Original Article

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 propriocep-
tive 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 mea-
sures 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

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INTRODUCTION

Stroke is the result of bleeding in brain tissues or the
blockade of blood flow supplied to the brain, due to cere-
brovascular disease, cardiac disorder, or diabetes, etc. Most
stroke patients show symptoms of motor abnormality and
sensory disturbance as well as disturbance of conscious-
ness, language, and cognition, and paralysis or paresis[1]).
The control ability of central nervous system on the affect-
ed 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 reduc-
tion of muscle tone. About 65% of patients with stroke usu-
ally experience the loss of tactile sense, protective reaction
and proprioception[2, 3]).

In particular, left-right imbalance and asymmetric pos-
ture due to decline in mobility are characteristics of stoke.
These characteristics bias the center of gravity to the unaf-
fected side lower limb and weaken subjects' ability to main-

tain 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 af-
fects the righting and equilibrium reactions[4, 5]).

In static standing, the center of plantar pressure promi-
nently 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 unaf-
fected 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 muscu-
lar control disorder on the affected side lower limb[6, 7]), and
modification of the muscle recruitment pattern and the de-
layed contraction of paretic muscles are shown[8]). Stroke pa-
tients' 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 age[9–11]).

In exercise imagery training, movement is imagined
in the mind without any physical actions[12]). The imagery
induces information processing activity similar to perfor-
mance of the real task, promoting the learning of motor
function[13, 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 brain[15]), as well as

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the dorsal premotor cortex, superior parietal lobe and intraparietal sulcus are activated by exercise imagery training[16].

In exercise imagery training, stroke patients with limited mobility can activate the brain circuits by imagining movements, and active participation can be induced through the training[17, 18]. In stroke patients who performed exercise imagery 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 stroke[20]. Weight shifting interventions for hemiplegic patients suggest the possibility of exercise imagery training[21]. Stroke patients who were asked to imagine normal gait to train the normal movement of feet, showed improved gait functions[22].

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 imagery on the balance ability of stroke patients in proprioception training.

SUBJECTS AND METHODS

The subjects of this study were 36 patients hospitalized 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 selecting 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 Questions, the ability to stand independently for more than three minutes, the ability to walk farther than 10 m, and no orthopedic diseases that would have affected standing balance.

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 program used in this study was implemented by correcting and supplementing the suggestions of the aged examined[23, 24]. For the initial 4 weeks, training was conducted on a balance pad (Balance pad, Airex, Swiss) and consisted of 5 tasks. Patients were allowed to take a break of 10 seconds after performing each task, and 5 trials were regarded as 1 set, and a total of 5 sets were performed in 30 minutes. From 5 weeks to 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 performed motor imagery training in the cognitive rehabilitation room at a proper temperature, with no noise, in order to enhance concentration on the motor imagery training. To lower the stress and anxiety of the subjects, and relax the body and mind, armchairs with a backrest were used so that subjects could comfortably lean on them, and close their eyes[25]. The motor imagery training was divided into mobility imagery and visual imagery. The objective of mobility imagery is to imagine the inner sensory information during actual movements of body from the first person view, and the purpose of visual imagery is to imagine one's own movements of the body from a third person view. For the exact performance of motor imagery, cognitive functions and imagery of the movements were tested through the Mini Mental State Examination-Korea version and the Vividness of Movement Imagery Questions[26].

In this study, the mobility imagery training was conducted to encourage the subjects to feel the position senses of the ankle, knee and hip joints, the peripheral muscles, and sole. The subjects actively participated in the proprioception training program. In the motor imagery training, therapists asked the patients to imagine the contents of the proprioception program for 5 minutes, by directly reading aloud to them while reading, the subjects were asked some questions in order to ensure they were adequately performing the imagery training. The proprioception program was consisted of 4 sets performed in 25 minutes before the motor imagery training. The statistical analysis of this study was performed using PASW 18.0. The outcome measures of pre-intervention and 4 and 8 weeks were compared using repeated measures ANOVA. Significance was accepted for values of $p < 0.05$.

Table 1. Proprioceptive training program

Training with balance pad (1–4 week)	Training with balance board (5–8 week)
a. Standing with two feet support posture.	f. In standing position, moving the weight left and right maximally.
b. In standing position, moving both heels of feet up and down.	g. In standing position, moving the weight forward and backward maximally.
c. In standing position, bending and stretching both knees.	h. In standing position, bending and stretching both knees.
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.	i. In standing position, moving both heels of feet up and down.
e. In standing position, to keep your eyes closed.	j. In sitting a mat on position, sit-to-stand on a balance board.

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 reported 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 signifi-

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

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

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)

Group		Variable					
		K-BBS	TUG	AUWBR	AAPWBR	UAPWBR	JPSE
MTG (n=18)	Pre	40.50 ± 9.24	29.63 ± 10.02	15.22 ± 9.11	9.68 ± 4.14	9.7 ± 2.65	3.99 ± 1.61
	4 weeks	42.00 ± 8.00[1]	27.06 ± 9.28[1]*	12.15 ± 7.04[1]*	7.72 ± 3.44[1]*	8.09 ± 3.13[1]*	2.98 ± 1.14[1]
	8 weeks	44.61 ± 6.08[2,3]	24.89 ± 8.02[2,3]	9.48 ± 5.80[2,3†]	5.34 ± 2.02[2,3†]	5.71 ± 2.35[2,3†]	1.76 ± 0.63[2,3†]
PTG (n=18)	Pre	39.33 ± 5.32	29.39 ± 8.52	14.88 ± 4.14	10.53 ± 6.00	9.82 ± 6.95	4.39 ± 1.02
	4 weeks	40.17 ± 4.82[1]	27.98 ± 7.68[1]*	13.43 ± 3.44[1]*	9.46 ± 5.97[1]*	9.02 ± 6.27[1]*	3.81 ± 0.89[1]*
	8 weeks	41.22 ± 4.43[2,3†]	26.38 ± 7.16[2,3]	11.74 ± 2.02[2,3†]	8.11 ± 5.35[2,3†]	8.10 ± 5.79[2,3†]	3.11 ± 0.80[2,3†]

*, †$p<0.05$, 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 ($p<0.05$).

cant changes than the conventional proprioception training group. These results are consistent with the findings of two previous studies. One compared motor imagery and actual movement using brain scanning, and reported that both tasks resulted in the formation of the same neural networks in the premotor cortex, parietal lobe and cerebellum[30], and the other that motor imagery increased dynamic balance ability by activating the neural system[31]. These results suggest that in the motor imagery training with proprioception program, activation of the cerebrum and cerebellum affected proprioception, and the visual and vestibular organs responsible for balance ability, in particular, that the activation of the proprioception sensing the position and movements of joints affects the balance ability.

In the present study proprioception with motor imagery training showed greater improvement than conventional proprioception training of the weight bearing ratio of the unaffected affected 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[22]. 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.

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