The Effect of Balance Training With Upper Extremity Exercise on the Improvement of Balance Performance After Stroke

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Abstract

The purpose of this study was to investigate the effect of balance training with upper extremity exercise on the improvement of balance performance in people who have had a stroke. Eighteen candidates who have all experienced a stroke, were living in Dong-Gu, Ulsan and were participating in a community-based rehabilitation program, have been included in this study. The program was conducted three times weekly, 1 hour per session, for 7 consecutive weeks. Subjects were tested with 7 m and 100 m Timed Gait Test (sec), Timed Get Up and Go Test (sec), Functional Reach Test (cm) and 5 items of Berg's Balance Test at pre-training and post-training. Total balance index and balance ratios were measured by K.A.T. 3000. The balance training program performed by sitting on a chair and gymnastic ball and standing on stable and unstable surfaces during upper extremity exercises such as Proprioceptive Neuromuscular Facilitation (PNF) upper extremity pattern, placing a ball up from floor, throwing and catching it. After seven weekends of balance training, subjects showed a significant difference in balance test results. The exceptions were three items of Berg’s Balance Test (p<.05). Balance index score and affected and unaffected side balance ratio had a larger improvement than pre-training (p<.05). The result of this study showed that intervention of this balance training program could improve the balance performance in people who have had a stroke.

Key Words: Balance performance; Balance test; Balance training with upper extremity exercises; Stroke.

Introduction

Human movements are performed in a dynamic environment, with both predictable and unpredictable perturbations that are compensated with anticipatory and reactive control mechanisms (Bugnariu and Sveistrup, 2006). The ability to balance requires that the body's center of gravity or mass lie over the base of support (Nashner, 1989). Balance is important for the safe performance of many activities that require the ability to stand, reach, turn, and to bend down and pick up objects from the floor. It is dependent on sensory input, central processing (or motor control), and muscle strength and power (Hall and Brody, 1999; Judge, 2003).

The visual system provides information about the environment, location, and the direction and speed of movement within the environment. The vestibular system provides information about movement of the head, independent of visual cues. The somatosensory system provides information about the body’s position and contact from the skin through pressure, vibration, tactile sensors and muscle proprioceptors (Islam et al, 2004).

The central nervous system (CNS) must coordinate with motion across many joints and muscles.

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Methods

Subjects

Eighteen people, who have had a stroke, participated in this study. They were judged as on second or third grade of disability, living in Dong-Gu, Ulsan, and participating in a community based rehabilitation program. Subjects were excluded if they had any neurological or orthopedic diseases that might interfere with this study. They had to have a score higher than 90 points at the Korean version of Mini-Mental State Examination (MMSE-K, Kwon et al, 1988). Also, their scores of walking at the Motor Assessment Scale (MAS) had to be more than 3 points, their function of upper extremity had to be more than 4 points, and their function of hand had to be more than 4 points.

Balance Training Intervention Program

The program was conducted three times weekly, 1 hour per session, for 7 consecutive weeks. The daily exercise program consisted of 10 min general warm-up exercises, 40 min balance exercises, and 10 min cool-down/relaxation exercises, which is consistent with previous study designs (Kaeseler et al, 2007). We divided the subjects into two groups of people who had similar degrees of disability.

The balance training program was performed by sitting on a chair, sitting on a gymnastic ball and standing on a rigid surface. During this program, subjects performed upper extremity exercises such as the PNF upper extremity pattern. This exercise consists of participants reaching forward in various directions, picking up a ball from the floor, throwing a ball, catching a ball, and exchanging batons to the side and front, while maintaining balance.

Participants maintained balance with their eyes opened and closed as they stood on rigid surfaces and foam pads that had different densities. Participants trained to maintain balance while they stood on a Rocker board, Wobble board and Dome ball.

Therefore, the objective of this study was to investigate the effect of balance training with upper extremity exercise on the improvement of balance performance in persons who have had a stroke.
This balance training program had contents related to walking which was to stop suddenly. Also, they had to change velocity and direction as they were walking. The dual tasks of kicking and rolling a gymnastic ball while walking were included in this program (Table 1). In this program, a physical therapist, with four student assistants who majoring in physical therapy, supervised the two groups.

**Measures**

Subjects were tested on their balance performance with clinical balance tests and laboratory balance tests at pre-training and post-training.

**Clinical Balance Tests**

1) 7 m Timed Gait Test (sec): Measured time that subject walk 7 m as fast as possible (Kim, 2007).

2) 100 m Timed Gait Test (sec): Measured time that subject walk 100 m as fast as possible (Kim, 2007).

3) Functional Reach Test (cm): Lift arm to 90 degrees stretch out subject’s fingers and reach forward as far as the subject can. Distance recorded was from the finger tips with the subject in the most forward position (Row and Cavanagh, 2007).

4) Timed Get Up and Go Test (sec): Measured time during the subjects rise from a standard armchair, walk 2.4 m around a cone and return back to the chair into a seated position. An average score was obtained from three recorded (Kassler et al., 2007).

5) 5 items of Berg’s Balance Test (0~4 points): Measured score during the subjects standing unsupported with eye closed, standing on one leg (unaffected side), standing on one leg (affected side), turning to look behind over left and right shoulders while standing, standing unsupported one foot in front (O’Sullivan and Schmitz, 2001).

**Laboratory Balance Test**

1) Kinesthetic Ability Trainer 3000 (K.A.T. 3000): This equipment was recognized to have high reliability and validity were high. K.A.T 3000 has a small center on the round base and is designed to make slope toward lots of sides. The sensor that could detect the degrees of inclination was installed on the round base, and the cursor on monitor could move 3.5 mm per 1° of inclination. The sum of the scores in Q1, Q2, Q3 and Q4 partition on the monitor would balance index. This means that the higher the balance index, the lower the ability of balance performance. Total balance index, affected and unaffected side balance ratio, and forward and backward balance ratio were measured.

**Statistical Analysis**

Statistical analysis was performed using Windows SPSS version 12.0. Demographic data of subjects was summarized using descriptive analysis. The Wilcoxon Matched-Pairs Signed-Ranks test was used to comparing balance performance between pre-treatment and post-treatment. Significance was set at p<.05 and results are given as the mean±SD.

**Results**

**Demographic Data of Study Subjects**

Nine males and nine females subject, who have had a stroke, were included in this study. The mean age of the subjects was 59.26±6.68 years, the height was 162±4.38 cm, the weight was 63.00±11.39 kg and the time since their stroke was 57.47±45.46 months. The Injury type of hemorrhage was 7 (28.9%), infarction was 11 (61.1%), right hemiplegia was 10 (55.6%) and left hemiplegia was 9 (44.4%). The mean score of walking was 4.25±.65, function of upper extremity was 4.68±.67, function of hand was 4.94±.62 and MMSE-K was 23.52±1.71 (Table 2).

**Comparisons of Balance Test Between Pre-Treatment and Post-Treatment**

The results of the clinical balance tests are followed as in Table 3. In the 7 m Timed Gait Test, 1) Sport KAT balance System, Sport KAT, CA, USA.
Table 1. Weekly exercise schedule for improvement of balance performance

<table>
<thead>
<tr>
<th>Period</th>
<th>Contents of balance training</th>
<th>Posture and condition of surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st week</td>
<td>weight shifting, PNF upper extremity pattern, to reach toward various directions, to pick up a ball on the floor and throw the ball, to catch a ball, to exchange a baton another person the side and front.</td>
<td>sitting on a chair</td>
</tr>
<tr>
<td>2nd &amp; 3rd week</td>
<td>weight shifting, PNF upper pattern, to reach toward various directions, to pick up a ball on the floor and throw the ball, to catch a ball, to exchange a baton another person the side and front.</td>
<td>sitting on a gymnastic ball</td>
</tr>
<tr>
<td>4th &amp; 5th week</td>
<td>weight shifting, PNF upper pattern, to reach toward various directions, to pick up a ball on floor and throw the ball, to catch a ball, to exchange a baton another person the side and front, to kick a gymnastic ball.</td>
<td>standing on a rigid surface</td>
</tr>
<tr>
<td>6th week</td>
<td>weight shifting, to maintain balance with eyes opened and closed, to repeat 4th &amp; 5th week schedule</td>
<td>standing on foam pad, wobble board dome ball, rocker board</td>
</tr>
<tr>
<td>7th week</td>
<td>to stop while walking, to change velocity while walking, to change direction while walking, to place balls while walking, to roll a big gymnastic ball.</td>
<td>on the floor</td>
</tr>
</tbody>
</table>

10 m Timed Gait Test, and the Timed Get Up and Go Test, there were significant differences between pre-training and post-training (p<0.05). The result of Functional Reach Test increased significantly at post-training (p<0.05). The result of the standing un-supported with eyes closed test of the Berg balance test, turning to look behind over left and right shoulders while standing test and standing un-supported with foot in front test increased at post-training but it was not significant. The results of standing on one leg (affected side) test and standing on one leg (unaffected side) test showed a significantly increased (p<0.05) (Table 3).

Comparisons of Balance Index and Ratio between Pre-Treatment and Post-Treatment

The results of the laboratory balance test are in Table 4. After training, the result of the total balance index decreased significantly (p<0.05). This means that the balance performance had improved.

The results of affected and unaffected side balance ratio were not significantly different between pre-training and post-training. However, the ratio approached to 0, which means that the center of gravity that had leaned to the unaffected side moved to the affected side after training. The result of forward and backward balance ratio was significantly different. The ratio approached to 0, indicating that
Table 2. Demographic data of study subjects (N=18)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (male/female)</td>
<td>9 (50%) / 9 (50%)</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>69±6.68</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>162±4.38</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>68±11.99</td>
</tr>
<tr>
<td>Time since stroke</td>
<td>57±45.46</td>
</tr>
<tr>
<td>Type of stroke</td>
<td>7 (38.9%) / 11 (61.1%)</td>
</tr>
<tr>
<td>Hemiparetic side (RT/LT)</td>
<td>10 (56.6%) / 8 (44.4%)</td>
</tr>
<tr>
<td>MAS: walking</td>
<td>4.26±1.66</td>
</tr>
<tr>
<td>MAS: upper extremity function</td>
<td>4.68±1.67</td>
</tr>
<tr>
<td>MAS: hand function</td>
<td>4.94±1.62</td>
</tr>
<tr>
<td>MMSE-K</td>
<td>23.52±1.71</td>
</tr>
</tbody>
</table>

*MAS: Motor Assessment Scale.  
-MMSE-K: the Korean version of Mini-Mental State Examination.

Table 3. Comparisons of balance test between pre-treatment and post-treatment (N=18)

<table>
<thead>
<tr>
<th>Test</th>
<th>Pre-Tx</th>
<th>Post-Tx</th>
<th>Z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 m walking</td>
<td>12.22±6.43a</td>
<td>10.81±4.67</td>
<td>-2.091</td>
<td>.037</td>
</tr>
<tr>
<td>100 m walking</td>
<td>155.22±67.65</td>
<td>137.81±54.58</td>
<td>-2.548</td>
<td>.011</td>
</tr>
<tr>
<td>TGUGTb</td>
<td>22.95±12.03</td>
<td>21.28±11.27</td>
<td>-2.635</td>
<td>.008</td>
</tr>
<tr>
<td>FRTc</td>
<td>16.92±7.29</td>
<td>19.85±7.96</td>
<td>-2.592</td>
<td>.010</td>
</tr>
<tr>
<td>SUBEde</td>
<td>3.88±3.25</td>
<td>4.00±4.00</td>
<td>-1.414</td>
<td>.157</td>
</tr>
<tr>
<td>SOLUf</td>
<td>2.72±1.44</td>
<td>3.11±1.32</td>
<td>-2.952</td>
<td>.003</td>
</tr>
<tr>
<td>SOLAf</td>
<td>1.33±1.18</td>
<td>1.50±1.04</td>
<td>-3.360</td>
<td>.001</td>
</tr>
<tr>
<td>TLBg</td>
<td>3.61±.69</td>
<td>3.65±.68</td>
<td>-0.778</td>
<td>.441</td>
</tr>
<tr>
<td>SUOFFh</td>
<td>3.50±.38</td>
<td>3.77±.73</td>
<td>-1.414</td>
<td>.157</td>
</tr>
</tbody>
</table>

*aMean±SD.  
bTGUGT: Timed Get Up and Go Test (sec).  
cFRT: Functional Reach Test (sec).  
dSUBE: standing unsupported with eye closed.  
eSOLU: standing on one leg (affected side).  
fSOLA: standing on one leg (unaffected side).  
gTLB: turning to look behind over left and right shoulders while standing.  
hSUOFF: standing unsupported one foot in front.

Table 4. Comparisons of balance index between pre-treatment and post-treatment (N=18)

<table>
<thead>
<tr>
<th></th>
<th>Pre-Tx</th>
<th>Post-Tx</th>
<th>Z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total BR</td>
<td>565.33±240.5</td>
<td>531.61±197</td>
<td>-2.156</td>
<td>.03</td>
</tr>
<tr>
<td>A &amp; U SBR</td>
<td>0.1±1.01</td>
<td>.17±.56</td>
<td>-.54</td>
<td>.58</td>
</tr>
<tr>
<td>P &amp; B BR</td>
<td>-82±33</td>
<td>-204±68</td>
<td>-3.65</td>
<td>.00</td>
</tr>
</tbody>
</table>

*Mean±SD.  
Total BR: total balance index.  
A & U SBR: affected and unaffected side balance ratio.  
P & B BR: forward and backward balance ratio.

Discussion

Majority of stroke patients are elderly. If they do not receive continuous and suitable supervision after hospital treatment, their physical strength and balance performance will decrease. This can lead to serious injuries. Also, if their extent of activity is limited to inside the house, it can cause physical problems as well as emotional problems (Lord et al., 2004). Therefore, it is very important to develop safe and effective exercise programs that improve endurance, muscle strength and functional movement (Biag and Shu, 2003).

Group exercise led by a physical therapist can increase patients exercise time and does not add to the therapist's workload (Dean et al., 1999). Furthermore, circuit class therapy had been associated with a significantly greater degree of independence in walking when discharged from rehabilitation and a significantly higher patient satisfaction with the amount of therapy received (Cuadra et al., 2007). Therefore, in this study, participants who were judged to have second or third grade disability participated in balance training program by group exercise.

Methods to evaluate balance performance are as following. Clinical tests are Berg balance test (Blanchard et al., 2007; Lynch, 2007), functional reaching test (Centama et al., 2007; Vagci et al., 2007), one legged stance test (Islam et al., 2004; Jonsson et al., 2004). Maeda et al (2001) used the Gravivocorder method that measures sway degree of COG as the subject...
standing on the foot platform, the Equi test system makes unpredictable perturbations and evaluates the symmetry of weight distribution and amplitude of body sway to maintain balance and adapt by postural reaction in terms of speed and accuracy (Shimada et al., 2003). Functional standing balance measured speed of the body’s sway (Pykälä et al., 2004).

In this study, subjects were tested 7 in Timed Gait Test (sec), 100 m Timed Gait Test (sec), Functional Reach Test (cm), Timed Get Up and Go Test (sec), 5 items of Berg’s Balance Test (0~4 points) as clinical tests. Their total balance index and balance ratios were measured by KAT-3000 as laboratory balance test.

To improve balance performance, when subjects move voluntarily on unstable surfaces, postural control is more complex and use more muscles (Arun et al., 1997). Carriere (1999) stated that having a client sitting on a gymnastic ball doing almost any exercise will require vestibular and proprioceptive feedback to make the appropriate adaptive responses. Therapists can tailor exercises to patient needs. Physical therapists can have the patient sit or stand on a moveable support of surface (gymnastic ball, wobble board), thereby stimulating adjustments through the displacement of the base of support. The patient learns to actively control their posture while the device is moved (therapist-initiated, reactive responses), or while the patient actively moves the device (patient-initiated, anticipatory responses) (O’Sullivan and Schmitz, 2001). The wobble board is designed to assist the reeducation of the proprioceptive system by improving mechanoreceptor function and restoring the normal neuromuscular feedback loop (Clark and Burde, 2006). In this study, subjects performed the program on unstable surfaces such as a gymnastic ball, wobble board, foam pad, rocker board and dome ball.

During fast movement of upper extremities, trunk muscles contract and are ready for movement before the upper extremity muscle contract (Arun and Latska, 1996). Reaching has been recognized as being an important component of the activities of daily living that requires the coordination of multiple upper extremity segments (Row and Cavanagh, 2002). Reaching (individual-initiated, anticipatory responses, open kinematic chain) for objects located beyond arm’s length requires not only the coordinated motion of the trunk and arm segments, but also an active contribution from the lower limbs (closed kinematic chain) to support and balance the body mass (Dean et al., 1996). Individuals with movement disorders, following stroke for example, frequently have difficulty coordinating movement of body segments and balancing during reaching tasks (Dean and Mackey, 1992). Dual task training such as half-kneeling, tall kneeling, standing while catching, throwing or kicking a ball, walking while carrying or reaching for an object are excellent choices (Hall and Brody, 1999).

Therefore, in this study, during upper extremity exercises such as PNF upper extremity pattern, reaching toward various directions, picking a ball up from the floor, throwing a ball, catching a ball, and exchanging batons with a person to the side and to the front, participants maintained balance. The dual tasks, kicking and rolling a gymnastic ball while walking, were included in this program. This balance training program had contents related to walking which were to stop suddenly and change velocity and direction while walking.

Practicing simple movements with locomotion of the body is effective when relearning the sense of balance. It is helpful that the patient gains confidence so they can move by themselves (Kutzofsky, 2001). Beng et al. (2003) reported that movements with the displacement of the center of gravity, such as standing up from chair and strengthening of the lower extremity, had an effect on the improvement of balance performance. To strengthen muscles and improve balance performance, the exercise program encouraged the use of the affected side and that program application was effective in the recovery of the upper extremity functions, gait and balance performance (Duncan, 2003). Nichols (1997) reported that the biofeedback system training improved gait symmetry of affected and unaffected sides and it maintained
the balance performance and gait symmetry after 4 weeks follow up. With various postures that have different shapes and sizes, PNF mat exercise program that modified PNF pattern and technique was effective on the improvement of balance performance (Song and Kim, 2007).

In this study, balance training with upper extremity movement caused a displacement of the center of gravity on stable and unstable surfaces, balance training-related gait such as the change of velocity and direction while walking, and dual task training such as kicking a ball and rolling a ball while walking, improved balance performance. Also, in this group exercise, volunteers and patients’ family members assisted the patients. Especially, the assistance of the patient’s family linked to the home program and the increase of exercise time. Also, patients’ degree of satisfaction was high and positive interaction between patients was also notable.

Conclusion

Our study investigated the effect of balance training with upper extremity exercise on the improvement of balance performance in people who had a stroke. Subjects were tested with 7 m and 100 m Timed Gait Test (sec), Timed Get Up and Go Test (sec), Functional Reach Test (cm) and 5 items of Berg balance test at pre-training and post-training. The total balance index and balance ratios were measured by KAT 3000. The balance training program was performed by sitting and standing on stable and unstable surfaces. During the upper extremity exercise such as PNF upper extremity pattern, picking up a ball from the floor, throwing, and catching, participants maintained balance. After seven weekends of balance training, subjects showed a significant difference in balance test result except with the three items of the Berg’s Balance Test (p<0.05). The balance index scores and affected and unaffected side balance ratios had a larger improvement than in pre-training (p<0.05). The result of this study showed that intervention of this balance training program could improve balance performance in people who have had a stroke.

References


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