Effects of proprioception training with exercise imagery on balance ability of stroke patients

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Abstract. [Purpose] The purpose of the present study was to examine and compare the effects of proprioceptive training accompanied by motor imagery training and general proprioceptive training on the balance of stroke patients. [Subjects and Methods] Thirty-six stroke patients were randomly assigned to either an experimental group of 18 patients or a control group of 18 patients. The experimental group was given motor imagery training for 5 minutes and proprioceptive training for 25 minutes, while the control group was given proprioceptive training for 30 minutes. Each session and training program was implemented 5 times a week for 8 weeks. The Korean version of the Berg Balance Scale (K-BBS), Timed Up and Go test (TUG), weight bearing ratio (AFA-50, Alfoots, Republic of Korea), and joint position sense error (Dualer IQ Inclinometer, JTECH Medical, USA) were measured. [Results] Both groups showed improvements in K-BBS, TUG, weight bearing ratio, and joint position sense error. The measures of the experimental group showed greater improvement than the control group. [Conclusion] Motor imagery training, which is not subject to time restrictions, is not very risky and can be used as an effective treatment method for improving the balance ability of stroke patients.

Key words: Motor imagery, Proprioception, Stroke

INTRODUCTION

Stroke is the result of bleeding in brain tissues or the blockade of blood flow supplied to the brain, due to cerebrovascular disease, cardiac disorder, or diabetes, etc. Most stroke patients show symptoms of motor abnormality and sensory disturbance as well as disturbance of consciousness, language, and cognition, and paralysis or paresis4). The control ability of central nervous system on the affected side of hemiplegic patients is impaired, and imbalance of protagonist and antagonistic muscle and excessive muscle tone, spasticity, are shown. The reasons for the lowering of balance ability are often proprioceptive injury and reduction of muscle tone. About 65% of patients with stroke usually experience the loss of tactile sense, protective reaction and proprioception5).

In particular, left-right imbalance and asymmetric posture due to decline in mobility are characteristics of stroke. These characteristics bias the center of gravity to the unaffected side lower limb and weaken subjects’ ability to maintain the body center within the base of support, resulting in a serious problem with postural control due to difficulty in controlling balance in the standing position, and also affects the rightsizing and equilibrium reactions4, 5).

In static standing, the center of plantar pressure prominently exhibits the anteriolateral sway. In order to maintain balance, a compensatory ankle strategy is used to allow the ground reaction force to effectively act on the unaffected side foot, which also causes muscular weakness and asymmetric postures. The reasons for this condition are explained by the lack of weight bearing ability or muscular control disorder on the affected side lower limb6, 7), and modification of the muscle recruitment pattern and the delayed contraction of paretic muscles are shown8). Stroke patients’ ability to properly react to various environments and tasks is decreased because of decline in left/right weight transfer ability, time of affected side lower limb support, and limit of stability. Also, their physical disturbance in standing is increased as much as two times, compared with normal persons of the same age9, 11).

In exercise imagery training, movement is imagined in the mind without any physical actions1). The imagery induces information processing activity similar to performance of the real task, promoting the learning of motor function13, 14). The results of Functional Magnetic Response Imaging (fMRI), which was used to examine the validity of exercise imagery training, suggest that both the primary motor cortex and the sensory fields of brain15), as well as...
the dorsal premotor cortex, superior parietal lobe and intra-
parietal sulci are activated by exercise imagery training26).

In exercise imagery training, stroke patients with limited
mobility can activate the brain circuits by imagining move-
ments, and active participation can be induced through the
training17, 18). In stroke patients who performed exercise im-
agery training, symmetry of the gait pattern improved in
the stance phase on the affected side,19) and the training can
also be used to improve the relearning of daily tasks after
acute stroke20). Weight shifting interventions for hemiplegic
patients suggest the possibility of exercise imagery train-
ing21). Stroke patients who were asked to imagine normal
gait to train the normal movement of feet, showed improved
gait functions22).

Although research regarding exercise imagery for stroke
patients has been variously implemented, the enhancement
of exercise performance with respect to the improvement
of upper limbs function, gait function, and change of brain
activation has been frequently studied.

Thus, this study examined the effects of exercise imag-
ery on the balance ability of stroke patients in propriocep-
tion training.

SUBJECTS AND METHODS

The subjects of this study were 36 patients hospital-
ized for the treatment of stroke in a hospital located in the
Republic of Korea. This study complied with the ethical
principles of the Declaration of Helsinki. All the subjects
and their guardians voluntarily agreed to participate in the
study after receiving explanations regarding the purpose
and procedures of the experiment, and signed an informed
consent statement before its start. The criteria for select-
ing the subjects were as follows: more than 6 months since
the onset of non-traumatic and unilateral stroke, a score of
more than 24 in the Korean version of the Mini Mental State
Examination, a score of less than 2.26 in the Vividness of
Movement Imagery Questions26).

The proprioception training program of the 18 patients
who met the inclusion criteria was conducted in two phases
for 30 minutes a session, 5 days a week, for 8 weeks. The
training was conducted on a balance board (Dynair ballkissen, Togu, Germany) and consisted of 5 tasks. It was conducted in the same way as
the initial 4 weeks, and the details of the training items are
described in Table 1. The training was conducted under the
instruction and support of therapists, given the difficulty of
the training, to ensure the safety of subjects.

After the proprioception training, the 18 patients per-
formed motor imagery training in the cognitive rehabilita-
tion room at a proper temperature, with no noise, in order
to enhance concentration on the motor imagery training.

Table 1. Proprioceptive training program

<table>
<thead>
<tr>
<th>Training with balance pad (1–4 week)</th>
<th>Training with balance board (5–8 week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Standing with two feet support posture.</td>
<td>f. In standing position, moving the weight left and right maximally.</td>
</tr>
<tr>
<td>b. In standing position, moving both heels of feet up and down.</td>
<td>g. In standing position, moving the weight forward and backward maximally.</td>
</tr>
<tr>
<td>c. In standing position, bending and stretching both knees.</td>
<td>h. In standing position, bending and stretching both knees.</td>
</tr>
<tr>
<td>d. While standing with widening each feet forward and backward, placing the unaffected side foot on a floor and the affected side foot on balance pad, putting the body forward with bending and stretching knees.</td>
<td>i. In standing position, moving both heels of feet up and down.</td>
</tr>
<tr>
<td>e. In standing position, to keep your eyes closed.</td>
<td>j. In sitting a mat on position, sit-to-stand on a balance board.</td>
</tr>
</tbody>
</table>
RESULTS

The general characteristics of the study subjects are displayed in Table 2.

In both groups, significant improvements were seen in the outcome measures with time \((p<0.05)\), and the motor imagery training group showed significantly greater improvements than the proprioception training group \((p<0.05)\) (Table 3).

DISCUSSION

This study aimed to provide reference data for planning the rehabilitation of stroke patients, by comparing the effects of proprioception training with motor imagery and conventional proprioception training performed for 8 weeks.

The results of this study show that K-BBS had significantly increased and TUG had significantly decreased in both groups after the training, and the changes of the motor imagery training group were more significant than those of the conventional proprioception training group. These results are in agreement with those of two previous studies. One reported that the joint scope of lower limbs and the static and dynamic balance index increased after motor imagery training\(^27\), and the other that the gait velocity significantly increased after training to enhance balance ability\(^9\). Since the ability to maintain balance in the standing position is a fundamental factor of stable independent gait and sensitively affects gait velocity\(^28\), we think that the gait velocity increased and the TUG time was decreased in the present study, due to the rise of the K-BBS scores.

Increased weight bearing on the unaffected lower limb of stroke patients largely affects the movement of the whole body. Therefore, the asymmetry of weight bearing on the lower limbs should be evaluated and weight bearing on the affected side needs to be corrected. This study evaluated the affected/unaffected side weight bearing ratios and the affected and unaffected sides anterior/posterior weight bearing ratios. Our results show that the affected and unaffected sides weight bearing ratios and the affected and unaffected sides anterior/posterior weight bearing ratios of both groups significantly decreased after the training, and the motor imagery training group showed more significant changes than those of the conventional proprioception training group. These results are in agreement with those of two previous studies. One reported that when motor imagery training was added to conventional movement training, the symmetry of muscle activity and its timing improved in stroke patients\(^29\), and the other that by preliminarily practicing daily activities through motor imagery, postural symmetry and postural control in the standing position were enhanced\(^21\). Thus, these results show that it helps to enhance the symmetry of hemiplegic patients’ affected and unaffected sides weight bearing and improve their affected and unaffected sides anterior/posterior weight bearing ratios of hemiplegic patients.

The joint position sense test is a method of evaluating the position of body segments without visual support, and this study conducted position sense tests of the ankle joint. Our results show that in both groups, the errors of position sense was decreased significantly after the training, and that the motor imagery training group showed more significant changes than those of the conventional proprioception training group. These results are in agreement with that of two previous studies. One reported the joint scope of lower limbs and the static and dynamic balance index increased after motor imagery training\(^27\), and the other that the gait velocity significantly increased after training to enhance balance ability\(^9\). Since the ability to maintain balance in the standing position is a fundamental factor of stable independent gait and sensitively affects gait velocity\(^28\), we think that the gait velocity increased and the TUG time was decreased in the present study, due to the rise of the K-BBS scores.

Table 2. The general characteristics of the subjects (N=36)

<table>
<thead>
<tr>
<th>Variable</th>
<th>MTG (n=18)</th>
<th>PTG (n=18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>9 (50%)</td>
<td>11 (61.1%)</td>
</tr>
<tr>
<td>Female</td>
<td>9 (50%)</td>
<td>7 (38.9%)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;65</td>
<td>14 (77.8%)</td>
<td>14 (77.8%)</td>
</tr>
<tr>
<td>≥65</td>
<td>4 (22.2%)</td>
<td>4 (22.2%)</td>
</tr>
<tr>
<td>Diagnosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infarction</td>
<td>15 (83.3%)</td>
<td>15 (83.3%)</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>3 (16.7%)</td>
<td>3 (16.7%)</td>
</tr>
<tr>
<td>Affected side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>9 (50%)</td>
<td>11 (61.1%)</td>
</tr>
<tr>
<td>Right</td>
<td>9 (50%)</td>
<td>7 (38.9%)</td>
</tr>
<tr>
<td>Onset time (month)</td>
<td>11.5 ± 1.58</td>
<td>11.61 ± 2.28</td>
</tr>
</tbody>
</table>

Values are N (%) or Mean ± SD, MTG: Motor imagery training group, PTG: Proprioceptive training group.

Table 3. Comparison of variables between the two groups (N=36)

<table>
<thead>
<tr>
<th>Group</th>
<th>Variable</th>
<th>MTG (n=18)</th>
<th>PTG (n=18)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K-BBS</td>
<td>TUG</td>
<td>AUWBR</td>
</tr>
<tr>
<td>4 weeks</td>
<td>42.00 ± 8.00(^1)</td>
<td>27.06 ± 9.28(*)</td>
<td>12.15 ± 7.04(*)</td>
</tr>
<tr>
<td>8 weeks</td>
<td>44.61 ± 6.08(^{2,3})</td>
<td>24.89 ± 8.02(^{2,3})</td>
<td>9.48 ± 5.80(^{2,3})</td>
</tr>
<tr>
<td>Pre</td>
<td>39.33 ± 5.32</td>
<td>29.39 ± 8.52</td>
<td>14.88 ± 4.14</td>
</tr>
<tr>
<td>4 weeks</td>
<td>40.17 ± 4.82(^1)</td>
<td>27.98 ± 7.68(*)</td>
<td>13.43 ± 3.44(*)</td>
</tr>
<tr>
<td>8 weeks</td>
<td>41.22 ± 4.43(^{2,3})</td>
<td>26.38 ± 7.16(^{2,3})</td>
<td>11.74 ± 2.02(^{2,3})</td>
</tr>
</tbody>
</table>

\(\ast\) \(p<0.05\), Mean ± SD, MTG: Motor imagery training group, PTG: Proprioceptive training group, K-BBS: Korean version of Berg balance scale, TUG: Timed up and go test, AUWBR: Affected side/Unaffected side weight bearing ratio, AAPWBR: Affected side anterior/posterior weight bearing ratio, UAPWBR: Unaffected side anterior/posterior weight bearing ratio, JPSE: Joint position sense error.

Comparison of the time dependent variable each group calculated by repeated measure ANOVA, \(^1\): pre4 weeks, \(^2\): 48 weeks, \(^3\): pre8 weeks (\(p<0.05\)).
Training for the enhancement of stroke patients' function and unaffected sides. Thus, further studies of motor imagery were not controlled for age, and joint position sense was measured only on the affected side, not both the affected and unaffected sides, indicating that the balance ability, postural symmetry and proprioception of the subjects were enhanced. These results suggest that proprioception with motor imagery can be used as a treatment option to improve the balance ability of stroke patients. Motor imagery can be conducted anywhere and at any time without treatment tools, and can be used together with a variety of long-term rehabilitation approaches for the treatment of patients with severe disabilities. In addition, motor imagery requires little energy consumption and motor skills can be learned effectively in motor imagery training without fear of injury.

Limitations of this study were the small number of participants, making it difficult to generalize the results, the activities of the subjects were not controlled except during the training time, the joint position sense error used to measure proprioception ability through posture reproduction were not controlled for age, and joint position sense was measured only on the affected side, not both the affected and unaffected sides. Thus, further studies of motor imagery training for the enhancement of stroke patients' function addressing these issues are required.

REFERENCES