Effects of Proprioceptive Neuromuscular Facilitation and Treadmill Training on the Balance and Walking Ability of Stroke Patients

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Purpose: The purpose of this study was to investigate the effects of combined training using proprioceptive neuromuscular facilitation (PNF) patterns and treadmills on the balance and walking ability of stroke patients.

Methods: Twenty-three stroke patients were randomized into a control group (n = 11), receiving only treadmill training and an experimental group (n = 12) receiving combined training. The use of both PNF exercise and treadmill were implemented in the combined training. Interventions were performed 5 times a week for 6 weeks. Balance ability was measured by a timed up and go (TUG) test. Walking ability was measured by a 10-meter walk test (10MWT) and a 6-minute walk test (6MWT). A paired t-test was used to compare differences between pre- and post-intervention and independent t-tests were used to compare between groups.

Results: Changes in TUG, 10MWT, and 6MWT before and after interventions were significantly different for both the experimental group and the control group (p < 0.05). In addition, within-group changes in the TUG, 10MWT, and 6MWT were more effective in the experimental group than in the control group (p < 0.05).

Conclusion: Combined training using PNF techniques and treadmills may be useful in improving the balance and walking ability of stroke patients.

Keywords: Balance ability, PNF, Stroke, Walking ability

INTRODUCTION

Stroke is a high incidence neurological disorder caused by an interruption of blood flow in the brain.¹ Depending on the degree of the injury and the area of the brain affected, a stroke can affect consciousness, sensory perception, language, cognitive skills, or motor skills.² In addition, abnormal patterns coordinating muscle tone, muscle timing, and movement resulting from a stroke can affect a person’s balance and walking ability.³

Losing one’s mobility is the greatest loss for stroke patients.⁴ Recovering the ability to walk is an important rehabilitation goal⁵ and is one of the greatest concerns for the patient, family, and therapist.⁶ However, most stroke patients have a slower gait cycle because of the difficulty in moving their affected extremity⁷ and thus, find it challenging to maintain balance when walking due to their asymmetric step and shorter stride.⁸ Balance is the ability to maintain one’s center of gravity within the base of support and to control proper body positioning by responding to various external environments.⁹ The ability to maintain one’s balance while walking is another important rehabilitation goal.¹⁰ Balance ability can be divided into static balance, which allows a steady stand on a fixed support surface, and dynamic balance, which can be sustained when there is external stimulation and agitation of the support surface. Dynamic balance is an essential factor in walking.¹¹

PNF is a technique that improves movement function by stimulating muscles, tendons, and joints, and increases muscle power, flexibility, and balance.¹² It has been used as an intervention in musculoskeletal disorders of muscles, bones, and joints and in central
nervous system disorders resulting from stroke.\textsuperscript{13-17} The basic principles used in PNF resulted in more muscle power when applying various patterns at the same time, and the use of combination patterns improved the proprioception, power, and stability of the trunk.\textsuperscript{18} Bobath\textsuperscript{19} noted that the pelvis is the key point for both leg control and gait pattern. Wang\textsuperscript{20} showed that PNF pelvic exercises resulted in changes in walking speed and rate in stroke patients. Trueblood et al.\textsuperscript{21} applied the PNF pelvic exercise to examine the effect of pelvic movement on the walking ability of stroke patients. Kim et al.\textsuperscript{22} when applying PNF pelvic and lower extremity exercises, showed a change in the balance ability of stroke patients.

The use of a treadmill is more effective than ground gait training. It reduces rigidity and improves the walking ability of stroke patients by enabling symmetrical walking while in a weight bearing state.\textsuperscript{23} A treadmill also constantly stimulates the calf muscles, which helps to improve balance and walking ability.\textsuperscript{24} Based on the central pattern generator theory, a treadmill activates afferent inputs by spinal level neurons and serves as a walking control for limb movement, weight shift, and posture alignment.\textsuperscript{25}

The pelvis and scapula are key points for the control of gait pattern.\textsuperscript{26} Previous studies have been applied only to the pelvis\textsuperscript{20,21,26} or patterns of coordinated exercises involving the upper and lower extremities.\textsuperscript{27,28} The purpose of this study was to investigate the effect of the combination of PNF and treadmill training on the balance and walking ability of stroke patients.

**RESEARCH METHOD**

1. **Study design**

This study was a single-blind randomized clinical trial that included 23 patients with hemiplegia due to stroke. The patients were randomly assigned to a treadmill training group (n = 11) and a combined training group (n = 12).

Timed up-and-go test (TUG) time, 10-m walk test (10MWT) score, and 6-minute walk test (6MWT) score were identified as the primary outcomes.

2. **Subjects**

This study was conducted on 23 patients at hospital D in city J for 6 weeks in January and February 2017. The subjects were inpatients aged 55 to 65 years, who had been diagnosed with hemiplegia due to stroke within the last 1 to 2 years. Inclusion criteria were: being able to independently walk 10 m, obtaining a score of 24 or greater on the mini mental state examination-Korea (MMSE-K) in order to be able to understand and follow the researcher’s instructions, and signing a consent form indicating that they fully understood the goals and procedures of this study. They were randomized into a control group (n = 11), receiving only treadmill training, and an experimental group (n = 12), receiving combined training (Table 1).

### Table 1. General characteristics of study subjects (n=23)

<table>
<thead>
<tr>
<th></th>
<th>Experimental group (n=12)</th>
<th>Control group (n=11)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (male/female)</td>
<td>7/5</td>
<td>7/4</td>
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<tr>
<td>Age (year)</td>
<td>60.75±3.11</td>
<td>60.64±3.41</td>
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<tr>
<td>Height (cm)</td>
<td>165.08±7.83</td>
<td>165.36±7.74</td>
<td>0.32</td>
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<tr>
<td>Weight (kg)</td>
<td>65.58±8.84</td>
<td>64.82±7.48</td>
<td>0.72</td>
</tr>
<tr>
<td>Affected side (right/left)</td>
<td>8/4</td>
<td>7/4</td>
<td>1.00</td>
</tr>
<tr>
<td>Stroke type (infarction/hemorrhage)</td>
<td>11/1</td>
<td>10/1</td>
<td>1.00</td>
</tr>
<tr>
<td>Onset time after stroke (month)</td>
<td>19.67±3.89</td>
<td>19.09±3.86</td>
<td>0.26</td>
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<tr>
<td>MMSE-K (score)</td>
<td>26.50±2.07</td>
<td>27.64±2.06</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation. MMSE-K: mini mental state examination-Korea, TUG: timed up and go test, 10MWT: 10-meter walking test, 6MWT: 6-minutes walking test.

3. **Measurements**

1) **TUG**

TUG is a simple test that can quickly measure mobility and balance with an intra-rater and inter-rater reliability correlation coefficient of r = 0.98-0.99. Beginning with a ‘start’ command, TUG measured the time that the subject took to rise from a 46-cm height armchair, walk 3 m, turn around as fast as possible in the direction of the affected side, walk back to the chair, and sit down.\textsuperscript{29}

2) **10MWT**

The 10MWT is a measure of one’s walking ability with an intra-rater and inter-rater reliability correlation coefficient of r = 0.95-0.96.\textsuperscript{30} Beginning with a ‘start’ command, the 10MWT measured the time required for the subject to walk 10 m on a course that was a total distance of 14 m. Tape, at 2 m and 12 m, indicated the start and end of the 10-m walking distance. The first and last 2 m of the course were used for acceleration and deceleration and were not timed.\textsuperscript{31}

3) **6MWT**

The 6MWT measures walking endurance\textsuperscript{32} with an intra-rater and
inter-rater reliability correlation coefficient of $r = 0.91$. The 6MWT displays a starting point and a halfway point with a total distance of 20 m on a flat floor with the course being repeated for a total of 6 minutes. The entire walking distance, including the number of repetitions between the starting point and the halfway point, was measured in meters (m).

4. Training program
In this study, the 40-minute training programs for both groups occurred 5 times a week for 6 weeks, with 5 minutes being allocated for warm up, 30 minutes devoted to the main exercise, and 5 minutes for cool down.

The training program was applied to: 1) overload, 2) progressive, 3) individual, 4) continue, and 5) reversibility.

1) Treadmill training program
The treadmill training consisted of warm-up, treadmill, and cool down. Warm-up and cool-down had a rhythmic initiation in scapular and pelvic patterns in a side-lying position. Warm-up and cool-down were applied for 5 minutes to prevent injury. Using only a treadmill, the training intensity was set at 11-15 using the Borg rating of perceived exertion (RPE) scale. Treadmill exercise was performed for 30 minutes to facilitate movement of the affected side.

2) Combined training program
The use of both PNF exercise and treadmill were implemented in the combined training program. In the PNF concept, therapists performed diametrical scapular and pelvic motion patterns using basic physical therapy principles, procedures, and techniques. The combined training consisted of warm-up, PNF, treadmill, and cool down. Warm-up and cool down had a rhythmic initiation in scapular and pelvic patterns in a side-lying position. PNF was applied for 15 minutes to facilitate movement of the affected side.

5. Data analysis
Statistical analyses were performed using the SPSS/PC for Windows version 18. The Shapiro-Wilk test was used to check the normal distribution of the data. The paired t-test was performed to compare differences in balance ability and walking ability within groups before and after interventions. The independent t-test was performed in order to compare the differences between the experimental and control groups. The level of significance was set at $\alpha = 0.05$.

RESULTS

1. Comparison of TUG changes
Within-group changes in the TUG test were significantly different, in both the experimental group ($p < 0.05$) and the control group ($p < 0.05$)(Table 2), with the experimental group showing greater improvement than the control group ($p < 0.05$)(Table 3).

2. Comparison of 10MWT changes
Within-group changes in the 10MWT were significantly different, in both the experimental group ($p < 0.05$) and the control group ($p < 0.05$)(Table 2), with the experimental group showing greater improvement than the control group ($p < 0.05$)(Table 3).

Table 2. The comparison of variable on pre and post in group

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre</th>
<th>Post</th>
<th>t</th>
<th>p</th>
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<tbody>
<tr>
<td>TUG (sec)</td>
<td>Experimental 16.18±1.07 12.63±1.58 12.03 0.00*</td>
<td>Control 16.97±1.98 14.95±2.31 6.73 0.00*</td>
<td></td>
<td></td>
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<tr>
<td>10MWT (sec)</td>
<td>Experimental 15.95±2.51 11.69±1.23 6.80 0.00*</td>
<td>Control 16.33±2.02 14.26±2.35 7.44 0.00*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6MWT (m)</td>
<td>Experimental 291.42±37.82 347.92±24.50 -7.75 0.00*</td>
<td>Control 294.27±35.05 312.73±33.57 -9.39 0.00*</td>
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Table 3. The comparison of changes in variables between post-test in both group

<table>
<thead>
<tr>
<th>Group</th>
<th>Experimental</th>
<th>Control</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TUG (sec)</td>
<td>12.63±1.58 14.95±2.31</td>
<td>-2.83 0.01*</td>
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<td></td>
</tr>
<tr>
<td>10MWT (sec)</td>
<td>11.69±1.23 14.26±2.35</td>
<td>-3.33 0.00*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6MWT (m)</td>
<td>347.92±24.50 312.73±33.57</td>
<td>2.89 0.01*</td>
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</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.
TUG: timed up and go test. 10MWT: 10-meter walking test. 6MWT: 6-minutes walking test.
*p < 0.05.
3. Comparison of 6MWT changes
Within-group changes in the 6MWT were significantly different, in both the experimental group (p < 0.05) and the control group (p < 0.05)(Table 2), with the experimental group showing greater improvement than the control group (p < 0.05)(Table 3).

DISCUSSION

In this study, 23 patients with hemiplegia due to stroke were randomly sorted into a treadmill training group (n = 11) and a combined training group (n = 12), with the change in balance and walking ability evaluated after 6 weeks of intervention.

Initially, therapists performed PNF symmetrical reciprocal combined scapular and pelvic patterns on the unaffected side of patients who were then asked to actively repeat each movement on both sides, thereby learning the motor skill through active assistance and resistance. Bobath\(^{19}\) performed interventions with the trunk or pelvis to facilitate the normal gait pattern of the hemiplegic patient, and found that the key point of movement control is in the proximal part of the body. In addition, interventions to stabilize the trunk of the body were implemented to reduce the atrophy of muscle tone and improve movement in patients with central nervous system injuries.

In this study, we used TUG, 10MWT, and 6MWT, all with high intra-rater reliability, to evaluate the balance and walking ability of hemiplegic patients due to stroke.\(^{20,30,31}\) The findings of this study may be helpful in predicting the stroke patients’ balance and walking abilities and their eventual return to independence. In this study, the TUG test was used to evaluate the dynamic and static balance abilities of stroke patients. The 10MWT was used to determine the change in gait speed of the stroke patients according to intervention for scapular and pelvic movements. The 6MWT was used to evaluate the change in gait endurance of the stroke patients according to scapular and pelvic movements, and the treadmill training.

Trueblood et al.\(^{21}\) reported improvement in walking ability after application of pelvic PNF-based exercise regimes on the affected side in 20 hemiplegic patients due to stroke. Wang\(^{20}\) identified changes in walking ability by applying rhythmic initiation, dynamic reversal, and slow reversal techniques to pelvic PNF-based exercise regimes by dividing hemiplegic patients into acute and chronic groups. As a result, there was an improvement early in the acute group, but no corresponding change in the chronic group. However, over time, changes did occur. Kim et al.\(^{22}\) applied a pelvic and lower extremity PNF exercise pattern with rhythmic initiation techniques to the affected side of hemiplegic patients, and obtained a positive change in balance and activities associated with daily living.

In this study, we applied a symmetrical reciprocal combined scapular and pelvic PNF exercise pattern to the unaffected side of hemiplegic patients to eliminate their fear of pain associated with movement in comparison to previous studies. The combination of sympathetic reciprocals through scapular and pelvic exercises initiated on the unaffected side, transferred new neurological innervations to the patients’ affected side and in combination with the positive effects of treadmill walking, resulted in their ability to maintain balance and proper gait cycles.

Kim et al.\(^{26}\) obtained a positive effect for balance and walking ability after applying the limb pattern PNF to hemiplegic stroke patients. Lim\(^{27}\) obtained a positive effect for balance and walking ability by applying the sprint and skate PNF patterns to hemiplegic patients. These studies wish to suggest a more positive outcome using these PNF patterns, compared to the present study by more closely approximating the gait pattern. However, Bobath\(^{19}\) suggested that development of normal trunk control ability is essential and that interventions to stabilize the trunk, reducing muscle atrophy, and allowing for free limb movement, should precede additional interventions such as the scapular and pelvic PNF patterns.

In this study, both the combined and treadmill training groups showed improvement in balance and walking ability. The symmetrical reciprocal combined scapular and pelvic PNF patterns reestablished motor control for the gait pattern. Treadmill exercises with increased trunk stability may have had a positive impact on balance and walking ability.

This study was effective in improving balance and walking ability by applying PNF exercises and treadmill training programs to hemiplegic stroke patients, therefore, we consider this combined program to be useful for these patients.

REFERENCES


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