

Effects of Abdominal Stimulation during Inspiratory Muscle Training on Respiratory Function of Chronic Stroke Patients

JU-HYEON JUNG, MS, PT¹⁾, JE-MYUNG SHIM, PhD, PT^{2)*}, HAE-YEON KWON, MS, PT³⁾,
HA-ROO KIM, MS, PT⁴⁾, BO-IN KIM, MS, PT⁴⁾

¹⁾ Department of Physical Therapy, Rehabilitation Center, Gimhea Good Morning Hospital, Republic of Korea

²⁾ Department of Physical Therapy, College of Health and Science, Kangwon National University: 346 Hwangjo-ri, Dogye-eup Samcheok-si, Kangwon-do 245-905, Republic of Korea

³⁾ Department of Physical Therapy, Graduate School, Catholic University of Pusan, Republic of Korea

⁴⁾ Department of Physical Therapy, Graduate School, College of Rehabilitation Science, Daegu University, Republic of Korea

Abstract. [Purpose] The purpose of the present study was to verify a new method for improving respiratory functions by applying both abdominal stimulation and inspiratory muscle training (IMT) to train the inspiratory muscle and the expiratory muscle simultaneously, to improve the efficiency of IMT of chronic stroke patients. [Subjects] Eighteen stroke patients were randomly assigned to an experimental group (n = 9) and a control group (n = 9). [Methods] The experimental group was administered IMT with abdominal stimulation, and the control group was administered only IMT. During the intervention period, the experimental group and control group received training 20 min/day, 3 times/wk, for 4 weeks. To examine the lung functions of the subjects, FVC, FEV₁, PEF, and FEF_{25–75} were measured using an electronic spirometer. The diaphragm thickness ratio was calculated from measurements made with a 7.5-MHz linear probe ultrasonic imaging system. [Result] The experimental group and the control group showed significant increases in diaphragm thickness ratio on the paretic side, but not on the non-paretic side. With regard to lung function, the experimental group showed significant increases in FEV₁, PEF, and FEF_{25–75}. The changes between before and after the intervention in the two groups were compared with each other, and the results showed significant differences in FEV₁ and PEF. [Conclusion] The present study identified that IMT accompanied by abdominal stimulation improved the pulmonary function of chronic stroke patients.

Key words: Abdominal stimulation, Inspiratory muscle training, Stroke

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INTRODUCTION

The decline in respiratory function of stroke patients is caused by reduced physical activity. The decline in cardiopulmonary function is related to reduced oxygen transport ability caused by extended bed rest after hospitalization¹⁾. This condition can cause stroke patients who require intensive rehabilitation to tire easily during aerobic activities requiring endurance, thereby restricting their performance of daily living activities. Consequently, the success rate of rehabilitation drops because functional recovery is hindered²⁾.

In a study conducted by Khedr et al.³⁾, 40% of stroke patients showed decreases in diaphragm displacement. The

results of analysis of lung function show only 50% of the values expected of normal adults^{4, 5)}. Among the different types of training used to improve respiratory functions, inspiratory muscle training (IMT) improves inspiratory muscle strength and endurance, regardless of damage to the inspiratory muscles, by applying loads to the diaphragm and the accessory muscles of the inspiratory muscles⁶⁾. It was reported that IMT performed by subacute stroke patients for six months improved lung function, maximal inspiratory pressure (MIP), exercise tolerance, and pulmonary function indexes⁷⁾. In a study conducted by Britto et al.⁸⁾ of chronic stroke patients, IMT for eight weeks improved MIP and inspiratory muscular endurance (IME).

Gollee et al.⁹⁾ reported that neuromuscular stimulation of the abdominal muscles supported respiration and the application of simple surface stimulation to major paralyzed expiratory muscles induced even muscle contraction, thus helping to improve cough and forced expiration. It was reported that abdominal muscle stimulation improved respiratory functions during expiration, because the contraction of the abdominal muscles caused by stimulation induces

*Corresponding author. Je-myung Shim (e-mail: sjm7897@hanmail.net)

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increased coughing and directly increases MIP to improve expiratory flow⁹). Gollee et al.⁹ also reported that abdominal muscle stimulation could improve conditions in which respiratory rates increase because of decreased lung volume. Abdominal muscle stimulation also improved lung function of paretic patients with decreased functional residual capacity (FRC) and elastic recoil during inspiration⁹.

Previous studies have shown that among the methods used to improve the respiratory function of stroke patients, IMT is an excellent intervention for improving inspiratory muscle strength and endurance⁷). However, it has had limited success at directly improving forced expiration. In addition, abdominal muscle stimulation induced improvement in forced expiration of patients with nervous system disorders, showing decline in respiratory function caused by respiratory air passage obstruction or decreased forced expiration.

The present study aimed to verify more efficient IMT method, the IMT used in clinics with abdominal muscle stimulation, and identify the effects of the new IMT method on the improvement of the respiratory function of chronic stroke patients.

SUBJECTS AND METHODS

The participants were eighteen stroke patients (11 males, 7 females) who voluntarily consented to participate in the study. They had a full understanding of its objective and consented to participation. They were randomly and equally divided into two groups: an experimental group and a control group. The experimental group received abdominal stimulation while performing inspiratory muscle training, and the control group only performed inspiratory muscle training. Both groups performed the training 3 times per week, non-consecutively, for 4 weeks.

This study was approved by the Kangwon National University Institutional Review Board. The average age, height, weight, and body mass index (BMI) of the experimental group were 54.44 years, 159.86 cm, 63.68 kg, and 24.82 kg/m², respectively, and the average time since stroke onset was 40.55 months. The average age, height, weight, and body mass index (BMI) of the control group were 55.88 years, 158.7 cm, 62.32 kg, and 24.71 kg/m², respectively, and the average time since stroke onset was 46.22 months.

The subjects of the present study were patients who had been diagnosed with stroke using computed tomography and had hemiplegia as a sequela of partial damage of the cerebral hemisphere. The following exclusion criteria were stroke patients who had had the disease for at least six months or were receiving physical therapy in hospital but not receiving any particular treatment for rehabilitation.

Lung-function was measured with a spirometer (CHESTGRAPH HI 101, Chest M.I. Inc., Japan). A full explanation accompanied by a demonstration was given to the participants in advance. Lung function was examined three times, and the results of reliability were chosen for the analysis. The subjects maintained an upright sitting position, and the measurement values included FVC, FEV₁, the PEF, and FEF₂₅₋₇₅.

Changes in the diaphragm thickness were analyzed using ultrasonography (Logiq 7, GE Co., USA). For all subjects, the mid axillary lines between ribs 8 and 9 on both sides were checked in a standing posture, then the chest wall was perpendicularly illuminated by a linear transducer (5.0–14.0 MHz) in an upright sitting position to observe the region between rib 8 and rib 9 in 2D images. The diaphragm thickness was measured as the distance between two parallel lines that appear bright in the middle of the pleura and in the middle peritoneum. The distance was measured three times, and the average value was calculated¹⁰).

The diaphragm thickness ratio (TR) was calculated. The formula of Enright et al.¹⁰) formula was used to obtain standardized diaphragm thickness ratios (TR). TR = (Diaphragm thickness during MIP maneuver of FRC / Mean thickness while relaxing at FRC).

Abdominal stimulation was applied when the subject was sitting with 90° hip flexion. A functional electrical stimulator (Microstim, Medel GmbH, Germany) was used. The adhesive surface electrodes (PROTENS electrodes 48 × 48 mm, Biopro-Tech Inc, Korea) were attached to the abdominal muscles (rectus abdominis muscle, lateral abdominal muscle)^{11, 12}). The electricity used had symmetric biphasic rectangular waveforms, a pulse duration of 250 μs, a frequency of 40 Hz, a maximum output of 90 mA, and a stimulation intensity ranging from 10 to 30 mA. The stimulation began at low intensity and was gradually increased. Stimulation time per session was 20 minutes (current flowing time 5 seconds, no current flowing time 5 seconds, and gradient variation 2.5 seconds).

Using a threshold IMT device (Threshold Inspiratory Muscle Trainer, Respironics Health Scan, Inc., USA) during an expiration after one inspiration, the patient pressed the current flowing switch with his/her hand on the non-paretic side to induce expiration while stimulation was applied to the abdominal region⁹). The therapist helped if a patient had difficulty pressing the switch because of a coordination disorder. For both other groups, IMT was identically performed with 30% of the maximal inspiratory pressure (MIP) for 20 minutes per session, three times per week for four weeks, a total of 12 times.

Data obtained from the two groups of subjects were analyzed using SPSS 18.0 (SPSS Inc., Chicago, IL, USA). Data are presented as medians (interquartile range). Because of the small size of the study sample, non-parametric tests were used, and between-group comparisons were performed using the Mann–Whitney U-test. Within-group comparisons were made using Wilcoxon's signed rank test. The level of statistical significance was chosen as $\alpha=0.05$.

RESULTS

Changes in lung function found after the four-week intervention are shown in Table 1. FEV₁, PEF, and FEF₂₅₋₇₅ increased significantly ($p < 0.05$). The comparison of comparing the number of changes between before and after the intervention in the experimental group and the control group revealed significant differences in FEV₁ and PEF ($p < 0.05$).

After implementing abdominal stimulation during inspi-

Table 1. The values of the variables measured before and after the intervention (n=18)

Group	Pre-test	Post-test	Change	
TR (Paretic side)				
Experimental	1.74±0.27	2.16±0.29	*	0.42±0.28
Control	1.72±0.33	2.00±0.24	*	0.28±0.25
TR (Non-paretic side)				
Experimental	1.75±0.28	1.99±0.28		0.23±0.33
Control	1.82±0.30	2.05±0.37		0.22±0.27
FVC (% predicted)				
Experimental	59.03±21.83	65.44±15.09		6.41±9.77
Control	62.68±19.29	62.63±15.72		0.05±17.21
FEV ₁ (% predicted)				
Experimental	59.15±19.74	74.81±17.91	*	15.65±14.74
Control	72.23±22.01	73.17±17.77		0.94±18.16
PEF (% predicted)				
Experimental	41.72±19.19	67.50±15.97	*	25.77±26.47
Control	52.95±14.17	50.82±15.73		2.13±8.14
FEF ₂₅₋₇₅ (% predicted)				
Experimental	71.58±32.40	92.98±28.88	*	25.54±29.62
Control	97.13±18.96	95.06±21.23		2.07±19.20

*Statistical significance, $p \leq 0.05$

TR= diaphragm thickening ratio, FVC=Forced vital capacity, FEV₁=Forced expiratory volume in one second, PEF=Peak expiratory flow, FEF₂₅₋₇₅= Forced expiratory flow between 25% and 75% of vital capacity

ratory muscle training in the experimental group and the control group, TR significantly increased on the paretic side ($p < 0.05$), but not on the non-paretic side. The comparison of changes between before and after the intervention in the experimental group and the control group revealed no significant difference on either the paretic side or the non-paretic side (Table 1).

DISCUSSION

Kim¹³⁾ reported that increase in the residual capacity or decrease in the lung volume of stroke patients causes weakening of the inspiratory muscle and the expiratory muscle. The muscles necessary for maintaining posture and the muscles that act during breathing are closely related. The difficulties of stroke patients in maintaining posture and their deteriorated trunk stability cause the weakening of the expiratory muscles that maintain posture¹³⁾. Because these expiratory muscles are weak, patients with abdominal muscle paresis, including stroke, experience inability to clean the air passage and are prone to respiratory infections¹⁴⁾. Therefore, Gollee et al.⁹⁾ suggested applying neuromuscular stimulation to the abdominal muscles to help the contraction of the major expiratory muscles and to increase expiratory flows and tidal volumes, in order to improve respiration function.

The present study examined a method designed to combine IMT with abdominal muscle stimulation to improve forced expiration. In order to examine the effects of the new IMT method, the new method was performed by the

experimental group, whereas only IMT was performed by the control group. Moreover, the abdominal stimulation was applied in order to strengthen the expiratory muscle in order to try to improve the cost and time efficiency of using IMT devices with other types of devices, as well as to avoid interrupting subject's breathing pattern.

Enright et al.¹⁰⁾ reported that when the effects of IMT were checked in healthy adults, diaphragm thicknesses and TR at maximal inspiration showed significant increases after exercises lasting for eight weeks. A previous study that conducted IMT for cystic fibrosis patients reported that diaphragm thicknesses and TR at maximal inspiration showed significant increases¹⁵⁾. In the present study, the TR of the diaphragm on the paretic side showed significant increases in both the experimental group and the control group, consistent with the results of previous studies. The values of TR also increased on the non-paretic side although this increase was not statistically significant.

Sutbeyaz et al.⁷⁾ divided subacute stroke patients into an IMT group, a breathing retraining group, and a control group. They conducted interventions six times per week for six weeks and compared lung function among the groups. Their results showed significant increases in FVC, FEV₁, FEF₂₅₋₇₅, and maximal inspiratory pressure (MIP), but no increase in PEF in the inspiratory muscle-training group. In a study conducted by Britto et al.⁸⁾, MIP and IME (inspiratory muscular endurance) were measured after IMT, and showed significant increases. In a study conducted by Enright et al.¹⁵⁾, a group which performed IMT showed significant increases in TLC (total lung capacity) and VC (vital

capacity), but not in FVC and FEV₁. Moreover, in a study conducted by Fregonezi et al.¹⁶⁾, the IMT group showed no significant changes in FVC, FEV₁, or TLC.

Interpreting the results of these previous studies, although IMT shows clear effects on TR, and MIP, the effects of IMT on lung function are inconsistent. In particular, we identified that the effects of IMT are not strong enough to improve forced expiration. Therefore, in the present study, in order to improve forced expiration, abdominal stimulation was applied during IMT.

Our results show significant increases in FEV₁, PEF, and FEF₂₅₋₇₅ and the changes in FEV₁ and PEF showed significant differences between the two groups. These results were similar to the results of a study conducted by Cheng et al.¹⁷⁾, who reported significant increases in FVC, FEV₁, and PEF after applying abdominal stimulation for four weeks. In a study conducted by Lee et al.¹⁸⁾, stimulation was applied to the anterior and posterolateral regions of the abdomen. Their results showed significant increases in FVC, FEV₁, and PEF, which is consistent with the results of the present study. Therefore, abdominal stimulation reeducates the expiratory muscles, improves muscle strength and endurance, and induces powerful contraction of the expiratory muscles through repetitive afferent stimulation of the abdominal muscles, thereby increasing intra-abdominal pressure, facilitating upward movement of the diaphragm and decreasing pleural pressure and lung volume, thereby improving expiratory and sputum discharge abilities¹⁷⁾.

If IMT were performed by stroke patients with pulmonary function problems resulting from damage to the respiratory muscles caused by stroke and reduced exercise capacity, abdominal muscle stimulation would improve respiratory function. However, we admit this study had some limitations. The researchers conducted a four-week experiment, and due to the short period of experiment, it was difficult to examine the positive effects on lung function (FVC) of the experimental and control groups. For this reason, it will be necessary to conduct long term experiments that include a more comprehensive analysis of the impact of abdominal stimulation during IMT intervention on chronic stroke patients.

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