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Effects of Seated Exercise of Thoracic and Abdominal Muscles on Upper Extremity Function and Trunk Muscles Activity in Patients with Chronic Stroke

Background: Weakness of the abdominal and mid thoracic muscles the lead to thoracic kyphosis of stroke patients. The trunk muscles activity of stroke patients is significantly related to upper extremity.
Objectives: To investigate the effect of seated exercise of thoracic and abdominal muscles on upper extremity function and trunk muscles activity in stroke patients.
Design: One-group pretest-posttest design.
Methods: A total of 27 stroke patients were recruited. All stroke patient were given seated abdominal exercise (posterior pelvic tilt exercises) and thoracic exercise (postural-correction exercise). All exercises were conducted for 30 minutes, three times a week for four weeks. The manual function test (MFT) and electromyography (EMG) were measured, and EMG electrodes were attached to thoracic paraspinal muscles and lower rectus abdominal muscles. EMG signal is expressed as %RVC (reference voluntary contraction).
Results: Experimental group showed significant increases in abdominal muscles, paraspinal muscles activity and MFT total score, items of arm motion (forward elevation of the upper extremity, lateral elevation of the upper extremity, touch the occiput with the palm) in MFT after four weeks.
Conclusion: These results suggest that, in stroke patients, seated exercise of thoracic and abdominal muscles contribute to improve trunk muscles activity and upper extremity function in stroke patients.

Keywords: *Abdominal muscles; Seated exercise; Stroke; Thoracic paraspinal muscles; Upper extremity*

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INTRODUCTION

Stroke is a disease that causes 30 deaths per 100,000 people due to cerebral infarction and brain hemorrhage (primary, subarachnoid hemorrhage).[1,2] In strokes that result in irreversible physical disability, most surviving patients suffer from hemiparesis. Functional impairment of stroke patients with hemiparesis is closely related to the extent of trunk dysfunction, followed by arm dysfunction.[3] Problems with arm function that typically appear after stroke include paresis, reduced dexterity, abnormal muscle tone, sensory deficit,[4] and musculoskeletal problems including pain.[5] For stroke patients, trunk support devices improve arm function.[6] Seated trunk rehabilitation is recommended for trunk control and arm function.[7-10]

For independent living skills, sitting postural control is one of the important prognostic indicators of functional outcome in stroke patients, and restoration of sitting postural control is an important goal for rehabilitation after stroke.[11]

When sitting, trunk postural control depends on spine and pelvic alignment.[7,12] Because of postural asymmetry, stroke patients exhibit forward head posture in relation to thoracic kyphosis in sitting position.[13] Postural asymmetry after stroke may result from weakness of thoracic extensor muscles and lumbar flexor muscles.[12] This postural disorder is described as upper or lower cross syndrome.[14] The upper cross syndrome is characterized by increased thoracic kyphosis (hunching) with weak lower and middle trapezius, and the lower cross syndrome by increased anterior tilt due to the weakness of abdominal muscles.[14]

Taping has been used to decrease thoracic kyphosis and facilitate abdominal muscles in stroke patients with this postural disorder.[12,15] Taping has the advantage of aligning the joints and improving muscle re-education, but does not provide strength.[16] Trunk exercise improves trunk muscle activity.[17] The seated exercise program for thoracic muscles conducted in this study was developed to ensure proper alignment of the neck and waist through the straightening of the middle spine area (scapular retraction).[18] Seated exercise of abdominal muscles can promote abdominal muscle contraction through posterior pelvic tilt, which facilitates lower abdominal contraction among upper abdominal and lower abdominal muscles.[19,20] The purpose of this study was to find a program wherein the thoracic spine and abdominal muscles could be exercised in a sitting position, thereby improving torso activity and arm function.

SUBJECTS AND METHODS

Subjects

The study was conducted at the rehabilitation hospital in Gyeonggi-do. Twenty-seven stroke patients selected by screening were evaluated at baseline and after four weeks of intervention.

Subjects were included if they had a score of 24 or higher on the mini-mental state examination (Korean version), ability to sit independently (static balance point on the trunk impairment scale 5 or more), a score of 1+ or less on the modified Ashworth Scale (MAS), and a first stroke that had occurred more than 6 months previously. Before the initial evaluation, the researcher explained to the purpose and method of the study to the study subjects. All subjects agreed to participate in the study.

Subjects were excluded if they were below Stage 4 on the Brunnstrom recovery scale, if they had been diagnosed with other neurological diseases such as Parkinson's disease, Huntington's disease or brain tumor, or if the expert judged that participation in the study was impossible. Table 1 shows the general characteristics of the study subjects.

Table 1. General characteristics (Mean±SD)

Classification	Experimental groups (n=27)
Gender (male/female)	19/8
Paretic side (left/right)	7/20
Type (infarction/hemorrhage)	16/11
Stroke duration (month)	10.96 ± 3.57
K-MMSE (point)	25.81 ± 2.51
Age (years)	61.70 ± 11.56
Height (cm)	164.85 ± 6.81
Weight (kg)	71.04 ± 8.04

K-MMSE: Korean - version of mini mental state examination

Study design

This was a single group open intervention study with outcome assessments by a therapist who did not have detailed knowledge of the study. The required sample size (G* Power 3.1.9.2, Germany) was estimated using effect size .80, significance level .05 and power .80, and twenty-seven subjects were admitted to allow for dropouts. The intervention was seated exercise of thoracic and abdominal muscles, with outcomes evaluated by testing arm and trunk muscle function.

The exercise was designed with the advice of a professor of nursing and a professor of physical therapy.

Experimental procedure

All participants in this study were either admitted to a rehabilitation hospital or undergoing outpatient treatment. The intervention was conducted by 5 neurological physiotherapists with at least 3 years of experience, and the researcher supervised the intervention. The exercises were conducted for 30 minutes, three times a week for four weeks. At the beginning of each session, subjects were seated at the treatment table with hip and knee joints in 90° flexion.

Thoracic exercise method

The thoracic exercise was performed with the subject's elbow extended and shoulder in external rotation (Figure 1). If this position could not be achieved in the affected arm, the therapist assisted the palm to reach the treatment table by taking the subject's shoulder external rotation, elbow extension, and wrist extension postures. The other arm was placed in the same posture. The therapist kept the subject's arm rotated externally and induced mid-thoracic region extension (scapular retraction). When this posture was achieved, the chin was drawn forward, and the patient directed to inhale deeply and exhale slowly.[18] The thoracic exercise was maintained for 30 seconds and followed by a 30 second rest (1 set). Fifteen sets were performed over 15 minutes.

Pelvic tilt exercise method using a smartphone

Abdominal and posterior tilt exercises were performed using a smartphone inclinometer (Clinometer).[21–23] After palpating anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS) and marking the tape between them, the maximum pelvic anteroposterior tilt was measured using the inclinometer (Figure 2). The points at 50% of maximum anterior and posterior tilt from the neutral position were set, and the pelvic posterior tilt exercise involved movement from less than 50% of the anterior pelvic tilt to more than 50% of the posterior pelvic tilt. This exercise was maintained for 30 seconds and followed by a 30 second rest (1 set). Fifteen sets were performed over 15 minutes.

Outcome Measures

All subjects in this study were evaluated at baseline and after 4 weeks of intervention. All evaluations were evaluated by a physical therapist with at least 8 years of physical therapy experience.

Figure 1. Thoracic exercise method

Figure 2. Pelvic tilt exercise method using a smartphone

Manual function test (MFT)

A MFT comprising assessment of arm motion and manipulative activity was performed.[24] Arm motion testing included four components: forward elevation of the upper extremity (Task FE), lateral elevation of the upper extremity (Task LE), "touch the occiput with the palm" (Task PO), and "touch the dorsum with the palm" (Task PD). Manipulative activity testing included grasp and pinch, and activities involving both arm and hand ("carry a cube" and "pegboard"). All components were measured on a four point scale (1–4), except for grasp (1–3 points), pinch grasp (1–3 points), and "pegboard" (1–6 points).The higher the score (maximum 32 points), the better the arm function. This test has been reported as very reliable.[25]

Trunk muscle activity

Electromyography (EMG; Wave–Wireless EMG, Cometa, Italy) was used to evaluate the subject's trunk muscle activity. Sampling was 2000 Hz, bandpass filtering was 10–200 Hz, and EMG signals were processed as Root Mean Square (RMS) and calculated as % Reference voluntary contraction (%RVC). First, RMS values of midthoracic paraspinal, and rectus abdominis EMG signals were extracted while in slumped sitting posture for 5 seconds. Second, RMS values of midthoracic paraspinal and rectus abdominis EMG signals were extracted while expiring for 5 seconds sitting upright. In the rectus abdominis EMG electrodes umbilical region, it was attached to the paretic side 2 cm and the upper 2 cm. The midthoracic paraspinal muscles EMG electrodes were attached to the paretic side paraspinal muscles of T6.

Statistical Analyses

The data were statistically analyzed using SPSS 21.0 software (IBM Corp., Armonk, NY, USA). Descriptive statistics were used for the general characteristics of the subjects. The normal distribution of data was confirmed by the Shapiro–Wilk test. The muscle activity changes were analyzed using Student's t–test for paired values. The MFT changes were analyzed using the Wilcoxon signed rank test. A statistical significance level of .05 was used.

RESULTS

Changes in MFT and trunk muscle activity

After four weeks of seated exercise of thoracic and abdominal muscles, the experimental group experienced

Table 2. MFT comparison of pre and post intervention (Mean±SD)

Classification	Experimental group (n=27)		Z	P
	Pre–test	Post–test		
Forward elevation of the upper extremity	2.04 ± .76	2.33 ± .68	–2.828	.005**
Lateral elevation of the upper extremity	1.81 ± .68	2.07 ± .62	–2.646	.008**
Touch the occiput with the palm	1.74 ± .71	2.07 ± .68	–3.000	.003**
Touch the dorsum with the palm	1.70 ± .67	1.81 ± .62	–1.732	.083
Grasp	1.52 ± .80	1.59 ± .84	–1.414	.157
Pinch grasp	1.37 ± .93	1.41 ± .89	–1.000	.317
Carry a cube	1.00 ± 1.07	1.04 ± 1.06	–1.000	.317
Pergboard	.74 ± .81	.78 ± .80	–1.000	.317
Manual functional test (total point)	11.93 ± 5.99	13.11 ± 5.42	–3.330	.001

*$P<.05$, **$P<.01$

Table 3. Trunk muscles activity comparison of pre and post intervention (Mean±SD)

Classification	Experimental group (n=27)		t	P
	Pre–test	Post–test		
Latissimus dorsi muscle % reference voluntary contraction	99.43 ± 13.16	105.05 ± 16.93	–2.514	.018*
External oblique abdominal muscle % reference voluntary contraction	105.13 ± 26.32	113.36 ± 27.51	–2.403	.024*

*$P<.05$.

significant improvements in the midthoracic, paraspinal, and rectus abdominis %RVC and MFT total scores, forward elevation of the upper extremity (Task FE), lateral elevation of the upper extremity (Task LE), and "touch the occiput with the palm" (Task PO) ($P<.05$) (Tables 2 and 3). However, there was no significant change in "touch the dorsum with the palm" (Task PD), "grasp, pinch grasp, carry a cube", and "pegboard" items ($P>.05$).

DISCUSSION

The stroke patients participating in present study showed a significant increase in MFT total score after seated exercise of thoracic and abdominal muscles. MFT items showed a significant increase in Task FE, Task LE, and Task PO items.

The back muscle taping applied to stroke patients significantly increased the MFT total score from[11,30] points to 13.00 points.[8] The back muscle taping could be spine corrected via trunk extension, which increased the MFT by placing the scapula in the optimal position on the ribcage through kinematic changes of the scapulothoracic joint. However, the previous study presented only the MFT total score, so the specific difference was not known. To perform Task FE, Task LE, and Task PO, shoulder flexion movements, abduction movements, and external rotation movements are required, respectively. Patients with stroke usually have upper limb disability, due to spasticity, joint dislocation, and pain,[5] and shoulder internal rotation position.[26] The shoulder internal rotation position can develop into contracture, but the 30–minute external rotation position can prevent contracture.[26,27] In the seated exercise of thoracic muscles conducted in this study, maintained shoulder external rotation is the basic position.[28] The thoracic extension and chin tuck positions performed from this position create an upright position.[18,29] Seated thoracic exercise is thought to improve pectoralis major muscles and improve MFT by promoting external rotator muscles.

The stroke patients participating in this study showed a significant increase in midthoracic paraspinal and rectus abdominis muscle activity after seated exercise of thoracic and abdominal muscles. The trunk exercise, which consisted of curl up, abdominal hollowing, bridge, and quadruped exercise, showed no significant difference in stroke abdominal muscles activity.[30] The difference between previous studies and present studies is considered to be a difference in the EMG signal collection method. In previous studies, % maximal voluntary isometric contraction (%MVIC) was measured in abdominal muscles, and %RVC was measured in erector spinae because %MVIC measurement was difficult. In this study, %RVC was measured for both muscles. In addition, truncal exercises did not significantly increase the lumbar erector spinae %RVC.[30] In this study, thoracic paraspinal muscle %RVC was measured. Therefore, even for the same abdominal exercise, differences may occur depending on the EMG measurement method and the measurement site.

In present study, because seated exercise of thoracic muscles can increase lumbar lordosis, we tried to reduce stress on the lumbar spine by increasing intra-abdominal pressure through expiration.[18] Rectus abdominis activity is thought to have increased because the seated abdominal exercise involves lower abdominal contraction through posterior pelvic tilt.[20,31]

The pelvic tilt exercise performed in a similar way to this study improved the range of pelvic tilt and joint position sense.[23] In addition, pelvic tilt exercise using pressure-based visual biofeedback improved gait speed, stride length, and pelvic tilt range of patients with Alzheimer's disease.[22] The improvement of postural control through pelvic tilt exercise supports the results of present study.

The strength of present study was that all of the stroke patients who participated in present study were those who were using wheelchairs, so they were patients living in a sitting position. Therefore, this seated exercise confirmed that the thoracic and abdominal muscle activity and upper extremity function of the stroke patients with weakened mid thoracic and abdominal muscles were improved.

Despite the above results, this study has some limitations. First, it is difficult to generalize because the subjects who participated in this study withal had mild to moderate stroke. Second, since the scores for each MFT item evaluated in this study could not accurately confirm the change in the range of motion of the joint, it is necessary to check other evaluations for the arm function evaluation. Third, since the single group design has only the experimental group, the internal validity may be low. It is expected that the effects of seated exercise of thoracic and abdominal muscles will be clarified in larger test which include other trunk exercise[32] or arm training[33].

CONCLUSION

The seated exercise of thoracic and abdominal muscles can improve upper extremity function and trunk muscle activity. Thus, seated exercise of thoracic and abdominal muscles would result in better outcome of trunk muscles activity and upper extremity function for stroke patients.

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