33]:** Each patient was instructed to stand against the wall with his feet shoulder width apart (not touching the wall) and positioned the non-affected arm closer to the wall at 90° of shoulder abduction with open fingers. The assessor put a mark on the wall at the tip of the middle finger (first mark). Without touching the wall, the patient was instructed to reach sideways as far as possible, while both feet were maintained in full contact with the ground. Neither knee flexion nor trunk rotation or flexion was permitted. The assessor put a mark on the wall at the tip of the middle finger at the end of the movement (second mark). The distance between the two marks was measured and recorded.

- **Timed up and go (TUG) test [34]:** Each patient was instructed to stand from a chair, walk three meters, turn and walk back to the chair and sit down again.

- **Medio-lateral (M-L) stability:** It was assessed by using the Biodex stability system (Biodex corporation, Shirley, NY). Each patient was instructed to stand bare feet on the platform. The height of the screen display and the support handles were adjusted according to the patient’s height. The patient was instructed to achieve a centered position on a slightly unstable platform and to keep the cursor centered on the screen grid.

- **The maximum angle of lateral sway of the trunk during standing from sitting:** It was assessed by using Opto-electronic motion analysis (Qualisys motion capture system, Goteborgsvgen 74, SE-43363 Savedalen, SWEDEN). First, calibration of the system was done. Then, each patient was asked to take off his clothes except the short. Eight skin markers (four in each side) were stuck to the skin over specific bony landmarks as follows: 1- Acromion process, 2- Greater trochanter, 3- Lateral aspect of the knee joint line, 4- Lateral malleolus.

- **Each patient was instructed to sit on a chair with adjustable height with both feet at the same level and fully supported on the ground, the knee angle was 105° [35] and upper limbs folded in front of the chest. Each patient was asked to stand up in his natural way.**

- **The Q trac was used to capture the motion while Q tools program was used to analyze the lateral**
sway of the trunk during standing from sitting and the maximum angle of sway was determined and recorded.

Each test was repeated three times and the average was taken.

**B- Treatment procedure:**

Patients in both groups received traditional physical therapy program for one hour per session for three sessions per week for eight successive weeks. Additionally, patients in group A received a designed re-education program for the hip abductors for 30min.

- The traditional exercise program consisted of: Controlling spasticity (through positioning, weight bearing, Bobath technique), stretching of tight muscles (as ankle plantar flexors, hip abductors, knee and hip extensors, trunk side flexors), strengthening exercises (for the weak lower limb and back muscles), balance training (through assuming upright postures, changes of positions and weight shifting exercises) and gait training.

- The designed re-education program for the hip abductors was conducted through the following steps:

  **Step I:** Quick stretch: It was applied from supine lying position. Each patient was asked to try to abduct the affected limb directly after the application of quick stretch as much as he can. This was accompanied by tapping on hip abductors. When a response was felt, this procedure was repeated from side lying position (on the non-affected side).

  **Step II:** Synkinetic movement: It was conducted through resisting the hip abductors of the non-affected side from supine lying position. At the same time, the patient was instructed to concentrate in his affected side and try to abduct his affected hip joint as much as he can.

  **Step III:** EMG biofeedback training: It was applied by using Myomed 432 unit for electronic registration of muscle activity. This step started, as soon as, there was voluntary control over the hip abductors (initiation of movement). Two self adhesive electrodes were located halfway between the iliac crest and the greater trochanter after shaving the hair and cleaning this area by cotton and alcohol. The ground electrode was located on the medial side of the tibia [36].

  At first the EMG biofeedback was applied on the non-affected side and the patient was instructed to abduct his non-affected hip to notice the relationship between effort and both light and sound. As soon as the patient understood the procedure and became familiar with it, the electrodes were applied on the hip abductors of the affected side. The patient was instructed to abduct his affected hip as much as he can and to do his best to make the light higher and the sound louder. It was applied while the patient was in supine lying position. The patient was asked to maintain each contraction for five to 10 seconds and to relax for 15 to 20 seconds. When the patient controlled the movement from this position, the procedure was repeated from side lying position (on the non-affected side). When there was control over this movement from side lying position, the procedure was repeated from standing position.

  **Step IV:** Graduated active exercises: As there was voluntary control over the hip abductors, graduated active exercises (active assisted, active free and active resisted) for the hip abductors were applied from supine lying position and side lying position (on the non-affected side).

  For more gains, active free exercises were conducted from standing position through instructing the patient to do the following gradations:

  - Abduct the affected limb (while standing on the non-affected side).
  - Stand on the affected side and to raise the non-affected side on a step in front of him.
  - Stand on the affected side and to abduct the non-affected side.
  - Stand and take a step side way first by the affected side then by the non-affected side.

**Data analysis:**

ANOVA was used to analyze the pre, post-treatment and follow-up values of the measured variables within the group. Unpaired t-test was used to analyze the patients’ general characteristics and the pre, post-treatment and follow-up between the two groups. The least significant difference (LSD) test was used to show the difference between pre & post-treatment, post-treatment & follow-up within the same group. The alpha point of 0.05 was used as a level of statistical significance (when \(p<0.05\), the difference is significant and when \(p<0.01\), the difference is highly significant).

**Results**

Comparative data regarding the general characteristics of patients (including age, weight, height and duration of illness) revealed non significant differences between both groups (\(p=0.33, 0.61, 0.79, 0.46\) respectively) i.e., they were matched (Table 1).
**Lateral reach test (LRT):**

ANOVA showed highly significant difference in both groups ($p<0.0001$). On the other hand, there was non significant difference between both groups at pre-treatment ($p=0.45$) and highly significant difference at post-treatment and at follow-up ($p<0.0001$) as shown in Table (2). There was a highly significant difference between pre & post-treatment in both groups ($p<0.0001$). The difference between post-treatment & follow-up was significant in group A ($p=0.03$) and non significant in group B ($p=0.92$).

**Timed up and go (TUG) test:**

ANOVA showed a highly significant difference in group A ($p<0.0001$) and a significant difference in group B ($p=0.03$). There was no significant difference between both groups at pre-treatment ($p=0.81$) and highly significant difference at post-treatment and at follow-up ($p=0.005$, $p<0.0001$ respectively) as shown in Table (3). The difference between pre & post-treatment was highly significant in group A ($p<0.0001$) and significant in group B ($p=0.03$). Additionally, the difference between post-treatment & follow-up was significant in group A ($p=0.04$) and non significant in group B ($p=0.69$).

**Medio-lateral (M-L) stability:**

ANOVA showed a highly significant difference in group A ($p<0.0001$) and a significant difference in group B ($p=0.03$). There was no significant difference between both groups at pre-treatment ($p=0.91$) and a highly significant difference at post-treatment and at follow-up ($p=0.005$, $p<0.0001$ respectively) as shown in Table (4). The difference between pre & post-treatment was highly significant in group A ($p<0.0001$) and significant in group B ($p=0.04$). Additionally, the difference between post-treatment & follow-up was significant in group A ($p=0.04$) and non significant in group B ($p=0.72$).

The maximum angle of lateral sway of the trunk during standing from sitting:

ANOVA showed a highly significant difference in group A and group B ($p<0.0001, p=0.004$ respectively). There was significant difference between both groups at pre-treatment ($p=0.55$) and highly significant difference at post-treatment and at follow-up ($p<0.0001$) as shown in Table (5). The difference between pre & post-treatment was highly significant in group A ($p<0.0001$) and significant in group B ($p=0.02$). Additionally, the difference between post-treatment & follow-up was significant in group A ($p=0.02$) and non significant in group B ($p=0.31$).

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**Table (1): General characteristics of patients in both groups (A&B).**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group (A) Mean±SD</th>
<th>Group (B) Mean±SD</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>54.4±6.24</td>
<td>53±4.74</td>
<td>0.985</td>
<td>0.33 (NS)</td>
</tr>
<tr>
<td>Weight</td>
<td>70.75±6.51</td>
<td>71.75±6.11</td>
<td>0.501</td>
<td>0.61 (NS)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.8±6.86</td>
<td>169.3±6.57</td>
<td>0.259</td>
<td>0.79 (NS)</td>
</tr>
<tr>
<td>Duration of illness</td>
<td>11.9±3.11</td>
<td>11.2±2.93</td>
<td>0.732</td>
<td>0.46 (NS)</td>
</tr>
</tbody>
</table>

Significant at $p<0.05$. (NS): Not significant ($p>0.05$).

**Table (2): Comparison between the mean values of LRT for both groups at pre, post-treatment and follow-up.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-treatment Mean±SD</th>
<th>Post-treatment Mean±SD</th>
<th>Follow-up Mean±SD</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>10.8±0.89</td>
<td>14.93±1.44</td>
<td>15.8±1.49</td>
<td>84.2</td>
<td>&lt;0.0001 **</td>
</tr>
<tr>
<td>t-value</td>
<td>0.757</td>
<td>8.567</td>
<td>10.572</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.45 (NS)</td>
<td>&lt;0.0001 **</td>
<td>&lt;0.0001 **</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant at $p<0.05$. (NS): Not significant ($p>0.05$). **Highly significant ($p<0.01$).

**Table (3): Comparison between the mean values of TUG test for both groups at pre, post-treatment and follow-up.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-treatment Mean±SD</th>
<th>Post-treatment Mean±SD</th>
<th>Follow-up Mean±SD</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>45.05±4.12</td>
<td>33.35±7.34</td>
<td>28.35±6.37</td>
<td>28.75</td>
<td>&lt;0.0001 **</td>
</tr>
<tr>
<td>t-value</td>
<td>0.237</td>
<td>2.973</td>
<td>4.891</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.81 (NS)</td>
<td>0.005 **</td>
<td>&lt;0.0001 **</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant at $p<0.05$. * Significant at $p<0.05$. **Highly significant ($p<0.01$).

**Table (4): Comparison between the mean values of M-L stability for both groups at pre, post-treatment and follow-up.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-treatment Mean±SD</th>
<th>Post-treatment Mean±SD</th>
<th>Follow-up Mean±SD</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>3.5±0.72</td>
<td>2.5±0.57</td>
<td>2.1±0.49</td>
<td>28.75</td>
<td>&lt;0.0001 **</td>
</tr>
<tr>
<td>t-value</td>
<td>0.109</td>
<td>0.91 (NS)</td>
<td>0.243</td>
<td>0.03 *</td>
<td>*</td>
</tr>
<tr>
<td>p-value</td>
<td>0.005 **</td>
<td>&lt;0.0001 **</td>
<td>&lt;0.0001 **</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant at $p<0.05$. * Significant at $p<0.05$. **Highly significant ($p<0.01$).

**Table (5): Comparison between the mean values of the maximum angle of lateral sway of the trunk during standing from sitting for both groups at pre, post-treatment and follow-up.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-treatment Mean±SD</th>
<th>Post-treatment Mean±SD</th>
<th>Follow-up Mean±SD</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>27.2±4.53</td>
<td>18.5±3.54</td>
<td>16.0±5±1.76</td>
<td>68.53</td>
<td>&lt;0.0001 **</td>
</tr>
<tr>
<td>t-value</td>
<td>0.594</td>
<td>5.762</td>
<td>7.719</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.55 (NS)</td>
<td>&lt;0.0001 **</td>
<td>&lt;0.0001 **</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant at $p<0.05$. **Highly significant ($p<0.01$).
Discussion

This study was conducted to evaluate the efficacy of augmented training program for hip abductors in stroke patients as compared with the traditional treatment program and also to evaluate the long-term effect of this program. The results of the present study revealed significant increase in both LRT and the M-L stability in both groups (in favour of the study group). Also, it showed significant decrease in both TUG test and the maximum angle of lateral sway of the trunk during standing from sitting in both groups (in favour of the study group).

Concerning the significant differences in the control group, this can be justified as follows:

- Traditional exercises including controlling spasticity, stretching of tight muscles, strengthening exercises for the weak muscles and balance training could improve the control on hip abductors which improve the ability to counteract leaning by the trunk to the non-affected side and could ensure stability of the pelvis, as well as, ensuring more stability of the trunk on the pelvis and in turn better balance and better function. This agrees with the opinion of Horak [37] who concluded that impairments in ROM, tone, strength, and muscle control can influence postural control. Also, it is in agreement with the opinion of Bohannon [38] and Geurts et al. [25] who concluded that motor weakness in stroke patients may participate in postural instability. Also, this is supported by the opinion of Adams et al. [15] and Perry [16] who concluded that weakness of the gluteus medius muscle affects lateral stabilization of the hip and pelvis resulting in lack of the ability to counteract leaning by the trunk toward the non-affected side.

- The improved control on the hip abductors provides stability of the pelvis resulting in better alignment [24]. This might decrease the time needed for standing from sitting, in addition to, decrease of the maximum angle of lateral sway. Also, it gives a chance for patients to increase the single limb support phase on the affected side that allows advancement of the non affected limb, and in turn increasing the speed of walking and consequently decrease in TUG test. This opinion is supported by the opinion of MacKinnon & Winter [1] who concluded that hip abductors act to control balance of the trunk and swing leg about the supporting hip during gait. Also, this opinion is supported by the opinion of Mercer et al. [39] and Maguire et al. [40] who concluded that strengthening of hip abductors for the hemiplegic patients improves gait. This is in agreement with the opinion of di Fabio [21] who reported that following stroke, reduced muscle function in the lower stroke affects the ability to support, shift and balance the body mass.

- Traditional exercises are suggested to decrease fear of falling which is one of the most important complications post stroke and so improving activities [4].

- As balance training is performed from upright postures, this caused better orientation of the pelvis and body parts resulting in better results [38].

These findings were consistent with the conclusion of de Oliveira et al. [31]. In addition to the previous explanations the more significant improvement in the study group can be explained as follows:

- Quick stretch and tapping might facilitate muscle contraction through their action primarily on the muscle spindle primary endings. It can be suggested that, the use of these techniques can potentiate each other and produce reflex contraction of hip abductor muscles while providing weak inhibition of the antagonistic muscles (hip abductors) through reciprocal innervation. This is consistent with the opinion of O’ Sullivan [41].

- Synkinetic movement is thought to potentiate and reinforce the short lived effect of quick stretch and tapping [41] through making more firing and recruitment of motor units resulting in more control on the hip abductors of the affected side. This is in agreement with the opinion of Sawyer & LaVigne [42].

- EMG biofeedback added more reinforcement and more volitional control over the hip abductors. This can be justified by many reasons:

  - EMG biofeedback is suggested to increase motor unit recruitment through teaching the patient to increase the electrical activity of the hip abductors and to rebuild more voluntary control over them resulting in regaining neuromuscular control and increase strength of these muscles. This opinion is supported by the opinion of Mulder et al. [43], Herrington [44] and Prentice [45].

  - EMG biofeedback is suggested to make facilitation of transmission of neural impulses to the hip abductors through repeated passage of excitation over the same neural pathways (through decreasing the impedance along this neural pathway) or through facilitation of unused pathways. This is supported by Huang et al. [46].
- EMG biofeedback aided the patients to produce repetitive contraction of the hip abductor muscles which in turn might produce some local effects within the muscles themselves including temporary increase in muscle metabolism with its associated consequences of increased nutrients, oxygen uptake and increased local blood flow followed by an increase in capillary density surrounding the trained muscle fibers. These local effects can contribute to the improvement in muscle strength. This assumption is consistent with the findings of Low & Reed [47].

- EMG biofeedback with its audio-visual inputs can provide good information about the subject's volitional effort. Also, it can improve sensory awareness of the hip abductors through the repetitive training movement [48]. This improvement in sensory awareness may help in improving muscle response and facilitation. This is in agreement with the opinion of Shumway-Cook & Woollacott [49] who concluded that motor responses and activation of muscle synergies are influenced by sensory feedback and by attention.

- EMG biofeedback is very effective in motivating the patients as it provides patients with audio-visual signals which are important for error reduction during task performance [48,49].

As well the use of biofeedback provides patients who have sensorimotor impairments with opportunities to regain the ability to assess different physiological responses and possibly to learn self-control of those responses [46].

- The re-education program is suggested to produce excitation of the sensory cortex (through stimulation of proprioceptors, exteroceptors, visual and auditory inputs) and enhance the somatosensory mechanism which in turn excites the motor cortex. Excitation of the motor cortex might facilitate the proper motor neurons, and the appropriate number of motor neurons that are required for this activity. In turn, this excitation is accompanied by inhibition of the inappropriate motor neurons [41]. This is consistent with the opinion of de Oliveira et al. [31] who reported that the integration of the somatosensory mechanism with both of visual and vestibular systems is crucial for adequate postural control.

- The repetitive motor training via EMG biofeedback with its potent facilitatory effect added to it the cumulative effect from quick stretch, tapping and synkinetic movement were very effective in increasing the control on the hip abductors and improving balance and functional activities in the study group. Moreover, the application of graduated active exercises caused more neuro-muscular control on the hip abductors resulting in more improvement in balance and functional activities. The application of such program enhanced using of the hemiplegic side which promote plasticity in the affected hemisphere through emphasizing the use of previously established neural networks and are associated with improved function [40].

The findings of this study is consistent with the findings of Leroux et al. [50].

Also, the significant differences between post-treatment and follow-up in the study group can be justified as follows:

- This study suggested multisensory approach that included exteroceptive, proprioceptive, visual and auditory stimulation which is effective more than traditional exercises. This opinion is supported by the opinion of Chen et al. [51] who suggested that excessive postural oscillations and instability that occur mainly in the frontal plane may be improved through better somatosensory integration, with gradual increase in use of proprioceptive and exteroceptive afferent information of the paretic lower limb. Also, this is consistent with the opinion of Yelnik et al. [52] who reported that multisensory training approach could be more efficient than a traditional one.

- The improved multisensory integration with increased self-confidence might improve the ability to analyze, compare, and select the pertinent sensory information to maintain balance and prevent falls [9].

- Moreover, training of hip abductors from standing position is suggested to make more control on the hip abductors of the affected side. It is supported by the opinion of Marsden et al. [53]. As well, the re-education program is suggested to make more enhancement of self-confidence and more decrease in the fear of falling that will enhance balance, functional activities and independence [4]. Moreover, the re-education program caused more orientation of the pelvis and body parts resulting in better performance.

The long-term effect in the study group might be attributed to the different effects of the combination between traditional exercises and the re-education program that is suggested to improve learning. This opinion is consistent with the opinion of Kerdoncuff et al. [54] and Van Peppen et al. [55].
who concluded that practice is believed to be essential for effective learning of complex tasks.

The cumulative effects of quick stretch, tapping, synkinetic movement, EMG biofeedback and graduated active exercises on the hip abductors were the main justification of the significant improvement at the end of this re-education program.

Conclusion:

Proper training program for hip abductors in stroke patients can improve balance and can enhance functional activities. Therefore, this augmented training program for hip abductors is very effective in the rehabilitation of stroke patients as it can improve motor relearning and it has a long-term effect on balance and functional activities.

References


