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Original Article

Effects of phase proprioceptive training on balance in patients with chronic stroke

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Abstract. [Purpose] This study aimed to investigate the effect of phase proprioceptive training on balance in patients with chronic stroke. [Subjects and Methods] Participants included 30 patients with stroke who were randomly assigned to the proprioceptive training group (n=15) or control group (n=15). Participants in the proprioceptive training group underwent proprioceptive training and received general physical therapy each for a total of 20 thirty-minute sessions, five times per week, during a period of four weeks; the control group received general physical therapy for a total of 20 sixty-minute sessions, five times per week, during a period of four weeks. [Results] All participants were evaluated with the Berg Balance Scale, Timed Up and Go (TUG) test, and Activities-specific Balance Confidence (ABC) Scale instrument before and after intervention. After training, the differences in BBS, TUG, and ABC scores in the proprioceptive group were significantly greater than those in the control group. [Conclusion] In conclusion, proprioceptive training was effective on balance ability. Therefore, proprioceptive training may be efficient when combining general physical therapy with phase proprioceptive training for patients with impairments of balance. Further research is needed to investigate proprioceptive training methods.

Key words: Stroke, Proprioception training, Balance

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INTRODUCTION

Patients with stroke typically show decreased motor skills and impairment to their senses, cognition, and visual perception; moreover, they encounter impaired physical function, making independent walking difficult due to a reduction in balance ability, walking speed, and gait endurance[1–3)]. Most patients with stroke will have twice the postural perturbation while standing than will a normal person[4)] and have a reduction in stability limits as well[5)]. Such a reduction in balance ability makes it difficult for patients to walk and produce functional movement, which can lead to difficulties in everyday life; furthermore, if a patient with stroke experiences a fall, it can further negatively affect their walking ability[6)]. Therefore, balance retraining is one of the most important categories for rehabilitation in patients with neurological impairment such as hemiparalysis[7)].

Sensory systems utilized for balance are the proprioceptive, vestibular, and visual systems[8)]. Generally, patients with stroke experience damage to all three sensory systems, with proprioception being affected the most in approximately 11–85% of the patient population[9)]. Proprioception provides basic information for balance, and is spread throughout the skin, ligaments, tendons, and muscles[8)]; information such as postural recognition, body location, joint speed, angle, and its ratio of movement that control each movement of each bodily activity is transmitted to the central nervous system, which allows for the production of normal movement, maintains dynamic safety for the joints, and protects the joints from external damage[10)]. Such damage to proprioception can exhibit great difficulties in maintaining postural control for patients with stroke[11)]; in particular, damaged lower limb proprioception can affect postural body sway[12)]. As a result, proprioception recovery is an important factor during rehabilitation for these patients, and has an important role in preventing functional instability and

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Table 1. The process of phase proprioceptive training

Phase proprioceptive training	Time
Stage 1: Stable stage (Stable surface) Standing training on stable floor (1st set: EO, 2nd set: EC)	4 mins/set
Maintain standing position	10 sec/5 times/set
Both heels up and down	10 sec/5 times/set
Maintain standing on one leg by turns	10 sec/5 times/set
Stage 2: Dynamic stage (Unstable surface) Standing training on unstable surface (Airex balance surface) (1st set: EO, 2nd set: EC)	6 mins/set
Maintain standing position	10 sec/5 times/set
Both heels up and down	10 sec/5 times/set
Maintain standing on one leg by turns	5 sec/10 times/set
Forward one step by turns	10 sec/5 times/set
Stage 3: Functional stage Standing training on unstable surface (Airex balance surface)	10 min
Walking on the same place	6 min
Both feet together, standing with back and forth foot position	10 sec/5 times
Sit down→ Squat position→ Stand up	1 min

EO: eyes open; EC: eyes closed

further injury to the damaged joints[13]. Therefore, studies on methods for improving proprioception following damage have found that providing unstable surfaces for patients with stroke during rehabilitation can increase external agitation, quickly modify sensory and motor skills by effectively changing postural orientation capability, and help patients independently change their own posture[8]. In targeting patients with ankle joint instability, Matsusaka et al.[14] found that balance training on unstable surfaces reduced the time required to normalize the patients' postural sway, and Eun-jung Kim et al.[15] concluded that training helped improve walking speed, walking posture, and lower limb muscles strength. Furthermore, Hong-won Suh and Myung-chul Kim[16] claimed that training on unstable surfaces was more effective than that on stable surfaces in improving proprioception in patients with chronic stroke. As mentioned before, studies conducted thus far have focused on analyzing the patient's standing posture balance on an unstable surface. However, there is a lack of research on a training program involving a dynamic versus a static environment. Moreover, because muscle activity patterns are different between static postures and dynamic postures, researchers suggest that posture adjustment rehabilitation should be conducted more dynamically to understand its carryover effect on function and effectiveness[17]. Therefore, the following study aimed to assess the effectiveness of phased proprioception training on the balancing ability of patients with stroke.

SUBJECTS AND METHODS

Thirty patients with stroke, admitted at C hospital located in Gyeonggido, were enrolled; informed consent was obtained from all enrolled participants prior to initiating the study protocol. The intervention was applied to the proprioception training group (n=15) and control group (n=15). Inclusion criteria for the study were as follows: a history of stroke within the prior 6 months or more, and ability to understand the directions from the researchers (those with a MMSE-K score of 24 or greater). Exclusion criteria were as follows: presence of acute musculoskeletal symptoms, inability to communicate, and those deemed unable to participate in the study by the researchers. The following research was approved by the bioethics review board at Sahmyook University.

The proprioception training program used in the study is shown in Table 1[18]. The physical therapists selected for participation in the study had more than 3 years of career experience, and the training was overseen by 6 therapists.

The control group underwent Bobath neurodevelopment treatment and proprioceptive neuromuscular facilitation[19], range of motion exercises, stretch exercises, upper and lower limb muscle strength exercises, gait training, bike exercise[20], and other general physical therapies applied to the group for 60 minutes, 5 times a week for 4 weeks.

The TUG test is used to assess functional motor skills. The assessment involves recording the time required for the person to stand up from a 46-cm tall chair with armrests, walk 3 meters away, and return to sit on the chair again. The individual being tested can wear their usual shoes and use any assistive aids necessary, but cannot receive help from anyone during the measurement. The test-retest reliability of the TUG test is r=0.99. We repeated the measurement three times and calculated the average.

The BBS is often utilized for measuring the balance ability of patients with hemiplegia from senile disorder and stroke

Table 2. General characteristics of the participants (N=30)

		Phase proprioceptive training group (n=15)	Control group (n=15)
Age (years)		58.27[a] ± 13.11	55.07 ± 13.83
Height (cm)		170.07 ± 5.70	168.20 ± 8.06
Weight (kg)		67.53 ± 8.07	68.93 ± 7.85
Duration (months)		13.53 ± 5.13	15.27 ± 4.18
MMSE-K (score)		26.87 ± 1.80	25.93 ± 1.58
Gender (n)	men	13 (86.7%)	12 (80.0%)
	women	2 (13.3%)	3 (20.0%)

MMSE-K: mini-mental state examination Korea
[a]Mean ± SD

Table 3. Change in the berg balance scale (BBS) (N=30)

		Phase proprioceptive training group (n=15)	Control group (n=15)
BBS (score)	pre	45.47 ± 4.93[a]	47.00 ± 5.18
	post	47.07 ± 5.22	47.27 ± 5.08
	Post-pre	1.60 ± 1.72*†	0.27 ± 0.96
TUG (sec)	pre	19.63[a] ± 8.64	17.24 ± 6.57
	post	17.40 ± 9.64	16.76 ± 6.86
	Post-pre	–2.23 ± 2.31*†	–0.48 ± 1.14
ABC (score)	pre	48.96[a] ± 13.06	52.67 ± 17.12
	post	52.88 ± 16.50	53.33 ± 17.92
	Post-pre	3.92 ± 5.30*†	0.67 ± 2.26

BBS: berg balance scale; TUG: timed up & go test; ABC: activities-specific balance confidence scale
[a]Mean ± SD
Significant difference, Paired t-test: *$p<0.05$
Significant difference, Independent t-test: †$p<0.05$

while moving or in a standing position. The following measurement tool has an intra-examiner reliability of r=0.99, and inter-examiner reliability of r=0.98, which both show high reliability[21)]. In this study, detailed explanations and demonstrations of each test were performed for the participants before taking measurements.

To measure balance confidence, we utilized the Activities-specific Balance Confidence Scale, which is a method that involves surveys, and shows high test-retest reliability (ICC=0.85; 95% CI 0.68–0.93)[22, 23)].

All data processing and statistical analysis were conducted with SPSS ver. 19.0 to compute means and standard deviations. All participants were tested for normality, and general characteristics were examined through descriptive statistics. We used a paired t-test to analyze changes in the dependent variables pre- and post- treatment within each group. To compare differences in the dependent variable between groups, an independent samples t-test was used. Statistical significance level for all data was set at $p<0.05$.

RESULTS

The general characteristics of the study participants are summarized in Table 2. The measurement results of the BBS showed a statistically significant increase ($p<0.05$) after training compared to before in the proprioception training group; the proprioception training group showed a statistically significant ($p<0.05$) difference compared to the general physical therapy group (Table 3). The results of the TUG test result showed a statistically significant decrease ($p<0.05$) in the proprioception training group after training compared to before; the proprioception training group showed a statistically significant ($p<0.05$) difference compared to the general physical therapy group (Table 3). In terms of the ABC scale, there was a statistically significant increase ($p<0.05$) after training compared to before; the proprioception training group showed a statistically significant ($p<0.05$) effect when compared to the general physical therapy group (Table 3).

DISCUSSION

Eva et al.[24] found that the factors for balance ability reduction among patients with stroke were a reduction in joint movement, changes in muscle tension, muscle weakness, damaged visual perception, and decline in proprioception. Additionally, a reduction in balance ability along with proprioception can lead to problems with lower extremity joints and spatial awareness while walking, which ultimately increases difficulty in maintaining balance for the patient[25]. These issues can hinder daily activities, motor recovery, and ultimately increase fall risk[26].

To compare the balance ability of patients before and after proprioception training, we utilized the BBS, TUG test, and ABC scale to measure changes in the patient's balance ability. These methods are generally used quite often for evaluating the changes in balance ability; moreover, they can evaluate balance ability without the need for specialized equipment, and are therefore widely used for clinical testing[5]. Among them, the TUG test quantifies dynamic balance ability and functional mobility. Additionally, this method has been proven to be reliable and valid in measuring clinical changes over time[27]. Healthy men have been shown to have average TUG values of between 8–13.1 seconds[28], and the test takes <10 sec to complete in normal people with no neurological damage[29]. Finch et al.[30] showed that values below 10 seconds indicated that the person has independent balance ability, values between 20 and 30 seconds showed that, although independent, the person posed an increased fall risk, and values higher than 30 seconds indicated that the person was dependent in activities of daily living.

Elizabeth et al.[31] conducted basic tactile, spatial, and proprioception training in sitting and standing positions with the eyes closed in 21 acute stroke patients for two weeks, and found statistically significant improvements in postural control and TUG scores. Similarly, Park[32] found that TUG scores reduced from 20.5 seconds to 15.3 seconds in stroke patients that had engaged in an ankle joint proprioception training program. The TUG tests conducted in this research showed similar results. This can be interpreted as the result of improved balance ability through an increase in lower limb spatial positional sense and body weight support capacity through proprioception training. The BBS is widely used as a method for measuring balance ability in hemiplegic patients due to senile diseases and stroke while moving or in a standing posture[21]. Geiger et al.[5] conducted balance and movement research on stroke patients and reported that BBS scores increased from 45.36 to 51.54 after participation in a visual feedback exercise program. Byung-yong Hwang[33] also found an increase in BBS scores from 49.5 to 50.6 in the proprioception training group. The BBS scores in the current study also showed an increase from 45.47 to 47.07 in the proprioception training group. This can be explained as an improvement in maintaining postural stability through reflexive postural control and dynamic responsiveness and a protective reflex on unstable surfaces through muscle contraction around the ankle joints.

The ABC scale is an evaluation method composed of an ordinal scale, which has been recognized for its reliability and validity, and found to be appropriate for use in evaluating various factors influencing balance in a clinical environment[34]. Wang-hoon Ahn et al.[35] conducted a comparative analysis between a balance training group and control group including chronic stroke patients on unstable surfaces, and confirmed a statistically significant difference in ABC scale values between the test group and control group before and after the intervention. Similar to previous studies, the current study also found statistically significant improvements in the proprioception training group. This can be interpreted as the result of increased balance confidence through an improvement in the balancing and walking ability of stroke patients after proprioception training; moreover, these improvements led to increased participation and activity of the patients.

Our research confirmed improvements in balance ability of stroke patients after participating in proprioception training in the current study. In terms of muscle activity, the involved muscles contract to maintain balance on the unstable surface. Furthermore, the reason for increased muscle activity resulting from increased instability is that the body is reacting in an effort to ensure balance and stability in an unstable environment[9]. Additionally, balance training on unstable surfaces enhance joint mobility, normalize neuromuscular control, and improve unconscious motor response to afferent nerve stimulation required for dynamic joint control[36]. This continued stimulation facilitates increased muscle spindle sensitivity through gamma-motorneurons, which is then transferred to a-motorneurons that activate muscle fibers resulting in improved motor output. This was found to have a positive effect on joint stability[37]. Therefore, the improvement in balance ability in the current study can be explained to be the result of increased muscle activity through proprioception training on unstable surfaces, ultimately leading to improved joint stability.

Proprioception is based on feedback and feedforward control mechanisms and provides information on the movement and location of individual body parts. This mechanism assists in correcting and maintaining posture, and controlled and coordinated movements between the head, body, upper and lower limbs[38]. Balance training on unstable surfaces is very effective in increasing proprioceptive inputs and allows the proprioceptive receptors to process the information more efficiently[39], resulting in changes in the recruitment patterns of the nerve roots[40]. Furthermore, balance training on unstable surfaces increases nerve conduction velocity speed of group II functional neurons, which in turn reduces the time required for muscle activation in postural control[37]. Moreover, afferent nerve input through the cerebral cortex is improved, which allows for a more effective response to external agitation while walking[41]. In conclusion, phase proprioceptive training is effective in patients with chronic stroke with reduced balanced ability. Further research in this area is warranted.

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