

Effect of Respiratory Muscle Stretching on Pulmonary Function and Balance and Trunk Control Ability in Patients with Stroke

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Purpose: The current study aimed to examine the effects of respiratory muscle stretching on pulmonary function and balance and trunk control ability in patients with hemiplegic stroke. **Methods:** The participants were diagnosed with hemiplegic stroke. They were assigned to either the intervention group, which included those who performed respiratory muscle stretching, and the control group, which included those who did not perform respiratory muscle stretching. All participants performed a general therapeutic exercise. The intervention group performed respiratory muscle stretching in addition to the general therapeutic exercise 3 times a week for 8 weeks. Pulmonary function was assessed using forced vital capacity (FVC), forced expiratory volume in 1 second (FEV₁), FEV₁/FVC ratio, and peak expiratory flow (PEF). Balance and trunk control ability was evaluated using the Trunk impairment scale (TIS) and Timed Up and Go test (TUG). **Results:** The intervention group presented with significant improvements in FVC, FEV₁, and PEF after 8 weeks of exercise ($p<.05$). However, the control group did not ($p>.05$). The TUG and TIS parameters indicated significant functional improvement in the intervention and control groups. The intervention group had a higher pulmonary function than the control group. However, among all parameters, only PEF significantly differed between the two groups ($p<.05$). **Conclusion:** Respiratory muscle stretching has a positive effect on pulmonary function in patients with stroke.

Key words: Respiratory muscle stretching, Pulmonary function, Balance, Trunk control, Stroke

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I. Introduction

Stroke is a cerebrovascular disease that leaves chronic disabilities and places a physical and economic burdens on patients. The most common problems after a stroke include paralysis and impairment of sensory and motor skills, cognition, language, visual perception, and swallowing functions. Paralysis on one side of the body is the most frequent problem experienced by more than 80% of stroke patients(Nguyen et al., 2021). In addition, loss of muscle mass and limited physical activity pose significant barriers to activities of daily living.

The asymmetric trunk and mal-alignment due to hemiplegia consume inefficient energy and induce impairment in maintaining the center of gravity within the base of support, causing secondary disability of gait and balance control as well as impairment in activities of daily

living(Haruyama et al., 2017). Asymmetrical trunk movement is related to asymmetrical activation of respiratory muscles, which causes lack of trunk postural control(Terui et al., 2021).

Individuals with stroke commonly have altered breathing pattern(Lanini et al., 2003), decreased strength of the respiratory muscles (Menezes et al., 2016), and reduced activity of the paretic diaphragm(Khedr et al., 2000). Weakened intercostal muscles, diaphragm, and abdominal muscles activated asymmetrically, with decreased elasticity of paralyzed diaphragm result in insufficient ventilatory function, which negatively affects motor performance and function(Praud and Redding, 2019).

Respiratory problems can cause a vicious circle. such as respiratory muscles becoming shorter and weaker. Muscle stretching extends the connective, vascular, skin, and nervous tissues through mechanisms involving deformation

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and structural adaptation of the muscles generally used in activities of daily living (Galea, 2021; Stecco 2020). The increased risk of death due to respiratory complications due to neuromuscular disease may no longer be ignored, and the significance of respiratory rehabilitation is growing.

Respiratory training also helps stroke patients to increase muscle endurance, as well as respiratory strength and improve breathing ventilation (Lista-Paz et al., 2019; Wu et al., 2020). Respiratory muscle stretching has been suggested as an intervention that may reduce chest wall stiffness, consequently increasing its expansion and improving ventilation patterns in patients with chronic obstructive pulmonary disease (De Sa et al., 2017; Leelarungrayub et al., 2009). Moreno et al. (2007) noted that stretching to the trunk has a positive effect on the length-tension relationship, resulting in an increase in respiratory function and the strength of the respiratory muscles.

Research on respiratory training and respiratory muscle intervention for stroke is still insufficient compared to studies on patients with cardiopulmonary diseases or spinal cord injury who show direct respiratory problems. Previous studies examining the effects of respiratory training on stroke patients most have only focused on recovery of pulmonary function. Thus, it is also needed into how it affects balance, trunk control ability, as well as pulmonary function. The aim of this study was to examine the effects of respiratory muscle stretching on pulmonary function and balance, and trunk control ability in hemiplegic stroke patients.

II. Methods

1. Subjects

The study was conducted on patients with stroke at C rehabilitation hospital, Chungcheongnam-do. Study participation included a total of 20 patients who heard the purpose of the study and showed their intention to participate. The selection criteria were: (1) diagnosed with stroke at least 3 months ago, (2) able to walk independently or with an aid and walk at least 3 meters under supervision, (3) no cognitive impairment (score of 24 or more on the Korean version of the Mini-Mental State Examination

[K-MMSE]). This study received approval from the Sunmoon University Institutional Bioethics Committee prior to the experiment (SM-202101-001-2).

This study was single-blind and randomly assigning the intervention group and control group through a lottery method, and blinding patients to their allocated groups. During the training period, all groups applied existing therapeutic exercises consisting neurodevelopmental exercise therapy, mat training, and gait training, 5 times a week. The intervention group additionally performed respiratory muscle stretching for 15 minutes per session, three times a week for eight weeks. Before and after the intervention, all subjects were assessed for pulmonary function, balance, and trunk control.

2. Respiratory muscle stretching

Respiratory muscle stretching was performed on the trapezius, sternocleidomastoid, sternocleidomastoid, pectoralis major, and intercostal muscles by a physical therapist with at least 4 years of clinical experience. Stretching was applied based on passive and hold-relax stretching techniques to the bilateral trapezius, sternocleidomastoid, and pectoralis major muscles in the supine and lateral position. Each was passively stretched to full range of motion, held in the position with an isometric contraction for 5 seconds slightly below range, followed by 5 seconds of relaxation. Two sets of five repetitions were performed one minute apart for each muscle. The intercostal muscles were stretched in a side lying position during inspiration, and the ribs on both sides were checked during expiration.

3. Outcome measures

Pulmonary function was evaluated using Spirometry (PONY FX, COSMED, Italy). We evaluated the forced vital capacity (FVC), forced expiratory volume in 1 second (FEV₁), the ratio of forced expiratory volume for 1 second to forced vital capacity (FEV₁/FVC), and peak expiratory flow (PEF). The measurement was repeated three times until highly reproducible results were obtained, and the highest value was used. The timed up and go test (TUG), a test that quickly measures functional mobility and balance, was used to evaluate balance. To check trunk control ability,

balance and trunk coordination were measured and scored in the sitting position using trunk impairment scale (TIS).

4. Statistical analysis

The statistical package of social sciences (SPSS) software for Windows version 22.0 (IBM Corp) was used. A non-parametric paired samples t-test was conducted to resolve the differences between each group before and after the experiment, and an independent samples t-test with the Mann-Whitney U test was conducted to check the differences between the two groups. All data were reported as mean and standard deviation (SD), and the significance level was set at $p < .05$.

III. Results

General characteristics are shown in Table 1. The general characteristics of the subjects showed no significant differences between groups ($p > .05$).

The intervention group showed significant improvements in FVC, FEV₁, and PEF after 8 weeks. Conversely, the control group did not show any significant changes ($p > .05$) (Table 2). TUG and TIS results showed significant functional improvement in both groups ($p < .05$). Compared with the control group, the intervention group showed higher pulmonary function. Only PEF showed a significant

Table 1. General characteristics of the subjects

	Intervention group (n=10)	Control group (n=10)	<i>p</i>
Gender (M/F)	8/2	6/4	
Paretic side (R/L)	3/7	6/4	
Age (year)	53.16±11.07	55.85±8.93	0.517
Height (cm)	165.83±6.82	166.14±7.96	0.885
Weight (kg)	69.33±17.82	64.10±12.78	0.886
Onset duration (month)	14.66±4.96	14.40±4.21	0.943
MMSE-K (score)	28.00±4.96	26.85±2.19	0.348
Smoker /Non-smoker	4/6	5/5	
Smoking duration (years)	19.83±11.19	21.83±15.89	0.615

Table 2. Comparison of balance and trunk impairment scale

		Intervention group (n=10)	Control group (n=10)	<i>p</i>
FVC	Pre-test	2.42±0.81	2.06±0.53	
	Post-test	2.82±2.79	2.20±0.45	0.064
	<i>p</i>	0.005**	0.109	
FEV ₁	Pre-test	2.02±0.61	1.75±0.40	
	Post-test	2.53±0.73	2.00±0.56	0.074
	<i>p</i>	0.016*	0.241	
FEV ₁ /FVC	Pre-test	0.86±0.17	0.86±0.14	
	Post-test	0.89±0.12	0.92±0.22	0.082
	<i>p</i>	0.646	0.646	
PEF	Pre-test	3.79±1.36	2.99±0.68	
	Post-test	4.51±1.06	3.33±0.94	0.023*
	<i>p</i>	0.022*	0.074	
TUG	Pre-test	27.44±12.48	32.28±13.05	
	Post-test	23.04±10.70	28.20±12.01	0.307
	<i>p</i>	0.005**	0.017*	
TIS	Pre-test	12.20±2.74	11.50±2.20	
	Post-test	14.20±2.44	13.25±2.12	0.278
	<i>p</i>	0.004**	0.010*	

FVC: Forced vital capacity, FEV₁: forced expiratory volume in 1 second, FEV₁/FVC: the ratio of forced expiratory volume for 1 second to forced vital capacity, PEF: peak expiratory flow, TUG: Timed up and go test, TIS: Trunk Impairment Scale,

* $p < 0.05$, ** $p < 0.01$

difference ($p < .05$). The other values did not differ significantly ($p > .05$).

IV. Discussion

Poor coordination due to hemiparesis after stroke alters the breathing mechanisms along with physical imbalance, causing limitations in the individual's function and movement. This negatively impacts postural alignment, resulting in selective trunk muscle underactivity and rib instability (Iyengar et al., 2014). Therefore, it is essential to apply respiratory intervention to restore the reduced pulmonary function of stroke patients. This study aimed to investigate the effect of respiratory muscle stretching on patients with stroke suffering respiratory limitations similar

to those with restrictive lung disease.

In this study, the intervention group that performed respiratory muscle stretching showed improvements in FVC, FEV₁, and PEF. When the muscle is immobilized due to stroke paralysis, the number of sarcomeres decreases and the deposition of connective tissue increases owing to the modification of contractile proteins and mitochondrial metabolism, resulting in shortening of the muscle and limiting of thoracic movement(Mukund and Subramaniam, 2020; Cho et al., 2019). It is considered that stretching of the respiratory accessory muscles could increase the functional length of muscle and facilitate the interaction between actin and myosin, by that improving the compliance of the chest wall by relaxing the muscles that play a part in thoracic movements.

Wada et al. (2016) evaluated the effect of combining respiratory muscle stretching and aerobic exercise in COPD patients and secured that the respiratory muscle effort required to attain the same lung volume was reduced in the group that combined respiratory muscle stretching and aerobic exercise. According to a study by De Sa et al. (2017), comparing the effects of respiratory muscle stretching on electromyographic activity, a significant decrease in electrical activity of the upper trapezius and sternocleidomastoid was observed, along with a decrease in the respiratory rate and minute volume after respiratory muscle stretching(De Sa et al., 2017). De Andrade et al.(2005) reported that the EMG activity of muscles tends to decrease immediately after stretching, and the RMS ratio of the diaphragm was relatively larger. This result means that the application of muscle stretching leads to changes in the muscle fibers around the ribcage, resulting in an increase in the participation rate of the diaphragm and ribcage movement during breathing., supporting our study, which supports this study.

In this study, TUG and TIS showed significant improvement in all groups after 8 weeks, but there was no significant difference between groups was observed. A study by Hodges et al(2001) found that contraction of respiratory muscles is associated with trunk control and that motor neuron activity is organized to contribute to both postural maintenance and breathing during tasks requiring repetitive trunk posture changes. Jandt et al(2011) compared the associations between trunk control, respiratory muscle

strength, and pulmonary function in stroke patients and noted that consistent and statistically significant correlations were found between TIS and peak expiratory flow, and TIS and peak expiratory pressure. In the case of chronic spinal cord injury patients showing characteristics of restrictive lung disease, it was reported that inspiratory muscle performance was correlated with balance ability, and sitting balance ability could be partially predicted by respiratory function evaluation(Palermo et al., 2022). A study applying diaphragm stretching to cerebral palsy showed a significant increase in diaphragmatic mobility, lower and abdominal chest expansions(Bennett et al., 2021). This could be explained by stretching the respiratory muscles, which improves chest wall flexibility and improves diaphragm function, which helps with trunk stability.

In this study, both the intervention and control groups consistently received main exercise treatment such as strength, balance exercise, and gait training according to the patient's functional recovery status for 8 weeks, 5 times a week, so it was confirmed that functional balance and trunk control ability were improved. Many previous studies have proven that exercise therapy, including trunk stabilization exercises, in stroke patients helps in effective functional recovery in trunk control, sitting and standing posture balance, and mobility(Van Criekinge et al., 2019; Rai et al., 2014; Cabanas-Valdés, 2016).

However, given that the intensity or method of stretching was not gradually changed according to the patient's condition, it is believed that it would have been weak to bring about a greater effect enough to widen the gap between groups after the patient reached a certain functional level.

There are several limitations to this study. First, it is difficult to generalize the study results to all patients with stroke due to the small sample size recruited. When recruiting subjects, it is necessary to consider special characteristics such as age, gender, height, weight, smoking status. Second, because the intensity or method of stretching was not gradually changed and applied depending on the patient's condition, the intensity of the intervention may have been weak for patients with a relatively good level of function. Thirdly, there was difficulty in controlling the rest of the exercise therapy other than the intervention. In future research, it is necessary to clarify the effects of

respiratory muscle stretching by classifying subjects in detail and applying interventions that consider the subjects' individual characteristics.

V. Conclusion

Stretching respiratory muscles for stroke has a positive effect in improving pulmonary function. Therefore, additional respiratory muscle stretching is recommended for hemiplegic stroke patients to improve pulmonary function.

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