Effects of Lumbar Stabilization Training on Postural Stability and Gait in Patients with Stroke

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Purpose The purpose of this study was to investigate the effects of lumbar stabilization training on postural stability and gait in stroke patient. ***Methods*** Subjects were recruited 30 patients with stroke. They were randomly assigned to either the study group or control group. Both groups received equal amount of intervention sessions for 30 minutes a day, 3 times a week for 8 weeks. Lumbar alignment was measured using flexible ruler, muscle activity was measured using surface EMG, and gait characteristics were measured using 10m walk test. ***Results*** The study group showed significant changes in lumbar alignment, muscle activities in erector spinae muscle, hamstring muscle, and gait of the stroke patient. ***Conclusion*** Based on results of this study, lumbar stabilization training was effective therapeutic approach in improving postural stability and gait improvement in stroke patients.

Key words Stroke, Hemiplegia, Lumbar stabilization, Balance, Gait

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Received date 01 Feb 2021
Revised date 08 Feb 2021
Accept date 15 Feb 2021

Ⅰ. Introduction

Stroke induces neurologic impairments in the motor and sensory pathways, and neurologic impairments manifest as various symptoms, such as muscle weakness, abnormal muscle tension, asymmetrical movement, and reduced balance. These symptoms in turn cause trunk mal-alignment.[1,2] Postural control is the way our central nervous system regulates sensory information from other systems in order to produce adequate motor output to maintain a controlled, upright posture and created through alignment between the key control points and the basal plane.[3] Trunk alignment is influenced by passive structures, namely the lumbar vertebra and pelvis, and active structure, namely muscles.[4] The lumbar vertebra provides durability and elasticity for the body and helps maintain balance by achieving trunk stability.[5] Further, force couples of the hip extensor, hip flexor, abdominal muscle, and erector spinae are related to pelvic tilt and determines the lumbar alignment.[6] Stroke patients develop hyper-lordosis due to the weakness, imbalance, and abnormal sequence of muscle contraction involved in pelvic alignment, and the consequently extended abdominal muscle and hip extensor induces muscle stretch weakness.[7]

Human gait refers to the movement from one place to the target through regular repetitive feet motions, and this involves the regulation of body sway through stability of the head, trunk, arms, and legs. Stroke patients have difficulty with regular, repetitive motions because their neurologic impairment diminishes the activity of the core stability muscles needed for gait, trunk mal-alignment, and abnormal sequence of muscle contraction.[8] Therefore, recovery of normal trunk and pelvic movement is essential for gait in stroke patients and achieving gait in order to carry on an independent daily living is the most important goal of rehabilitation for stroke patients.[9]

A previous study on the general patients with low back pain reported that lumbar stabilization training

http:dx.doi.org/10.17817/2021.02.08.1111641

reduced pain and strengthened the trunk muscles.[10] A study on stroke patients found that lumbar stabilization training improved patient's postural control and proprioception.[11] While previous studies reported that increasing the strength and stability of pelvic muscles through bridge exercise and pelvic tilt training had positive effects on balance and gait in stroke patients, studies on the effects of training utilizing changes in pelvic tilt and lumbar curve on lumbar stabilization are lacking. The purpose of this study was to investigate the effects of lumbar stabilization training on postural stability and gait in stroke patient.

II. Materials and Methods

1. Study subject

This study was conducted on 30 patients who had been diagnosed with stroke at B hospital in Seongnam, Gyeonggi, and meet the inclusion criteria. The participants provided an informed consent, and data were collected from August to October 2020. The intervention was administered over eight weeks, with 30 minutes a day, 3 times a week for 8 weeks. Pre- and post-intervention evaluations were performed by the same therapist (Table 1.).

1) At least six months from onset
2) A K-MMSE score of 24 or higher, indicating capability to understand and follow instructions
3) No orthopedic diseases of the pelvis and trunk that would affect the study
4) Those who can walk 10m without aid.
5) Those who understand and consent to the participation agreement of this study

2. Study design

The study group was randomly assigned into two groups: a lumbar stabilization training group and a conventional physical therapy group. A total of 30 randomly selected patients were assigned to study and control groups, and a preliminary evaluation was performed. For both groups, both groups received equal amount of intervention sessions for 30 minutes a day, 3 times a week for 8 weeks, the study group conducted lumbar stabilization training group, and the control group conducted program for conventional physical therapy included joint range of motion exercise, muscle strengthening exercise.

3. Outcome Measures

1) Flexible ruler

Lumbar alignment was assessed using a flexible ruler. A flexible ruler is made of a bendable metal strip covered with plastic, and it can be used to take an impression of a person's spinal shape. The interrater reliability for measuring lordosis with a flexible ruler was high (r=.90),[12] and there was a strong linear relationship (r=.87) between the lordotic angle obtained from

Table 1. General characteristics of the subjects

Variables	Study group (n=15)	Control group (n=15)	X^2/t	*p*
Gender (M/F, %)	7/8(46/54)	7/6(67/33)	.144[b]	0.705
Paretic side (R/L, %)	8/7(54/46)	5/8(44/56)	0.619	0.431
Age (year)	55.40±5.87[a]	53.15±6.89	.931[c]	0.36
Height (cm)	171.46±3.70	169.15±7.27	1.082	0.289
Weight (kg)	63.27±9.07	62.86±6.71	0.132	0.896
Duration (month)	14.40±5.75	13.23±6.27	0.514	0.611
MMSE-K (score)	26.00±1.35	26.84±1.77	−0.416	0.681
K-MBI (score)	76.73±3.28	78.15±5.35	-0.859	0.398

Note. K-MBI: modified barthel index-Korean version. [a]mean±standard deviation, [b]chi-square test, [c]independent t-test the flexible ruler and that obtained from an x-ray.[13)]

When measuring the lordotic angle, the participant stands, gazing forward with the two feet 10cm apart. An impression of the lumbar spine is taken through C7, T12, L4, and S2 vertebrae.[14)] Linear distance (S) is determined by drawing a perpendicular line on L4 from a straight line from T12 to S2 (L). Then, the lordotic angle is calculated using trigonometry.

$\Theta = 4(\arctan [2h/ L])$

2) EMG

In this study, root mean square (RMS) values were used for all electromyogram (EMG) signals, and in consideration of the fact that the participants are stroke patients with muscle weakening, muscle activity was standardized with muscle contraction as the reference contraction(reference voluntary contraction, RVC) and using %RVC.[15)] To measure muscle activity, a 2-kg sandbag was placed on the non-affected arm, and measurement was taken for 10 seconds with the elbow joint at 0° extension and shoulder joint at 90° flexion and external rotation. The first and last 3 seconds were removed, and the values during the middle 4 seconds were used. The electrodes were placed as follows: 3 cm from the umbilicus for the rectus abdominis, midpoint between the anterior superior iliac spine and patella for the quadriceps femoris, the midpoint between the spinous process of L1 and lateral plane of the trunk for the erector spinae (low back), and the midpoint between the ischial tuberosity and lateral condyle for the hamstring muscles.

3) 10m walk test

The 10-m walk test is a simple and easy test for assessing stroke patients gait. The patients were asked to walk 14 m at their comfortable pace, and the first and last 2 m were excluded from the measurement. The test was performed three times, and the mean value for each test was computed. A one-minute rest was taken between measurements to minimize muscle fatigue. The gait characteristics were calculated using the ratio after obtaining the time and the number of footsteps in the 10m walk test.

4. Therapeutic interventions

1) Lordosis control training

After pressing the lordosis device, control lumbar curvature through hip lifting exercise. Lumbar curvature adjustment strengthens lumbar muscles and stabilizes the lumbar spine.

① To suppress the compensation of the upper trunk during lumbar stability training, strap patient’s upper trunk with a belt.

② Instruct patient to push the “lordosis device” and induce posterior pelvic tilt.

③ With number ②, lift the pelvis as much as possible from the bed and maintain for five seconds. Do five sets of five reps.

5. Statistical analysis

The statistics of this study were calculated using SPSS(ver. 18.0). The general characteristics of the subjects were descriptive statistics, chi-square test, and in-

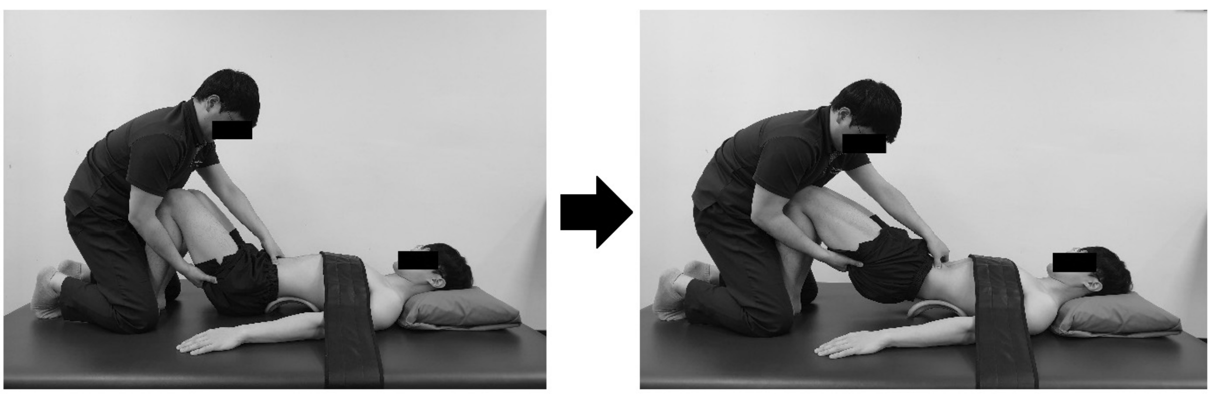

Figure 1. Intervention of lumbar stabilization training program

dependent t-test to determine the differences between groups. Shapiro-Wilk test was performed to test the normality of the study group and the control group. When the initial values of the study group and the control group achieve normality, a paired t-test was performed for the amount of change before and after the study to analyze the effectiveness within the two groups, and the amount of change before and after the intervention was an independent t-test to analyze the difference between groups. If normality was not achieved, Wilcoxon's test was performed on the amount of change before and after the study to analyze the effectiveness within the two groups, and the Mann Whitney test was performed on the amount of change before and after the intervention to analyze the difference between groups. The statistical significance level was set to .05.

Ⅲ. Results

Change in angle of lumbar lordosis in the lumbar alignment test, there was a significant difference in lumbar lordosis angle and trunk length before and after intervention in the Study group (p<.001), and in the Control group, there was a significant difference only in trunk length (p<.01). Comparison between the groups showed that there were significant differences in both lumbar lordosis angle and trunk length (p<.05) (Table 2.). Change in muscle activation in the muscle activity test, there was a significant difference in the erector spinae muscle and the hamstring muscle before and after intervention in both the Study group and the Control group (p<.01). Comparison between the groups also showed a significant difference in the erector spinae muscle (p<.05) and the hamstring muscle (p<.01) (Table 3.). Change in gait in the gait test, there were significant differences in gait velocity, cadence, and stride length before and after intervention in the Study group (p<.01). Between groups, there were significant differences in gait velocity and stride length (p<.05) (Table 4.).

Ⅳ. Discussion

This study investigated the effects of lumbar stability training on lumbar alignment, muscle activity, and gait in stroke patients. Previous studies reported a lumbar lordosis angle range of 33 ° ~37° measured using a flexible ruler in the general population, and with reference to this range,[16] the participants of this study have greater lumbar lordosis angles compared to the general population. In this study, strapping a belt around the upper trunk to suppress compensation during lumbar stability exercise enabled a selective

Table 2. Comparison of lumbar alignment between group

Variables		Study group (n=15)	Control group (n=13)	*t*	*p*
lordosis angle (°)	Pre	40.69±1.72a	39.63±2.11		
	Post	39.19±1.45	38.98±1.52		
	Change	-1.50±0.57	-0.64±1.20	-2.348[c]	0.032
	t	-10.204b	-1.934		
	p	.000	0.077		
Trunk Length (cm)	Pre	53.07±1.67	53.08±1.93		
	Post	54.40±1.40	53.76±1.74		
	Change	1.33±0.90	0.69±0.63	-2.15	0.041
	t	5.739	3.952		
	p	.000	0.002		

Note. [a]mean±standard deviation, [b]paired t-test, [c]independent t-test

Table 3. Comparison of muscle activation between groups

(unit : %RVC)

Variables	Study group (n=15)			Control group (n=13)			z (p)
	pre	post	*Change*	pre	post	*Change*	
RA	123.37±43.88[a]	121.34±41.95	-2.03±20.42[b]	114.72±29.12	110.25±24.59	-4.47±26.61	-.714 (.475)[c]
QF	105.22±10.67	108.44±21.48	3.21±19.54	91.66±25.4	95.27±21.94	3.60±5.79	2.530 (.596)
ES	142.52±43.09	181.98±34.9	39.47±19.58*	141.44±24.03	166.07±21.48	24.63±11.68*	2.603 (.009)
HS	135.07±19.75	179.42±27.45	44.35±12.19*	132.97±28.93	164.00±26.05	31.03±5.57*	2.787 (.004)

Note. RA: rectus abdominis, QF: quadriceps femoris, ES: erector spinae, HS: hamstring
[a]mean±standard deviation, [b]Wilcoxon signed-rank test, [c]Mann-Whitney U test.

Table 4. Comparison of 10MWT between groups

Variables		Study group (n=15)	Control group (n=13)	z	p
Gait speed speed (m/sec)	Pre	0.44±0.06[a]	0.43±0.05	-2.612[c]	0.009
	Post	0.51±0.04	0.46±0.04		
	Change	0.07±0.05	0.03±0.03		
	z	-2.919[b]	-2.631		
	p	0.004	0.009		
Cadence (steps/min)	Pre	66.02±5.57	64.81±10.50	-1.405	0.16
	Post	68.55±4.50	66.50±11.20		
	Change	2.53±2.44	1.43± 1.22		
	z	-2.919	-2.831		
	p	0.004	0.005		
Stride length (cm)	Pre	61.88±25.48	60.36±23.29	-2.05	0.04
	Post	66.03±25.26	62.96±23.10		
	Change	4.15± 2.30	2.60± 2.75		
	z	-3.351	-2.726		
	p	0.001	0.006		

Note. [a]mean±standard deviation, [b]Wilcoxon signed-rank test, [c]Mann-Whitney U test

training of the lumbo-pelvic complex. By inhibiting the compensation of the upper trunk during pelvic tilt, the lumbar curvature was effectively adjusted to reduce the lordotic angle and increase the trunk height.

EMG findings showed that there were no significant changes in rectus abdominis activity after the experiment compared to the baseline, which can be understood based on previous results that the abdominal muscle contraction remains constant during a standing posture, which was the posture for measuring muscle activity, and that the lordotic angle in a standing posture is determined by the ratio of trunk flexor and extensor contraction as opposed to abdominal muscle contraction.[17)] Furthermore, our results are consistent with past findings that the erector spinae activity increased during arm elevation in order to correct the instability caused by a displacement of the center of mass.[18)] Our results were also in line with previous results that the hamstring muscles strongly contract to maintain balance when the center of mass is displaced, such as when reaching an object in front using the arms.[19] The lordosis device used in this study increased the hip flexion angle and lordotic angle compared to the general starting posture for bridge exercise. This led to greater changes in the length of the erector spinae and hamstring muscles, and because greater changes in muscle length more effectively activates the muscle spindles, it would have led to increased erector spinae and hamstring activities.

A prior study reported that lumbar stabilization training, such as bridge exercise, effectively controlled gait instability by improving trunk muscle coordination and thus increased gait speed and cadence, and this was consistent with our findings.[20] Another study observed that trunk training facilitated arm and leg movement by improving trunk stability, which in turn led to improved dynamic balance, and this was also consistent with our results.[21] As reported that lumbar stability training reduces excessive lordotic angles in stroke patients and improves weight shift on the affected side as a result of increased trunk and pelvic stability,[22] we observed that our intervention improved weight shift in the affected side and thus lengthened the stance phase in the affected side during walking, which led to increased swing phase in the unaffected side, thereby increasing stride length.[23]

In essence, lumbar stability training improved lumbar alignment, erector spinae and hamstring activities, gait speed, and stride length in stroke patients, and these results suggest that lumbar stabilization training through lumbar lordosis control may also be effective as the conventional physical therapy in improving postural stability and ambulation in stroke patients. This study has a few limitations. First, the sample only consisted of stroke patients of B hospital in Seongnam, Gyeonggi, who meet the inclusion criteria, so the results cannot be generalized to the entire stroke patient population. Second, due to the nature of inpatients of a long-term care hospital, it was difficult to control patients' treatment and daily lives other than the intervention program. Third, surface EMG was measured only in a single position (standing), and the unaffected side was not measured. As a result, we could not analyze the symmetry of muscle activities between the affected and unaffected sides or the flexor and extensor activity ratio. In the future, more participants will be needed to generalize the results of the study, and more detailed analysis of factors affecting the lumbar stability and the factors influencing them will be needed. A reasonable assessment tool is needed.

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