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Original Article

Combined respiratory muscle training facilitates expiratory muscle activity in stroke patients

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Abstract. [Purpose] The aim of this study was to investigate the effect of combined respiratory muscle training on expiratory muscle activity in stroke patients. [Subjects and Methods] Twenty-five stroke patients were assigned to either the intervention group (n=12) or the control group (n=13). Both groups participated in a conventional stroke rehabilitation program, while the intervention group also received respiratory muscle training for 20 to 30 minutes a day, 3 times a week, for 8 weeks. Surface electromyographic data were collected from the rectus abdominis, internal oblique, and external oblique on the paretic side. Pulmonary function (forced vital capacity) and cough capacity (peak expiratory flow) also were measured. [Results] Both groups showed a significant increase in muscle activity after the intervention. However, the intervention group also showed significant increases in forced vital capacity and peak expiratory flow. Comparison of the 2 groups revealed that the intervention group had greater improvements in pulmonary function, cough capacity, and muscle activity. [Conclusion] The results of this study suggest that combined respiratory muscle training has positive effects on both respiratory function and expiratory muscle activity in stroke patients.

Key words: Stroke, Combined respiratory muscle training, Muscle activity

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INTRODUCTION

Occurrence of stroke dramatically reduces patients' physical activity as a result of motor function impairment accompanied by muscle weakening. This increases the CO_2 sensitivity of the paralyzed muscles and impairs voluntary breathing, inducing asymmetric respiration[1)]. Moreover, hemiplegia caused by brain injury damages motor control function, which is essential for coordination of the respiratory muscles[2)]. Thus, respiratory function declines due to muscle weakening and impaired coordination[3)]. The major and minor muscles involved in inspiratory and expiratory functions are in continuous interaction with the static/dynamic and intrinsic/extrinsic environments associated with respiration[4)].

Stroke patients show reductions of both maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) compared to healthy age-matched subjects[5)]. In addition to their importance for ventilation, the inspiratory and expiratory muscles also are necessary to maintain upper airway patency through an efficient cough mechanism[6)]. Neuromuscular diseases often cause reductions of MIP and MEP as well as an imbalance of inspiratory vs expiratory muscles[7)].

In particular, weakening of the expiratory muscles of the abdomen and thorax reduces cough capacity and sputum elimination, leading to accumulation of respiratory secretion, and resulting in several respiratory-related complications[8)]. Considering the preventive function of cough to inhibit foreign body inhalation and aspiration, voluntary cough is a very important problem among stroke patients[9)]. Therefore, the authors suggest introducing respiratory muscle training (RMT) as a rehabilitation intervention in stroke patients.

Diverse training methods have been applied for respiratory rehabilitation in stroke patients. Among patients with sub-

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acute stroke, respiratory re-education training and inspiratory muscle training (IMT) were found to have beneficial effects on respiratory muscle function, training capacity, and quality of life[10]. Enhancement of lung function also was observed among chronic stroke patients who received inspiratory muscle resistive training[10]. In another study, expiratory muscle training (EMT) increased MEP in patients with neurologic disease, and improved maximal voluntary cough capacity in patients with moderate disability[11, 12].

Despite the numerous studies focusing on improvement of muscle strength via IMT in stroke patients, there are few studies investigating combined RMT including EMT. However, both IMT and EMT are necessary to improve respiratory function, such as cough capacity, in stroke patients.

The purposes of this study were to measure changes in activity of the expiratory muscles, including the rectus abdominis (RA), internal oblique (IO), and external oblique (EO), after combined RMT in stroke patients, and to assess the effect of expiratory muscle activity on respiratory function, such as cough capacity.

SUBJECTS AND METHODS

The participants were 25 stroke patients (intervention group: n=12, control group: n=13) who had a full understanding of the study and voluntarily consented to participate. Patients had the disease for at least 6 months. The intervention group comprised 7 men and 5 women with an average age, height, weight, body mass index and onset duration of 66.17 ± 4.08 years, 161.87 ± 7.79 cm, 58.56 ± 6.89 kg, 22.32 ± 1.80 kg/m^2 and 17.75 ± 4.26 months respectively. The paretic side was left in 7 patients and right in 5 patients. The control group comprised 6 men and 7 women with corresponding parameter values of 66.08 ± 3.70 years, 160.53 ± 7.20 cm, 56.36 ± 7.87 kg, 21.87 ± 2.68 kg/m^2 and 18.54 ± 4.48 months. The paretic side was left in 7 patients and right in 6 patients. No significant differences in baseline characteristics were found between groups. Patients were diagnosed as having stroke via computed tomographic examination and were capable of performing independent gait. The selection criteria of this study followed the standard of previous research[10]. This study was approved by the university institutional review board (CUPIRB-2014-023).

Both groups participated in a conventional stroke rehabilitation program, while the intervention group also received RMT for 20 to 30 minutes a day, 3 times a week, for 8 weeks. Combined RMT was performed using a threshold inspiratory muscle trainer (Respironics Inc.) and threshold positive expiratory pressure device (Respironics Inc.). IMT was performed by increasing inspiratory pressure in 3 phases (40%, 60%, and 80%), while EMT was performed by increasing expiratory pressure in 3 phases (10, 15, and 20 cmH_2O).

A spirometer (Pony FX; Cosmed Srl) was used to measure pulmonary function (forced vital capacity), MIP, and MEP, while a peak expiratory flow meter (MicroPeak; Carefusion) was used to measure cough capacity (peak expiratory flow) before applying the intervention in each group. For accurate measurements, participants were given sufficient explanations and demonstrations to help them understand before they were assessed in a sitting position with 90° flexion of the hip joint[13].

Expiratory muscle activity on the paretic side was measured using electromyography (EMG) (LXM3204; LAXTHA Inc.). Electrodes for surface EMG were attached to the RA, EO, and IO at locations consistent with previous studies[14, 15]. The sampling rate of EMG signals was set at 1,024 Hz. To remove noise from the EMG signals, raw data were processed by bandpass filtering in the range of 10 to 200 Hz, and then smoothed with the root mean square 20 ms after rectification[16]. This standardization method was used to compare EMG signals between subjects and muscles. The percent reference voluntary contraction (%RVC) method was used, which references muscle contraction of a particular movement as the standard[17]. With reference to a previous study, %RVC was used to measure activity of the expiratory muscles for 5 seconds with subjects in a stable state by using the mean value of the middle 3 seconds and excluding the first and last seconds. Expiratory muscle activity was measured with subjects in a sitting position with 90° flexion of the hip joint. Subjects were instructed to “keep the mouth closed for 5 seconds after exhaling the air out entirely.” They repeated this 3 times and the average value was used for analysis. Muscle activity during maximal breath holding also was measured, and subjects were given 1 minute of rest after EMG measurement. Measurements were taken immediately before and after the 8-week intervention.

Collected data were analyzed using PASW Statistics version 18.0 (SPSS Inc.). Differences after the intervention within each group were analyzed using the paired t-test, while differences between groups were analyzed using the independent t-test. Statistical significance was set at $p<0.05$.

RESULTS

Differences in the variables before and after the 8-week intervention in each group are shown in Table 1.

DISCUSSION

Based on our review of existing studies on RMT in stroke patients, secondary damage after stroke deteriorates motor performance capacity and exercise tolerance. Muscle weakening and impaired coordination further reduce respiratory function[3]. However, it was reported that strength and endurance of the respiratory muscles can be restored similar to other skeletal muscles. Functionally similar problems can occur from muscle weakening, decreased endurance, and accumulation

Table 1. Values of the variables before and after the intervention

	Group	Pre-test	Post-test	p	Post-Pre	p
RA (%)	Intervention	106.0 ± 4.2	113.4 ± 5.1	**	7.3 ± 3.0	**
	Control	103.7 ± 3.0	104.6 ± 3.7	*	0.8 ± 1.0	
EO (%)	Intervention	101.5 ± 2.7	108.5 ± 4.6	**	7.0 ± 2.5	**
	Control	99.6 ± 1.9	101.5 ± 1.6	**	1.0 ± 0.8	
IO (%)	Intervention	101.0 ± 2.5	106.3 ± 3.8	**	5.3 ± 2.2	**
	Control	99.4 ± 1.7	100.3 ± 1.6	*	0.9 ± 1.2	
FVC (L)	Intervention	1.67 ± 0.19	1.80 ± 0.26	**	0.13 ± 0.86	**
	Control	1.73 ± 0.19	1.70 ± 0.22		–0.02 ± 0.58	
MIP (cmH_2O)	Intervention	20.2 ± 3.5	22.2 ± 3.4	**	2.0 ± 1.2	**
	Control	18.4 ± 2.5	18.2 ± 2.6		–0.2 ± 0.5	
MEP (cmH_2O)	Intervention	23.3 ± 4.1	25.9 ± 3.9	**	2.5 ± 1.1	**
	Control	21.3 ± 2.2	20.7 ± 2.4	**	–0.6 ± 0.5	
PEF (L/min)	Intervention	262.5 ± 20.9	285.8 ± 26.0	**	23.3 ± 9.8	**
	Control	264.6 ± 24.3	258.4 ± 24.7	**	–6.1 ± 6.5	

All data are presented as mean ± SD.
*p<0.05, **p<0.01.
EO: external oblique; IO: internal oblique; FVC: forced vital capacity; MEP: maximal expiratory pressure; MIP: maximal inspiratory pressure; PEF: peak expiratory flow; RA: rectus abdominis

of muscle fatigue[18]. Therefore, the authors suggest RMT as a solution to these problems.

Much research has been conducted on RMT to enhance respiratory function in patients with lung and neurologic diseases. In a previous study, a significant increase in cough capacity was observed in the intervention group of stroke patients, who received RMT in addition to therapeutic exercise. This increase was significant compared to the control group, which received therapeutic exercise alone for 6 weeks[13].

In a previous study comparing the increase in cough capacity in stroke patients, the RMT group, which received RMT together with therapeutic exercise showed a greater increase than the control group, which received therapeutic exercise alone or 4 weeks[19]. These findings are consistent with our results. Consequently, although there may be a variation in the extent of impact depending on the method and duration of training, 8-week combined RMT is expected to positively affect respiratory function and cough capacity in stroke patients.

A previous study reported an increase in abdominal muscle activity after RMT in quadriplegic patients[20], while another study observed an increase in activity of the EO (8%) and RA (5%) in patients with muscular dystrophy[21]. These results resemble the effect of combined RMT on expiratory muscle activity. The increase in expiratory muscle activity in stroke patients is presumed to improve respiratory function, such as cough capacity, through lumbar stabilization and increased intra-abdominal pressure, which eventually helps with sputum elimination and reduces risk of aspiration.

In conclusion, the authors confirmed the benefits of RMT on lung function and expiratory muscle activity in this study. In particular, it is assumed that combined RMT, rather than therapeutic exercise alone, may further improve respiratory function, such as cough capacity.

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