

Effects of the Abdominal Drawing-in Maneuver and the Abdominal Expansion Maneuver on Grip Strength, Balance and Pulmonary Function in Stroke Patients

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Purpose: The purpose was to determine whether the application of the abdominal drawing-in maneuver (ADIM) and abdominal expansion maneuver (AEM) to stroke patients would affect their trunk stability, balance, pulmonary function, and grip strength.

Methods: The subjects were 36 stroke patients who were randomly and equally assigned to an ADIM group (n = 12), an AEM group (n = 12), and a control group (n = 12). The intervention was applied to each group three times per week, 30 minutes each time, for four weeks. Outcome measures were grip strength, modified functional reach test (mFRT) and pulmonary function. Pulmonary function was measured force expiratory volume at one second (FEV1), forced vital capacity (FVC), FEV1/FVC and peak expiratory flow (PEF) values.

Results: The results of the three groups showed statistically significant improvements in grip strength. The AEM group showed significantly greater differences in grip strength than either the ADIM group or the control group. In the anterior mFRT, the ADIM group showed significant improvements than the control group. The ADIM and AEM groups were shown statistically significant greater improvements in PEF between the baseline and post-intervention and the post-analysis revealed that the AEM group showed significantly greater improvements than the control group.

Conclusion: The results of this study indicate that the ADIM and AEM were effective in improving the PEF of pulmonary function. The ADIM was more effective than AEM in trunk stabilization.

Keywords: Stroke, Abdominal drawing-in maneuver, Abdominal expansion maneuver

INTRODUCTION

Stroke is the main cause of chronic disability in adults. About 50-70% of affected individuals recover functional independence, and within six months, about 50% of these patients present hemiplegia or hemiparesis.¹ The respiratory system on stroke patients depends on the structures affected by the lesion. The maintenance of normal respiration depends on the intact functional components of the neuromuscular system.² Ventilatory disturbances occur when the diseases affect the nervous system, the muscle routes or the thoracic cage, despite the lungs being normal.³ The loss of selectivity of the trunk muscle groups, which occurs in stroke patients, means that they become unable to stabilize their column in the erect position.¹

Normally, the deep abdominal (transverse abdominal; TrA, internal oblique; IO) muscles, in coordination with the deep multifidus muscle, play a central role in lumbar spinal stiffness, contributing to core stability.⁴ The TrA muscle is preferentially activated to maintain postural stability in the motor control of the trunk muscles during limb movement.^{5,6}

The secondary problem caused by a stroke is the decrease in the rib cage activity and the electrical activity by the result of the muscles disuse and the limited activity. In addition the problem causes the decrease in the cardiorespiratory control and the capacity of the oxygen transfer system, and consequently, it creates the oxygen debt resulting in the weakness of aerobic exercise capacity affecting the cardio-pulmonary function. The pulmonary function weakness

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significantly affects the maintenance of life, and it is an essential element to be maintained for improving the physical function and the quality of life in stroke patients.² In addition, the cardio-pulmonary function affects the trunk control which does an important role in the maintenance of standing position, body movements, balance and stability required for activities of daily living (ADL).

A symptom of the stroke is the reduction of the motor control for which the co-contraction of the muscles involved in the respiratory circulation is essential. The damage in respiratory function induces the dysfunction of the trunk posture and the weakness of the respiration muscle.⁷ In addition, the damage causes the decrease in up-down movement of the diaphragm over voluntary breathing and hyperpnea, which results in a continuous increase in the affected side diaphragm.⁸

Normally, the deep abdominal muscles, in coordination with the deep multifidus muscle, play a central role in lumbar spinal stiffness, contributing to core stability. The TrA muscle is preferentially activated to maintain postural stability in the motor control of the trunk muscles during limb movement.⁹ To improve the breathing ability of stroke patients, aerobic exercises and whole body muscle exercises have been attempted, and it has been reported that the application of the both methods improves the functional muscle strength and the level of metabolism.¹⁰ In addition, a study of hemiparesis patients shows that the weakening of the exhalation and inhalation muscles reduces the lung capacity and increases the lung residues. The study also shows significant decreases in maximum breath pressure in comparison with the control group.¹¹ Hodges and Gandevia¹² show that several respiratory system complications can be prevented when if inspiratory muscles in the abdomen and thoracic cage are reinforced which improves the ability of airway clearance ability.

The function of upper limb and hands is indispensable for ADL and independent daily life. The function should guarantee the ability of posture control against gravity and the trunk stability that can react efficiently to the distal activity. However, the disability of the upper limb due to hemiplegia is a significant obstacle for ADL, and it results in the decrease in the trunk stability and its rotation ability. This defect causes inefficiency in the movements of legs and arms, implying that the co-contraction of the muscles adjacent to the trunk is essential.¹³

The abdominal draw-in maneuver (ADIM), which is a common

methodology in clinics, is a trunk stabilization exercise in which TrA is selectively contracted earlier than other muscles in the surface such as the rectus abdominis, external oblique muscle (EOM), and internal oblique muscle (IOM). The ADIM has been widely used to improve the instability in lumbo-pelvis through neuromuscular rehabilitation of the transversus abdominis and IOM.¹⁴ To precisely carry out ADIM, a pressure biofeedback unit or visual feedback based on ultrasound images are used. These methods enable to check accurately the contraction of abdominal muscles. Recently, the abdominal expansion maneuver (AEM) has been studied as a method of respiration muscle strengthening and deep spinal stabilization respiration muscles, which are elements of the integrated spinal stabilizing system.¹⁵ Kolar¹⁶ shows that, if the navel is maintained in a front-downward while thoracic cage is not extended and the lower abdomen is expanded, the AEM can increase the co-contraction of the deep spinal stability muscle and intra-abdominal pressure (IAP), consequently ensuring the stability of lumbo-pelvic posture.

While the ADIM has been studied in the cases of strokes, the AEM has not been considered to study trunk stability and balance applying trunk stabilization exercises. Furthermore, there has not been a study applying the AEM as a respiration exercise to stroke patients although AEM has been studied for athletes or back pain patients.¹⁷ Therefore, this research is going to study how the application of the ADIM and AEM to stroke patients would affect the trunk stability, balance, pulmonary function, and grip strength.

METHODS

1. Subjects

This study was performed in the neurorehabilitation center in Deajeon, Republic of Korea. Thirty-six hospitalized stroke patients agreed to participate in this study after learning about the context of this study. The selection criteria were those older than 6 months, were diagnosed with stroke, could stand independently, and who had no cognitive impairment based on Mini-Mental State Examination (MMSE) results. Exclusion criteria included neurological problems apart from stroke, orthopedic impairments, and abnormal senses of vision and hearing. Participation in the study was voluntary and patients fully understood the purpose of the study. All participants were informed about the tests and the use of the results

and were asked to sign a written informed consent statement. The study was approved by Daejeon University's institutional review board and follows the principles outlined in the Declaration of Helsinki.

2. Interventions

This study was a single-blind randomized controlled trial and was conducted with stroke patients for 4 weeks. All the enrolled patients were randomly assigned by the selection of an opaque closed envelope from envelopes in which the group assignment was written. General surveys of a subject and pre-tests were conducted. The ADIM and AEM group performed 4 weeks of training thrice a week for 30 minutes. All subjects, including those in the control group, underwent a traditional physical treatment 15 times a week, for 60 minutes per session, over the course of 4 weeks. After 4 weeks, the final evaluation was performed, and each measurement was evaluated respectively. For exact execution of the therapy, physical therapists trained the subjects enough to be well-informed of the respiration exercise before intervention.

1) ADIM

Physical therapists in clinical practice assessed contraction of the TrA muscle during the draw-in maneuver by palpating the abdominal wall, placing a pressure biofeedback unit (Chattanooga group Inc, USA) under the abdominal wall in a prone position. It is inflated for the pressure gauge to go up to 70 mmHg, and then the subjects are trained to pull their abdomen toward spine until the pressure gauge, which is connected to the pressure biofeedback unit, to decline down around 6-10 mmHg. Subjects were then taught to preferentially activate their TrA by performing the ADIM with visual feedback from the pressure biofeedback unit.¹⁸

2) AEM

During the inspiratory phase of tidal breathing, the descent of the diaphragm increases the IAP, given that that the abdominal wall and pelvic floor maintain their respective tension. The lateral lower ribcage during the inspiratory phase of tidal breathing was expanded in a lateral direction, and minimal superior movements of the chest. Then the lower abdomen was expanded, and the navel was moving in an anterior-caudal (symphysis pubis) direction.¹⁵

3. Outcome measures

The modified functional reach test (mFRT) screening tool was measured the limits of stability in anterior and lateral directions. Subjects were sitting on chair their backs against the wall when the mFRT was performed. The stroke patients' affected side was tested, and their trunks were moved as far as possible without lifting their feet. Then, the acromion's distance was measured. As was the case for the mFRT, a physical therapist was on standby next to the participants while they were getting their balance assessed to increase safety. The average value was obtained after three measurements, and an inter-rater reliability from $r = 0.92$ to $r = 0.97$ was high.¹⁹

Hand strength isometric force was measured with the digital smedley spring dynamometer (Baseline, USA). This digital strain-gauge dynamometer displays force measurements to the nearest 0.2 kg to a maximum of 90 kg. The following standardized testing position for measuring grip strength was used, as advocated by the American Society of Hand Therapists: the participant is seated with shoulders adducted and neutrally rotated, elbow flexed at 90 deg, wrist between 0 and 30 deg extension, and between 0 and 15 deg ulnar deviation. It is measured three times each in the order of non-affected side and affected side, and the average of them is used. The average value was obtained after three measurements, and an inter-rater reliability of $r = 0.98$ was high.²⁰

Pulmonary function tests were performed by the researchers at least three times for each subject in a sitting position; Spirobank G (Medical International Research, Rome, Italy) spirometer and with a different mouthpiece for each subject. A practical presentation about the test and the way it is done was performed for the subjects before the test. The tests were performed according to the test procedure of The American Thoracic Society. Force expiratory volume at one second (FEV1), forced vital capacity (FVC), FEV1/FVC and peak expiratory flow (PEF) values were measured three times and the best result of the three measurements was recorded.²¹

3. Statistical analysis

The data collected in this study were analyzed using Windows SPSS version 18.0. Means and standard deviations were calculated for the general characteristics of the study subjects using technical analysis. Tests of homogeneity were performed using a Chi-square test. A paired t-test was used to discover the periodic measurement change of the before and after for each group. A one-way ANOVA was used

to discover the differences in the changes before and after interventions. When differences were found, the Scheffe's method was used as a posteriori test. All data were statistically significant at $\alpha = 0.05$.

RESULTS

No significant differences were observed among the three groups in terms of age, gender, body weight, height, time since stroke, affected side, and MMSE ($p > 0.05$). Outlines the general characteristics of the subjects (Table 1).

The results of ADIM, AEM, and control groups showed statistically significant improvements in affected and non-affected side grip strength between the baseline and post-intervention ($p < 0.05$).

Table 1. General characteristics of subjects

	ADIM (n= 12)	AEM (n= 12)	Control (n= 12)	χ^2/F
Age (year)	61.0±11.9	65.5±10.8	66.0±6.5	0.56
Gender (male/female)	5/7	6/6	5/7	0.74
Weight (kg)	61.6±8.9	65.4±14.8	59.2±10.7	0.59
Height (cm)	158.4±9.1	162.7±12.7	163.8±10.3	0.57
Time since stroke (month)	13.0±6.6	10.1±2.4	11.0±4.3	0.51
Affected side (left/right)	4/8	5/7	5/7	0.69
MMSE	28.3±1.9	28.1±1.9	27.5±2.2	0.74

ADIM, abdominal draw-in maneuver; AEM, abdominal expansion maneuver; MMSE, mini-mental state examination.

Table 2. Changes of grip strength and mFRT

		ADIM (n= 12)	AEM (n= 12)	Control (n= 12)	F
Affected side grip strength (kg)	Pre-test	12.24±6.22	6.51±7.00	8.46±6.97	1.422
	Post-test	14.56±5.14	8.83±9.02	9.39±6.58	1.592
	t	-3.402*	-2.503*	-1.573*	
	Change	2.33±1.93	2.31±2.45	0.93±1.66	1.247
Non-Affected side grip strength (kg)	Pre-test	20.59±6.98	17.70±11.55	21.19±9.56	0.286
	Post-test	21.34±6.39	22.93±9.84	21.79±8.11	0.069
	t	-1.930	-2.372*	-1.911*	
	Change	0.76±1.10	5.23±5.83**	0.60±0.89	4.635*
Anterior mFRT (cm)	Pre-test	16.16±11.67	13.76±8.32	19.00±7.94	0.571
	Post-test	31.12±8.01	25.41±15.34	21.45±7.55	1.671
	t	-4.041*	-2.436*	-4.353*	
	Change	14.96±10.47	11.65±12.65	2.45±1.59	3.826*
Lateral mFRT (cm)	Pre-test	10.06±4.72	7.77±4.13	12.39±4.55	1.977
	Post-test	16.74±6.42	13.74±6.42	15.09±7.58	0.205
	t	-1.385	-3.753*	-1.573	
	Change	6.68±13.63	5.97±4.21	2.70±4.86	0.453

*Significant difference with in groups; †Significant ADIM group; ‡Significant control group.

ADIM, abdominal draw-in maneuver; AEM, abdominal expansion maneuver; mFRT, modified functional reach test.

The post-analysis revealed that the AEM group showed significantly greater differences in grip strength than either the ADIM group or the control group ($p < 0.05$).

The affected anterior mFRT showed statistically significant increases in all three groups after the intervention ($p < 0.05$), and the ADIM group showed significantly greater improvements than the control group ($p < 0.05$). The AEM groups showed statistically significant increases in the affected side lateral mFRT between their baseline and post-intervention values ($p < 0.05$). However, there no inter-group differences in affected side lateral mFRT ($p > 0.05$) (Table 2).

Results of the pulmonary function tests, all three groups were not showed statistically significant improvements in FVC, FEV1, and FEV1/FVC between the baseline and post-intervention ($p > 0.05$). However, the ADIM and AEM groups were showed statistically significant improvements in PEF between the baseline and post-intervention ($p < 0.05$) and the post-analysis revealed that the AEM group showed significantly greater improvements than the control group ($p < 0.05$) (Table 3).

DISCUSSION

This study compares the effects of the ADIM and AEM on the balance, the pulmonary function, and upper extremity function of stroke patients. The before-after intervention study, after four-week

Table 3. Changes of respiratory function

		ADIM (n=12)	AEM (n=12)	Control (n=12)	F
FVC (L)	Pre-test	2.18±0.85	1.86±0.79	1.83±0.51	0.571
	Post-test	2.11±1.26	2.15±1.06	2.22±0.98	0.014
	t	0.164	-0.984	-1.259	
	change	-0.07±1.20	0.29±0.78	0.39±0.87	0.480
FEV1 (L)	Pre-test	2.00±0.79	1.79±0.81	1.79±0.50	0.230
	Post-test	2.01±0.79	2.17±0.98	2.06±0.89	0.058
	t	-0.037	-1.521	-0.870	
	change	0.01±0.75	0.38±0.67	0.27±0.86	0.467
FEV1/FVC (%)	Pre-test	93.00±10.32	95.57±5.71	98.13±2.10	1.080
	Post-test	96.00±14.71	99.14±7.85	94.38±10.29	1.091
	t	-0.359	-1.431	1.084	
	change	3.00±23.62	4.14±13.21	-3.75±10.17	0.806
PEF (L/s)	Pre-test	4.58±2.29	4.53±2.94	3.73±1.85	0.319
	Post-test	6.40±2.27	7.72±3.21	3.54±1.03	5.664
	t	-2.272*	-4.590*	0.357	
	change	1.82±2.27	3.19±1.84 [†]	-0.18±1.42	6.172*

*Significant difference with in groups; [†]Significant difference with control group. ADIM, abdominal draw in maneuver; AEM, abdominal expansion maneuver; FVC, forced vital capacity; FEV1, force expiratory volume at one second; PEF, peak expiratory flow.

application of ADIM and AEM, shows that the improvement of mFRT in the ADIM group, the improvement of hand grip force and PEF in the AEM group are observed. However, FEV1/FVC of the control group after intervention in pulmonary function decreases as precedent researches, and PEF decreases unlike the precedent researches which do not show a significant increase in PEF. This means that the intervention for the decline of pulmonary function is required in the rehabilitation process of chronic stroke patients.²²

The expansion and contraction of the lungs are affected by the capacity of the thoracic cage, and determined by skeletal mobility, the elasticity of adjacent soft tissues, and the strength of respiration muscles.²³ In the case of stroke patients, the hypertension of trunk and the asymmetric arrangement accompany.²⁴ Diaphragm, pelvic floor, and TrA control IAP and provide the stability of lumbopelvic posture. Such intrinsic spinal stabilization muscles provide spinal stiffness, in the cooperation with IAP, though which spinal dynamic stability is improved. When the spinal stabilization exercise is applied, the method of pushing the abdomen out through abdominal breathing is used.²⁵ This method can do the co-contraction of the diaphragm and deep stability muscles and increase the intra-abdominal pressure if the navel is maintained in a front-downward while the thoracic cage is not extended and the lower abdomen is

expanded in the phase of inhalation.

The application of the ADIM in this study is carried out in the prone position using a pressure bio-feedback unit, which has been commonly considered to enhance the stability in the lumbo-pelvic region during lower and upper extremity exercises.¹² The ADIM has been applied to adult patients with core muscle instability in the prone position, and it has been reported that the thickness of TrA and IOM increased. Another previous study also shows that the ADIM increases the abdominal deep muscle activity of TrA and ADIM, and that the increased muscle activity is observed in the group applied with ADIM.¹⁸

After a stroke, the ability of a patient to maintain trunk control in sitting and standing positions is a fundamental skill for achieving autonomy in activities of daily living. The trunk control performance of patients soon after a stroke has been found to be closely associated with long-term functional improvement.²⁶ In the few weeks after stroke, there may be alterations to the muscular tonus and changes to the viscoelastic properties of muscles, causing contracture of the hemiplegic side, as well as rigidity of the competed thoracic, which interfere with the biomechanical functioning of the thorax and may lead to a loss in the ability and performance of the respiratory movements and trunk.²⁷ One study shows that the

changes in muscle elasticity and tension cause variations in the ability of respiration exercise due to the stiffness of the thoracic cage and the contracture of affected side a few weeks after stroke.²⁸ Therefore, it is suggested to provide the highly intensive intervention that can affect the cardio pulmonary function after the diagnosis of stroke.²⁹ Based on these results, various studies for enhancing lung functions should be conducted continuously.

Jandt et al.²⁷ conducted a correlation study between respirator muscles, pulmonary function, and trunk control ability, and showed that the correlation ($r=0.426$, $p=0.054$) between the trunk impairment scale (TIS) and maximum inspiratory pressure is significant, but it is close to the level of significance. In addition, the correlation between TIS and maximum expiratory pressure is statistically significant. However, they showed that other indices of pulmonary function have nothing to do with trunk control, except the significant correlation between TIS and PEF. In this study, the change in the anterior mFRT in the groups of AEM and ADIM who do the breathing exercise is larger than the change of control group, and the change in the ADIM group shows statistically larger improvements compared with the control group. In addition, the change of PEF in the ADIM and AEM groups is larger compared with control group, which is following the results in the previous studies. This implies that, when a stroke patient does respiration exercise, not only conducting ADIM is effective for the trunk control ability, but also AEM has effects on the trunk control ability.

Spinal stabilization exercise has been developed for functional activity, and it contributes to the efficient control of physical movement.³⁰ Hand grip strength, which is a measure for forearm muscular strength, shows a high correlation with whole body strength, and the trunk muscles involved with the trunk stability affects not only the trunk movement but also the movement of legs and arms as a synergistic muscle.³¹

This study is carried out to suggest an efficient method for intervention of improving trunk stabilization, upper limb function, and pulmonary function. However, fifteen minutes as a duration of exercise is short to check the effects of the exercise, and there was a limitation in terms of accuracy in the breathing exercise through the AEM, while the breathing exercise using visual feedback through ADIM has been quantified. Therefore, future works for appropriate intervention period and the methodology for quantified AEM would be required.

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