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Effects of Therapeutic Climbing Training on the Balance and Gait Ability in Chronic Stroke Patients

Background: Therapeutic climbing training, which originated in Germany, is a wall-hanging rock climbing-based therapy to increase the body's coordination through movement of the upper and lower limbs against gravity. However, there are no studies examining the effectiveness of therapeutic climbing training to treat balance and gait ability in patients with chronic stroke.
Objectives: To investigate therapeutic climbing training program on balance and gait in patients with chronic stroke.
Design: Pretest-posttest control group design.
Methods: Fourteen patients with chronic hemiplegic stroke participated. Participants were randomized into the therapeutic climbing training group (TCTG, n=7) and the standard rehabilitation program group (SRPG, n=7) group. All subjects participated in the same standard rehabilitation program consisting of 60 minutes 5 times a week for 6 weeks. TCTG participated additionally in the therapeutic climbing program consisting of 30 minutes sessions 3 times a week for the same 6 weeks. Berg balance scale (BBS), Gaitview Measure, Timed up and go test (TUG) were measured.
Results: In the TCTG, revealed a statistical difference in BBS between the groups; in the difference of plantar pressure ratio in the static standing position revealed a statistical difference between the groups after training; the balance ability in the one-leg standing tests increased significantly; the time in TUG decreased significantly after training in both groups; The changes in the difference of dynamic plantar pressure ratio were reduced significantly in the TCTG.
Conclusion: Therapeutic climbing training contribute to improve balance and walking function in patients with chronic stroke.

Keywords: *Balance; Gait ability; Stroke; Therapeutic Climbing; Rehabilitation*

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INTRODUCTION

Stroke patients experience problems such as myotonus changes, muscle weakness, sensory impairment, and lack of independent movement control.[1] In particular, functional defects at balance ability and gait ability have a great effect on patient's life. Impaired balance ability can cause a decrease in confidence, gait endurance and speed in balance.[2] Poor gait ability is also an important physical factor that limits physical activity during daily life.[3] Most stroke patients are characterized by hemiplegia in which one side of the body is paralyzed from the sagittal plane. In particular, the decreased balance ability due to posture changes, asymmetrical weight distribution, and reduced weight shift increases the riskof falling, which leads to serious economic and social burdens.[4] Therefore, reduction in asymmetry is

an ideal goal in functional rehabilitation of hemiplegia patients, and the balance and gait ability of stroke patients is a major scale of functional status and recovery.[5,6] Maintaining endurance and strength of the trunk muscle is important to maintain stable movement and various postures in daily life.[7] If the trunk does not provide enough stability to control the posture, the function of the upper limb and balance and gait ability will be limited.[8,9] The proprioception training is essential to improve balance and trunk control ability.[10] Exercise on unstable surface is effective for improving body position awareness.[11] And trunk control training at the unstable surface is also very effective as a way to increase the proprioception input to the neuromuscular system.[12]

Therapeutic climbing training, started in Germany, is a therapeutic approach based on rock climbing, which increases the body's coordination through movement of the upper and lower limbs against the gravity by hanging on the wall. This training has been applied to orthopedic diseases, trauma, neurological and mental illnesses in the physical therapy field.[13] Therapeutic climbing training is effective in activating trunk and leg muscles by cross activation of the upper and lower limbs.[14] In addition, climbing training that maintains posture on unstable surface has a positive effect on postural alignment and balance because it affects the leg and trunk muscles.[15] We think that applying therapeutic climbing training to stroke patients could affect balance and walking ability.

Recently, several postural control training using unstable surface have been conducted for stroke patients, but there is few research applying therapeutic climbing training. The preceding therapeutic climbing training have been mainly applied to normal or patients suffering from musculoskeletal disorders. So this study explores if neurological patients can participate in therapeutic climbing training and presents the possibility and basic data on whether therapeutic climbing training program can be clinically mediated after analyzing the effect of balance and gait ability.

SUBJECTS AND METHODS

Subjects

To determine the sample size, the G*Power software (G-power software 3.1.9.4; Franz Faul, University of Kiel, Kiel, Germany) statistical power analysis software program was used. The alpha level was 0.05. The results of the power analysis showed that this study would require 7 patients with chronic stroke per group. We recruited 20 patients with chronic hemiparetic stroke who performed standard rehabilitation at a general hospital. We prepared sealed envelopes marked with O or X for randomization. After that, subjects selected envelopes and decided on a group. Subjects were screened according to the following selection and exclusion criteria. The inclusion criteria were as follows: A person has been diagnosed with hemiplegia due to stroke through MRI, CT at least 6 months ago; A person with sufficient perceptivity to follow simple instructions and understand the purpose of cognition (The korean version of the Mini-mental state examination score greater than 24 of 30); A person with a score of 2 or less on the Modified ashworth scale in each joint; A person can walk 10 meters independently without any assistance; A person can sit and stand independently;

Table 1. Characteristics of subjects

General characteristic	TCTG (n=7)	SRPG (n=7)	X^2/z	*P*
Sex, Male/Female (%)	6 / 1 (85.7 / 14.3)	5 / 2 (71.4 / 28.6)	.424	.515
Paretic side, Right/Left (%)	6 / 1 (85.7 / 14.3)	6 / 1 (85.7 / 14.3)	.000	1.000
Etiology, infarction/hemorrhage (%)	5 / 2 (71.4 / 28.6)	6 / 1 (85.7 / 14.3)	.424	.515
Age (years)	45.43 ± 16.46	55.57 ± 7.39	-1.487	.163
Height (cm)	167.43 ± 9.52	167.21 ± 5.70	.051	.960
Weight (kg)	71.14 ± 19.86	65.71 ± 8.81	.661	.521
Disease duration (months)	17.50 ± 17.93	16.56 ± 23.93	.083	.935

TCTG : therapeutic climbing training group, SRPG : standard rehabilitation program group

A person can grab by hand; A person agree in writing to the study.

Exclusion criteria were as follows: A person with heart disease; A person has respiratory diseases affecting activities; A person with orthopedic diseases; A person with neurological disorder of vestibular nerves, visual impairment and deafness that affect research; A person with severe pain, in daily life.

Two subjects were excluded because they did not meet the inclusion criteria. Eighteen selected subjects were included in the study. The subjects were fully informed about the experimental process, and we read the consent in accordance with the ethical standards of the Helsinki Declaration and obtained written consent from all subjects before proceeding. In addition, prior to conducting the experiment, the human subject ethics was approved by the Institutional Review Board of the Nambu University Institution (1041478-2018-HR-030).

Outcome Measures

Berg balance scale (BBS) The Berg balance scale is an objective assessment of static balance and dynamic balance, consisting of three categories: 'sitting', 'standing' and 'posture change'. The BBS, which is a total of 14 items, applied to each item with a minimum of 0 to maximum of 4 points, with a total score of 56 points, and the measurement tool has a high reliability of r=.98 in a study involving chronic stroke patients.[16,17]

Gaitview In the static test, we used a gait analyzer to examine the distribution of plantar pressure while in the standing state (Gaitview® AFA-50 system, alFOOTs Co., Korea) (Figure 1). When a subject stand of the plate, the static distribution of plantar pressure is measured and displayed in two divided ratios (left-right/front-back). We used the two ratio data divided into front-back/left-right distributions in the standing state to measure balance ability using the difference between distributions of plantar pressures when weight shift was shifted from affected to healthy sides. Plantar pressure distributions while standing were performed with bare feet, climbed onto the scaffold, spread his feet to shoulder width, walked three times, and stood still.[18] One leg standing ability of affected sides was evaluated using body center of gravity movements in the standing position with eyes open using Gaitview stability scores. Dynamic gait ability test moves the centerline of the body. In this study, we analyzed difference in the distribution ratio of the plantar pressure as the weight shift of the affected side and healthy side using two ratio data divided into front-back and left-right of gait state to conduct the dynamic test. And we performed a dynamic foot pressure test as follows. The subjects walked from two steps way from the foot rest and put with the left foot on the footrest. After that they walked more two steps, returned, put with the right foot on the foot rest. And we measured the distribution of the foot pressure both side.[18]

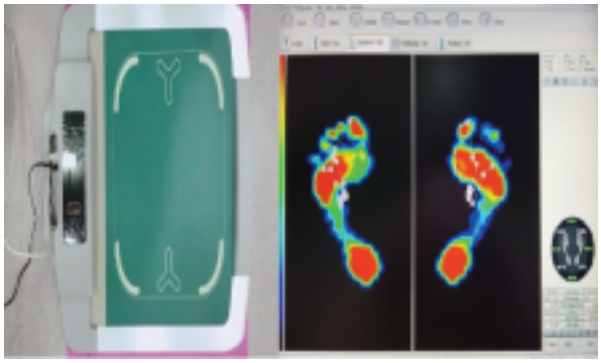

Figure 1. Procedure

Timed up and go test (TUG) TUG can measure the balance ability and basic mobility quickly by measuring the time to sit on a chair with armrests, get up, walk 3 m and then return to the chair. We could see that if the was more than 30 seconds, the basic mobility was dependent and he/she couldn't move alone at outside.[19] For stroke patients, confidence in the measurement is r=.99 and the confidence between the measures is r=.98, a reliable tool.[19]

Interventions

Therapeutic Climbing Training Group

We used Lazik's Potsdam model made in Germany for therapeutic climbing. Typically, the Potsdam model is included in the therapeutic climbing. Recently, study through therapeutic climbing has been frequently conducted in Korea.[20,21] The Potsdam model is a systematic model consisting of 32 variations with spine, shoulder, knee and ankle movements.[22] We chose six movements that stroke patients could follow easily and correspond to patterns of balance and gait enhancement (Figure 2). We chose the balance enhancing climbing pattern as follows. We selected 'tapping holes 1' & 'tapping holes 2' for spine core stabilization and 'straightening of the thoracic spine & depression of shoulder girdle' & 'climbing technique (shoulder move) abduction and external rotation' for shoulder girdle and shoulder joint stabilization.

For gait ability improvement, we selected 'squat' and 'traversing' for weight bearing similar to the actual walking pattern. When performing directional model, we did based on the paretic side.[23] An international standard wall (width 122.5*height 220.5 cm) and holder, certified by Fiji Climb, Germany, was used to facilitate therapeutic climbing indoors. In addition, we adjusted the position of the holder according to physical condition for patients to reduce the risk of falling and focus on the training.[24] We adjusted the position of the hold to suit the patient's physical state, and installed a mat underneath when applying training. To reduce the risk of falls during training, a therapist who has completed the "Therapeutic Climbing Instructor" course was placed directly behind the patient. The subjects performed this exercise for 30 minutes, including warm-up (5 minutes) and finishing (5 minutes). The exercise was conducted three

Figure 2. Therapeutic Climbing Training Program – Potsdam model
A–C: Tapping holes 1 (Balance increase pattern – spine core stabilization)
D–F: Tapping holes 2 (Balance increase pattern – spine core stabilization)
G–I: Straightening of the thoracic spine and depression of shoulder girdle (Balance increase pattern – shoulder girdle & shoulder joint stabilization)
J–L: Climbing technique 'shoulder move' adduction and external rotation (Balance increase pattern – shoulder girdle & shoulder joint stabilization)
M–O: Squat (Gait increase pattern – knee)
P–S : Traversing (Gait increase pattern – knee)

times a week for six weeks and a total of 18 times. During the 20 minute workout, each model was performed 10 times and each had break times after application. Retention time was adjusted according to the patient's ability.

Experimental Procedures

Eighteen stroke patients were randomly assigned to the TCTG (n=9) and the SRPG (n=9) before the preliminary inspection. We prepared sealed envelops that were marked with O or X for randomization. Subjects participated in the training program for six weeks after the pre-test. We conducted post-test two days after the last intervention. All measurements were taken while the patients were in the hospital. During the experiment, two subjects were dropped from each group due to health status, personal reasons, and discharge. Therefore, seven subjects from each group were included in the final analysis. All subjects participated in the same standard rehabilitation program consisting of 30 minutes of general physical therapy and 30 minutes of general occupational therapy, 5 times a week for 6 weeks. The TCTG participated additionally in the TCTG program for six weeks, 30 minutes per day, three times a week.

Data and Statistical Analysis

PASW Statistics 22 (SPSS Inc., Chicago, Illinois) was used for statistical analysis. We used independent t-test and chi-square test for descriptive statistic, mean and standard deviation homogeneity tests for each variable measured. The normalities of the quantitative data distribution were assessed using the shapiro wilk test ($P>.05$).

To analyze the within-group differences, Wilcoxon-signed rank test was used for non-parametric variables. To analyze intergroup differences, the Mann-Whitney U test was used for non-parametric variables. Statistical significance was accepted for P values $<.05$.

RESULTS

Balance

In BBS, TCTG increased by 7.57 scores and SRPG increased by 3.72 scores. There were significant differences between groups ($P<.05$). When comparing before and after training, the balance ability significantly increased in both the TCTG and the SRPG ($P<.05$).

As examining changes in the ratio of the plantar pressure difference (front-back/left-right) in the static standing position, TCTG decreased by 8.15 and SRPG decreased by 1.57 (front-back). And TCTG decreased by 9.03 and SRPG decreased by 1.6 (left-right). There was a significant difference between the

Table 2. Comparison of balance and gait ability within groups and between groups

	TCTG (n=7)		SRPG (n=7)		*z (P)*
	Pre-test	Post-test	Pre-test	Post-test	
Balance abilities					
Berg balance scale (score)	45.14 ± 11.17	52.71 ± 3.45*†	43.71 ± 6.65	47.43 ± 5.22*	−2.187 (.029)
Static front-back ratio difference (%)	11.49 ± 7.93	3.34 ± 2.99†	9.66 ± 6.24	8.09 ± 5.59	−2.051 (.040)
Static left-right ratio difference (%)	11.60 ± 7.68	2.57 ± 2.91*†	10.54 ± 7.71	8.94 ± 4.88	−2.558 (.011)
One leg standing ability (score)	84.29 ± 4.35	90.71 ± 1.70*	77.29 ± 14.29	89.0 ± 4.00	−.650 (.515)
Gait abilities					
Timed up and go test (sec)	11.67 ± 4.88	9.15 ± 3.84*†	14.88 ± 3.90	12.91 ± 4.06*	−1.981 (.048)
Dynamic front-back ratio difference (%)	15.80 ± 9.31	9.60 ± 6.96*	16.71 ± 9.00	14.11 ± 9.14	−.831 (.406)
Dynamic left-right ratio difference (%)	7.94 ± 4.57	2.94 ± 2.99*	5.69 ± 5.86	4.06 ± 5.36	−.064 (.949)

TCTG : therapeutic climbing training group, SRPG : standard rehabilitation program group
Value are expressed as Mean±SD
*$P<.05$, significant difference between pre-and post interventions within the group
†$P<.05$, significant difference between the change scores between the groups

groups after training ($P<.05$). When comparing the left-right plantar pressure difference before and after training, this decreased significantly in the therapeutic climbing training group ($P<.05$). also when comparing one leg standing results before and after the training, TCTG increased by 6.42 scores and SRPG increased by 11.71 scores. The balance ability significantly increased in the therapeutic climbing training group ($P<.05$) (Table 2).

Gait ability

In TUG, TCTG decreased by 2.52 seconds and SRPG decreased by 1.97 seconds. Measurement time in TUG significantly decreased comparing before and after training in both groups ($P<.05$). As examining changes in the ratio of the plantar pressure difference (front-back/left-right) in the dynamic test, TCTG decreased by 6.2 and SRPG decreased by 2.6 (front-back). And TCTG decreased by 5 and SRPG decreased by 1.63 (left-right). Changes in the dynamic plantar pressure (front-back/ left-right) ratio were significantly reduced in the TCTG after training ($P<.05$) (Table 2).

DISCUSSION

As a result of the balance ability, there was a significant difference between the groups and periods in the BBS and static plantar pressure (front-back/left-right) ratio change. Also there was also a significant difference in one-leg standing ability between before and after training.

If the subject moves the other limb with the affected side fixed, only the part except the fixed part moves. This could be the closed kinetic chain because we set a part which was far from the affected side as the closed kinetic chain position. This study led to natural weight support through therapeutic climbing training by fixing the affected side when limbs moving. Repetitive training also affected positively balance abilities, such as weight transfer ability and standing one leg of the affected side.

In the previous study, when performing the closed kinetic chain and open kinetic chain to hemiplegic patients, a group which did the closed kinetic chain showed a significant difference in the balance ability of Timed up and go test, One leg standing test, Berg balance test, etc.[25] This is consistent with the results of this study.

Also the importance of trunk control in hemiplegic patients is emphasized.[26] Previous studies have reported that the trunk muscle of the affected side had lower isometric muscle strength than the trunk muscle strength of the healthy side when using the upper limbs and this led to imbalance.[27] Based on this, the Potsdam model program which keep the body from falling off the wall with the weight bearing posture that grasps a holder on the wall continuously contracted the trunk muscle of the affected side and increased muscle strength of the subjects in the study. It is thought that the left-right imbalance of body was reduced.

We thought that the subjects more used their trunk strength to maintain a balance against holds, which are an unstable supporting surface, and due to increasing unstable direction of the lower limb. The results show that, as in previous studies of stroke patients, stroke patients experience co-contraction of muscles across body parts to maintain balance against unstable ground, and higher trunk muscle activity as the unstable orientation of the lower extremities increases.[28] This seems to guarantee stability and balance.

In addition, training on an unstable supporting surface is more effective in gait speed and increasing balance in patients with chronic stroke than training on an stable support training.[29] And training using an unstable supporting surface more improves posture control and dynamic balance ability of stroke patients than exercise using a stable supporting surface.[30]

Therefore, we decreased imbalance between the affected side and healthy side by improving the ability of supporting with foot or feet through weight bearing training. Also the balance ability was improved by inducing isometric contraction of the trunk muscles and increasing muscle activity through making patients maintain posture on the unstable supporting surface.

Based on a result of the gait ability in this study, the therapeutic climbing group had significant differences in the TUG, dynamic plantar pressure (front-back) ratio, and dynamic plantar pressure (left-right) ratio after the training.

Loss of dynamic balance reduces proper response ability to various environments and challenges.[31] As a result of investigating predictors related to falls after a stroke, It has been found that reduced balance and reduced walking speed can increase fall accidents and require equal dynamic balance and functional exercise training.[32] Previous studies above have shown that dynamic balance in stroke patients is closely related to walking ability.

The BBS and TUG used in this study are also the

test methods to measure dynamic balance. It is known that the better the BBS is, the closely there is a correlation with TUG improvement.[33,34] Measuring the dynamic balance and the ability to maintain a balance when moving over certain section, such as BBS and TUG, can help to determine the functional level of the patient and to predict the prognosis.[35] The results after the training showed significant differences in the time periods of both BBS and TUG, indicating that the dynamic balance ability was significantly improved through therapeutic climbing training.

Also, as a result of measuring static and dynamic balance after applying therapeutic climbing to 55 patients with chronic low back pain, it was reported that it improved balance immediately after treatment start and immediately after treatment finish.[36]

Climbing training can effectively derive not only static stability but also dynamic stability through isometric exercise using the change of gravity center and bottom surface in climbing wall.[37]

In addition, previous studies have shown that diagonal pattern self-exercise on unstable surfaces is a way to improve trunk control and improve balance and gait ability in stroke patients.[38] Therapeutic climbing corresponds to a diagonal pattern of self-exercise, and seems to have achieved the same result. And Another study found that diagonal exercise may improve scapular movement and gait when applied to the scapular adductor muscle in stroke patients. Among the therapeutic climbing movements, the movement using the scapular adductor muscle may have been affected.[39]

Looking at the results, there was no difference in walking ability between the two groups. However, the experimental group confirmed the difference in duration, and the control group did not show any differencein duration in all gait-related results. It was confirmed that there was a change in the improvement of walking ability of the climbing group. TCTG performed the same movement with the same tilt for all subjects. The training time was short and it was difficult to adjust the difficulty level for each individual, so it seems that it was not possible to show differences between groups. Therefore, this study seems to be able to improve gait ability because a significant difference in dynamic balance ability affects gait ability in therapeutic climbing training. I think that if you train for a long time and set the difficulty level for each individual, you can expect differences between groups.

As shown above, it was found that therapeutic climbing training for stroke patients brought positive changes in balance and walking ability. It is expected that this study may provide basic data on the possibility and effectiveness of a new exercise intervention called therapeutic climbing in stroke patients.

The limitation of this study is that it is difficult to expect the same results in other stroke patients in the future because of the short study period, the small number of subjects, and the large age difference in group. This study invites future studies using more diverse designs and larger sample sizes in therapeutic climbing to improve the generalizable potential of new findings. Future studies will need to identify in a variety of ways which of the therapeutic climbing programs of varying difficulty is effective for the balance and gait ability of stroke patients.

CONCLUSION

The results of this study show that therapeutic climbing training has a positive effect on balance and gait ability in stroke patients. Therefore, it is believed that therapeutic climbing training could be used as the basis for a rehabilitation program for stroke patients.

CONFLICT OF INTERESTS

The author declares that there are no conflicts of interest.

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