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Effects of Diagonal Pattern Self-Exercise on Trunk Control, Balance, and Gait Ability in Chronic Stroke Patients

Background: Weakness of the trunk muscles decreases the trunk control ability of stroke patients, which is significantly related to balance and gait.
Objectives: To compare the impact of diagonal pattern self-exercise on an unstable surface and a stable surface for trunk rehabilitation on trunk control, balance, and gait ability in stroke patients.
Design: Nonequivalent control group design.
Methods: Twenty four participants were randomized into the experimental group (diagonal pattern self-exercise while sitting on an unstable surface, n=12) and the control group (diagonal pattern self-exercise while sitting on a stable surface, n=12). All interventions were conducted for 30 minutes, three times a week for four weeks, and the trunk impairment scale (TIS), berg balance scale (BBS), functional gait assessment (FGA), and G-walk were measured.
Results: All groups indicated significant increases in all variables (TIS, BBS, FGA, cadence, speed, stride length) after four weeks. The TIS, BBS, FGA, cadence, gait speed, and stride length group-by-time were significantly different between the two groups.
Conclusion: We found that, in stroke patients, diagonal pattern self-exercise on an unstable surface is a more effective method for improving trunk control, balance, and gait ability than diagonal pattern self-exercise on a stable surface.

Keywords: *Unstable; Self exercises; Balance; Gait; Stroke: Trunk*

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INTRODUCTION

Most stroke patients experience balance and gait disability after neurological impairment,[1] and balance and gait disabilities are largely caused by weakness.[2,3] While weakness can affect one arm or one leg, trunk weakness can cause weaknesses in both arms and legs. This is because the trunk is connected as one, and it is controlled by both cerebral cortices.[4-6,8] Thus, the trunk control ability of stroke patients is significantly related to balance and gait.[9,10] The balance ability of stroke patients in the sitting position can predict the gait and prognosis.[11] Thus, reinforcement exercises or trunk rehabilitation can improve gait and balance by increasing trunk control in stroke patients.[12] To date, trunk rehabilitation in patients with stroke has increased respiratory function, the activity and control of trunk muscles, balance ability, and gait speeds by employing core stability and mobilization exercises.[13-18] Stabilization exercise increases abdominal pressure through abdominal and deep muscle contractions. The elevated abdominal pressure helps to increase stability, which in turn promotes trunk control, leading to balance and gait improvement.[13,14,18] Mobilization exercise improves trunk control, balance, and gait by increasing chest wall movements in stroke patients with reduced rib cage motion.[19] Constant rehabilitation must be performed to restore function in patients.[20] In this study, trunk rehabilitation involved diagonal pattern self-exercises in a sitting position on an unstable surface. Exercising on an unstable surface is an effective way to increase trunk stability as it stimulates palpation in the cerebral motor cortex and proprioception[21] and increases the activity of trunk muscles.[22] Recent comparison studies demonstrate that exercises on unstable surfaces are superior to exercises on stable surfaces.[23] The diagonal pattern exercise is an effective way to increase trunk mobility by moving the trunk in diagonal directions.[24] This exercise can be performed alone under the supervision and guidance of a guardian after a therapist trains the patient.[19] The diagonal pattern exercise involves significantly greater cortical activity, related to the integration of motor information, than a single plane exercise.[25] After the patient is discharged and visits the hospital as an outpatient, the frequency of treatment is decreased compared to that when the patient was hospitalized. Diagonal pattern exercises are generally performed at a low intensity.[19] In order to improve physical activity of stroke patients, high-intensity exercise is required. In this study, a diagonal pattern motion is performed with addition of an unstable support surface.

The purpose of this study was to investigate the effect of diagonal self-exercises while sitting on an unstable surface on trunk control, balance ability, and gait speed in chronic stroke patients in order to identify new self-exercises for nervous system rehabilitation.

SUBJECTS AND METHODS

Subjects

This study involved 24 patients with stroke who were admitted to S Hospital in Suwon-Si. Admitted stroke patients were recruited after age screening, and 24 subjects who met the subject selection criteria were selected.[19] Subjects who were selected included those who had been diagnosed with stroke for more than six months, scored 24 or more on the Korean version of the mini-mental state examination. Subjects who were excluded were those with unilateral neglect or severe sensory deficit and those taking prescribed medications that could affect balance. The purpose of the study was explained to every subject, and signed research agreement forms were obtained. This study was approved by the Institutional Review Board of Youngin University (2-1040966-AB-N-01-20-1910-HMR-153-6).

Experimental Procedures

In this nonequivalent control group design experiment, every subject underwent a baseline assessment, and after four weeks of intervention, a post-intervention assessment was performed. All interventions were conducted for 30 minutes, three times a week for four weeks. G-power software was used for sample size calculation. Twelve subjects each were assigned to the experimental group and control group. All subjects underwent conventional physical therapy. The researchers taught the subjects how to perform the diagonal pattern self-exercise while sitting on an unstable surface. Initial assessments were performed after signed consents were obtained, and post-intervention assessments were performed after the interventions were completed. All evaluations were conducted by a single physical therapist who was blinded to the study.

Interventions

The experimental group performed diagonal pattern self-exercises while sitting on an unstable surface. The diagonal pattern exercise is a trunk rehabilitation exercise to alleviate exercise disorder.[19] The exercise was performed in a sitting position on a height-adjustable bed. For unstable surface exercises, an anti-slip AIREX Balance Pad Elite (AIREX) (50 × 41 × 7 ㎝, 0.8 kg) was used. Balance pads were placed under the feet and hips of the subjects in the unstable surface exercise group. Subjects were told to clad ten fingers together in order to move the paralyzed hand. The control group performed diagonal pattern self-exercises while sitting. The diagonal pattern exercises consist of five stages, with each stage comprising two diagonal patterns. Each movement was performed five times within a period of one minute, followed by a 30-second rest. Completion of five different diagonal pattern exercises as described above was considered as the completion of one set of diagonal pattern exercises. A total of three sets for 30 minutes with 150 seconds of rest between every set were completed. All subjects were asked to focus their vision on the tips of the clasped hands during the exercises. Exercise methods and sequences are shown in Figure 1.

Outcome Measures

Trunk Impairment Scale (TIS)

The trunk impairment scale is an evaluation tool developed by Verheyden et al. in 2004 for the evaluation of the trunk of stroke patients. This scale is used to measure static sitting balance (3 items), dynamic sitting balance (10 items), and trunk coordination force (4 items). The inter-rater reliability of this evaluation scale ranges between r=.87 and r=.96, and the intra-rater reliability ranges between r=.87 to

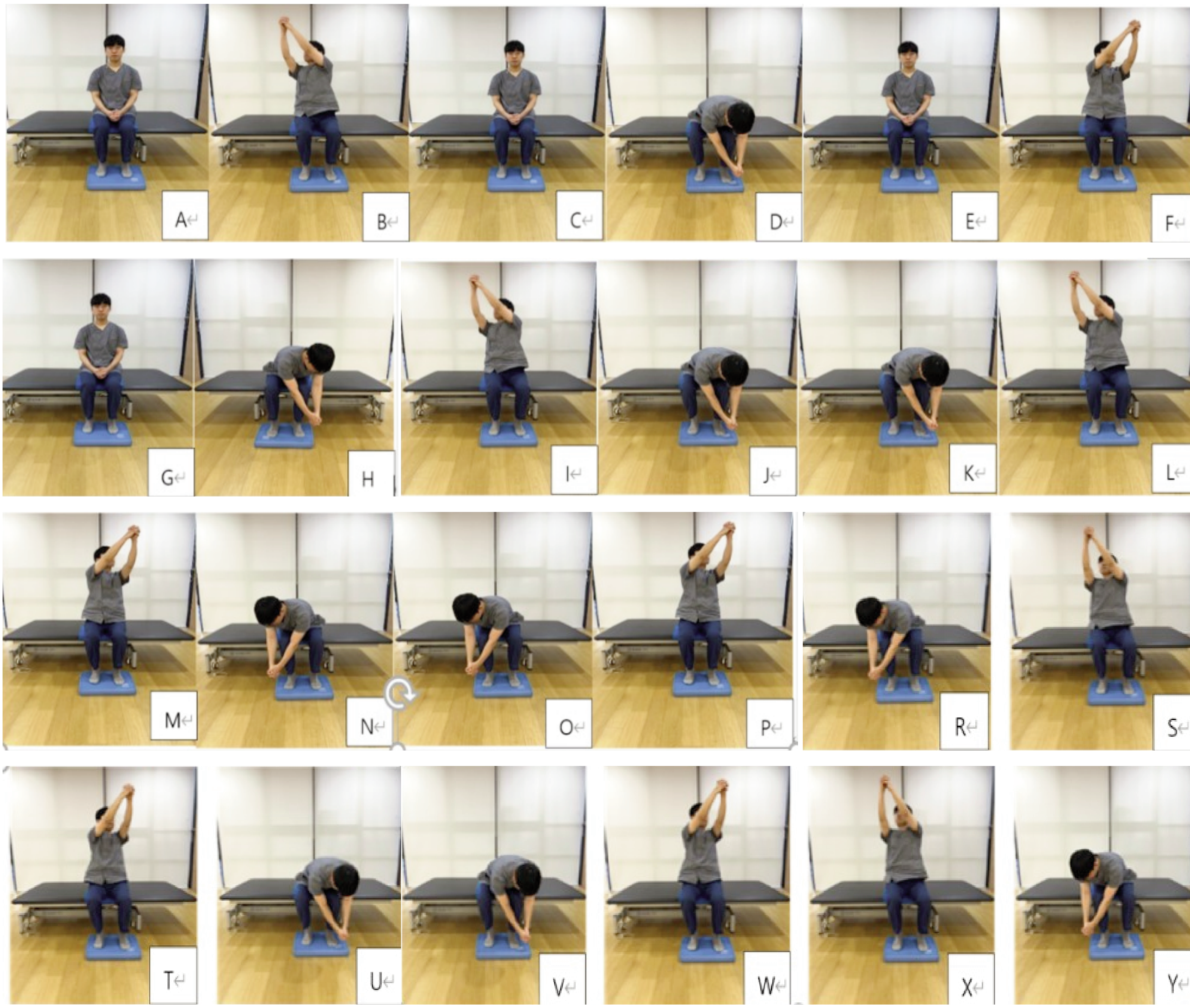

Figure 1. Diagonal pattern self–exercise while sitting on an unstable surface

A–B: Diagonal pattern exercise 1
C–D: Diagonal pattern exercise 2
E–F: Diagonal pattern exercise 3
G–H: Diagonal pattern exercise 4
I–J: Diagonal pattern exercise 5
K–L: Diagonal pattern exercise 6
M–N: Diagonal pattern exercise 7
O–P: Diagonal pattern exercise 8
R–U: Diagonal pattern exercise 9
V–Y: Diagonal pattern exercise 10

r=.96, indicating high reliability and internal validity.[25]

Berg balance scale (BBS)

The Berg balance scale is a functional evaluation tool that measures the ability to control balance.[26] This functional balance test considers three aspects: posture maintenance ability, voluntary exercise control, and reflection on external factors. It consists of 14 detailed evaluation items. Each item is divided into five levels of function, with the lowest and highest levels being 0 and 4 points, respectively. A total of 56 points can be obtained with a higher score indicating better balance. The intra–rater and inter–rater reliabilities for stroke patients are r=.95 and r=.97, respectively, indicating high reliability and validity.[27]

Functional gait assessment (FGA)

The functional gait assessment was developed by adding items and making a few changes to the existing dynamic gait index assessment tool.[28] It measures stability while gait tests are being performed. It consists of a total of 10 items, each of which is evaluated using a 4-point scale from 0 to 3 points. No disability and minor disabilities are assigned scores of 3 and 2, respectively. A score of 1 is assigned for moderate disabilities, while a score of 0 indicates severe disabilities. A total of 30 points can be obtained, with a higher score indicating higher functional gait performance. This test can also be performed on stroke patients to measure the patient's functional gait performance. The reliability of a re-test and inter-rater reliability for stroke patients are ICC=.97 and ICC=.94, respectively.[29]

Gait analysis

Gait analysis (G-walk, BTS, Italy) was performed to measure spatiotemporal gait variables among subjects. This instrument helps to analyze gait disorders and the effect of treatments in the clinic.[30] The instrument weighs 37 g and has a built-in 3-axis accelerometer (16 bit), magnetometer (13 bit), and gyroscope (16 bit) on a BTS G-sensor that is 78 x 40 x 18 mm in size. It can be fixed on the fifth spinal bone with a belt, allowing the subjects to walk comfortably. The movement of the center of gravity can be used to assess the gait wirelessly via Bluetooth using the BTS G-studio software installed on a laptop. In this study, an 8-m long pedestrian walkway was installed to allow the subjects to walk comfortably. The subjects were asked to maintain a standing position at the start of the test. When the "start" button was pressed on the BTS G-studio software, the "waiting for stabilization" window appeared while the subject maintained his/her standing position. When this window disappeared, the subjects were instructed to make a straight gait for a distance of 8 m at a comfortable speed. The "stop" button was pressed to terminate the evaluation.[31] In this study, the cadence (stride length per minute), average speed during the gait cycle, and stride length (the distance between the heel when the same foot touched the floor) were obtained as read-outs.

Data and Statistical Analyses

All data were analyzed using SPSS 21.0 software (IBM Corp., Armonk, NY, USA). The data for both the experimental and control groups were normally distributed. Thus, parametric tests were used. A homogeneity test between the two groups was performed using the independent t-test. The independent samples t-test and chi-square test were used to analyze the general characteristics of the subjects. The two-way repeated-measures analysis of variance was performed to evaluate the effects of the exercise. The within-subjects factor was time (pre-test and post-test). The between-subjects factor was group-by-time (experimental group and control group). When significant differences in group-by-time and time were observed, the Student's t-test was used. The statistical significance level was set at α=.05.

RESULTS

General characteristics of subjects

The general characteristics of the subjects are presented in Table 1.

Table 1. General characteristics

(Mean±SD)

	Control group (n=12)	Experimental group (n=12)	*P*
Man/Woman	6/6	7/5	.682
Left hemiparesis/Right hemiparesis	5/4	6/6	.408
Infarction/Hemorrhage	8/4	7/5	.673
Onset (month)	11.83 ± 3.88	10.50 ± 3.34	.377
K-MMSE (point)	26.33 ± 1.37	26.58 ± 1.16	.635
Age (years)	63.75 ± 7.47	62.08 ± 7.19	.583
Height (cm)	159.33 ± 5.87	162.50 ± 8.17	.287
Weight (kg)	64.83 ± 7.90	65.25 ± 7.61	.896

P<.05

K-MMSE: Korean version of mini mental state examination

Table 2. Comparison of TIS, BBS, FGA in Before and After (Mean±SD)

	Control group (n=12)		Experimental group (n=12)		F	P
	Pre-test	Post-test	Pre-test	Post-test		
TIS (score)	12.83 ± 4.47	13.92 ± 4.80[1]	15.50 ± 4.15	17.92 ± 4.12[1,2]	35.280	.01*
BBS (score)	32.10 ± 7.06	32.92 ± 6.76[1]	35.50 ± 5.96	37.75 ± 6.08[1,2]	25.140	.01*
FGA (score)	8.50 ± 5.58	9.42 ± 5.88[1]	7.83 ± 4.37	10.42 ± 4.81[1,2]	24.562	.01*

*P<.05
[1] Significant different pre-test and post-test (time)
[2] Significant different experimental group and control group (group-by-time)
Experimental group: Diagonal pattern self-exercises while sitting on an unstable surface
Control group: Diagonal pattern self-exercises while sitting
TIS: Trunk impairment scale
BBS: Berg balance scale
FGA : Functional gait assessment

Table 3. Comparison of Cadence, Speed, Stride length in pre-test and post-test (Mean±SD)

	Control group (n=12)		Experimental group (n=12)		F	P
	Pre-test	Post-test	Pre-test	Post-test		
Cadence (step/min)	79.52 ± 15.49	82.58 ± 17.17[1]	73.70 ± 18.12	85.23 ± 20.78[1,2]	38.395	.01*
Speed (m/s)	.75 ± .13	.78 ± .15[1]	.68 ± .14	.82 ± .17[1,2]	22.000	.01*
Stride length (m)	1.10 ± .08	1.14 ± .08[1]	1.11 ± .06	1.21 ± .10[1,2]	28.034	.01*

*P<.05
[1] Significant different pre-test and post-test (time)
[2] Significant different experimental group and control group (group-by-time)
Experimental group: Diagonal pattern self-exercises while sitting on an unstable surface
Control group: Diagonal pattern self-exercises while sitting

Changes in TIS, BBS, FGA, and gait parameter (cadence, gait speed, and stride length)

After four weeks of intervention, all groups experienced significant improvements in the TIS, BBS, FGA, and gait scores. The TIS, BBS, and FGA scores, and the cadence, gait speed, and stride length group-by-time were significantly different between the two groups (Tables 2 and 3)

DISCUSSION

After four weeks of intervention, both the experimental and control groups showed significant improvements in all variables including the TIS, BBS, and FGA scores and the cadence (steps/min), gait speed (m/s), and stride length (m). The TIS, BBS, and FGA scores, and the cadence, gait speeds, and stride length group-by-time were significantly different between the two groups.

The diagonal pattern exercises utilized in this study are trunk control, balance ability, and gait exercises based on chopping and reverse chopping of proprioceptive neuromuscular facilitation that promote the intercostal muscle, diaphragm, and abdominal muscle.[32] The self-diagonal pattern gymnastic exercise, similar to the exercise pattern used in the present study, improved the TIS score and the Tinetti gait index and decreased the center of pressure area both when the eyes were open and when they were closed, compared to the single plane trunk stretching exercise.[19] These results are consistent with those of the current study. The diagonal pattern exercise was designed to enable the repetition of trunk movement and weight shifting in the diagonal direction and in the sitting position during chopping and reverse chopping, respectively.

In order to increase the total TIS score, mobility, such as rotation of the trunk and lateral bending, is required.[33] The TIS score is positively correlated with the BBS score.[34] Moreover, repeated weight bearing training moves the gait asymmetrical body symmetrically, inputting the proprioceptor into the trunk. This leads to an increase in trunk balance, which improves gait.[35] Although studies have been conducted on acute and subacute stroke patients, the reported findings that the trunk PNF technique is effective in improving trunk control and balance in stroke patients support the results of this study.[36]

In this study, self-diagonal pattern exercises were performed to enhance mobility. Additionally, interventions on unstable surfaces were performed to promote stability. Trunk training on unstable surfaces are superior to training on stable surfaces in improving static and dynamic balance.[23] Trunk rehabilitation on unstable surfaces not only increases muscle activity but also improves trunk anticipatory postural adjustments and stimulates local and global stabilizers, which simultaneously contributes to trunk stability.[23] Trunk training on unstable surfaces improved the internal oblique abdominis (IO) muscle thickness, transverse abdominis (TrA) muscle thickness, and BBS scores of stroke patients.[37] In addition, it significantly improved the activity of the external oblique abdominis (EO) and IO muscles, the TIS score (dynamic, coordination, total), and the 10-m walk test score more than trunk training on stable surfaces.[38] In the current study, the experimental group, comprising patients who exercised on unstable surfaces, demonstrated significantly greater increases in TIS, BBS, and FGA scores, and cadence, gait speeds, and stride length than did the control group. Diagonal pattern exercises on unstable surfaces were performed to achieve stability and mobility enhancement simultaneously during trunk rehabilitation of stroke patients.

Therefore, the unstable surface with diagonal pattern exercise is thought to improve the trunk control, balance, and gait ability of stroke patients by changing the motor cortex through the diagonal pattern exercise[25] and activation of various trunk muscles through the unstable surface.[39] To the best of our knowledge, it is the first study to investigate trunk control, balance, and gait ability after diagonal pattern exercises on an unstable surface. Furthermore, improved trunk control, balance, and gait were observed. Thus, we believe that this exercise is a suitable self-exercise that can be constantly performed at home after discharge. In addition, stroke type (hemorrhages/infarction) is not related to balance. Neglect, weakness, and sensory loss can affect the balance of stroke patients. In this study, severe sensory deficit and neglect patients were excluded.[3]

Despite these results, this study has a number of limitations. First, this study involved patients with mild to moderate chronic stroke, since the patients had to perform the exercises on their own. Therefore, the effects cannot be generalized to severe stroke patients or those with acute and subacute stroke. Second, trunk rehabilitation in this study was performed using diagonal exercises on unstable surfaces to improve both motility and stability. However, due to the absence of proper control groups, we could not determine whether the effects on trunk control, balance, and gait were due to the diagonal pattern exercise or due to the training on the unstable surface. Third, improvements in trunk control and balance ability were only evaluated by a physical therapist rather than using an objective evaluation method.

Therefore, future studies involving the performance of diagonal patterns on both unstable and stable surfaces are required. Furthermore, diagonal pattern exercises and other trunk exercises[40] on unstable surfaces should be compared. Additionally, we expect to see larger sample sizes and a wider variety of evaluation tools in future studies.

CONCLUSION

In this study, we confirmed that diagonal pattern self-exercise has a positive effect on trunk control, balance, and gait ability in stroke patients. We found that diagonal pattern self-exercise on an unstable surface is a more effective method for improving trunk control, balance, and gait ability than is diagonal pattern self-exercise on a stable surface in stroke patients. If physiotherapists educate the patient in clinical settings, we expect that it will be a self-exercise method that will help with trunk control even after discharge (home training).

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