



Original Article

# Effects of inspiratory muscle training on balance ability and abdominal muscle thickness in chronic stroke patients

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**Abstract.** [Purpose] This study evaluated the effects of inspiratory muscle training on pulmonary function, deep abdominal muscle thickness, and balance ability in stroke patients. [Subjects] Twenty-three stroke patients were randomly allocated to an experimental (n = 11) or control group (n = 12). [Methods] The experimental group received inspiratory muscle training-based abdominal muscle strengthening with conventional physical therapy; the control group received standard abdominal muscle strengthening with conventional physical therapy. Treatment was conducted 20 minutes per day, 3 times per week for 6 weeks. Pulmonary function testing was performed using an electronic spirometer. Deep abdominal muscle thickness was measured by ultrasonography. Balance was measured using the Berg balance scale. [Results] Forced vital capacity, forced expiratory volume in 1 second, deep abdominal muscle thickness, and Berg balance scale scores were significantly improved in the experimental group than in the control group. [Conclusion] Abdominal muscle strengthening accompanied by inspiratory muscle training is recommended to improve pulmonary function in stroke patients, and may also be used as a practical adjunct to conventional physical therapy.

**Key words:** Abdominal muscle thickness, Pulmonary function, Stroke

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## INTRODUCTION

Abnormalities of posture, muscle tone, and motor control of voluntary movement, and reduced participation of trunk muscles, can affect motor abilities and respiratory muscle activities<sup>1)</sup>. Stroke resulting in weakness of these muscles can lead to cardiopulmonary volume adjustments and lack of oxygen, which can disrupt cardiovascular conditioning and the oxygen transfer system<sup>2)</sup>. This state can cause stroke patients, who require intensive rehabilitation, to tire easily during aerobic activities that require endurance, thereby restricting performance of activities of daily living<sup>3)</sup>.

Inspiratory muscle training (IMT) for improvement in respiratory function involves the application of a load to the diaphragm. Auxiliary inspiratory is reported to improve muscle strength and endurance. The basic principles of skeletal muscle strengthening were applied to the overload, specificity, and reversible<sup>4)</sup>. According to previous studies, IMT can improve maximal inspiratory pressure, lung function, endurance, and exercise performance after 6–8 weeks of training<sup>5, 6)</sup>. St. Croix et al.<sup>7)</sup> reported that respiratory metabolism is reflected in exercise performance. Bosnak et al.<sup>8)</sup> reported that IMT statistically increased quadriceps strength and balance ability in patients with heart failure. Exercise at greater than approximately 85% of maximum capacity was reported to cause fatigue in the diaphragm. Fatigue in respiratory muscles can be reduced or delayed by strengthening; this improves exercise capacity and respiratory movement, which are necessary for improvement

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in functionality<sup>9</sup>).

In chronic obstructive pulmonary disease patients, IMT, such as breathing exercise for thoracic mobility, has been widely used as a therapeutic intervention<sup>10</sup>. However, there is a lack of reports on IMT in patients with stroke, or chronic stroke patients with paralysis and coordination disorders caused by cerebrovascular disease, and the effects of balance ability on pulmonary function. The purpose of this study was to investigate the effects of IMT on balance ability and changes in abdominal thickness and lung function in chronic stroke patients, and to provide basic data for use in intervention programs for these patients.

## SUBJECTS AND METHODS

This study was approved by the Ethics Committee of Sahmyook University. Twenty-three stroke patients voluntarily participated in the current study. They were randomly divided into an experimental group (6 males and 5 females) and a control group (7 males and 5 females). The age, height, weight, Korean Mini-Mental State Examination (MMSE-K) score, and the duration from stroke onset until the time of the current study are summarized in Table 1. The inclusion criteria were: unilateral stroke that occurred 6 months prior to the study as determined by computed tomography (CT); the ability to perform breathing training for 30 minutes or longer; no sight impairment; modified Ashworth scale (MAS) score for upper and low extremities less than 2; and MMSE-K score greater than 24.

Both the experimental and control groups performed abdominal strengthening exercises and general physical therapy. Each 20-minute session was performed 3 times a week. Both groups performed general breathing exercises and basic physical therapy for 6 weeks. The experimental group performed IMT using an inspiratory muscle trainer for 20 minutes, 3 times a week for 6 weeks. Pulmonary function was measured using forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), peak expiratory flow (PEF), and the FEV1/FVC ratio. Fatigue was measured using the rating of perceived exertion (RPE) of Borg<sup>11</sup>. In each IMT session, exercise was performed 15 times per set, with a total of 10 sets. Warm-up and cool-down exercises were performed twice in each set, with a rest time of 60 seconds<sup>12</sup>. The warm-up and cool-down IMT resistance exercises were performed at 30% of maximum air pressure intake. The maximal inspiratory pressure was measured using a spirometer. The IMT was applied by divided between the more and less than 41 cmH<sub>2</sub>O during maximal inspiratory pressure<sup>13</sup>.

Abdominal strengthening exercise was performed according to the status of hemiplegia<sup>14</sup>. The program consisted of warm-up exercises for 5 minutes, IMT-based exercises for 20 minutes, and cool-down exercises for 5 minutes. The total exercise time was 30 minutes. This exercise program was performed 3 times a week for 6 weeks. The training intensity was adjusted according to the condition of the patient during the intervention.

Real-time B-mode 6–12 MHz ultrasonography (MySono U6, Samsung Medicine, Seoul, South Korea) was used to measure the thickness of the transverse abdominis (TA) and internal oblique (IO) muscles. The subjects were measured supine, with both feet positioned in line with the shoulder. A pillow was placed under the knees to maintain flexion. The probe was placed between the 12th rib and iliac crest 25 mm inside<sup>15</sup>. All images were obtained at the end of expiration to avoid TA mobilization at the start of expiration<sup>16</sup>. A vertical line was drawn across a horizon line 2 cm from the end of the inner corner of the TA in order to measure the muscle thicknesses of the TA and IO.

Pulmonary function was measured using a spirometer (Cardio Touch 3000-S, Bionet, LA, USA). A full explanation and demonstration were provided to the participants in advance. According to the guidelines of the American Thoracic Society, the subjects maintained an upright sitting position with 90° hip joint flexion. The FVC, FEV1, and PEF were measured.

**Table 1.** Characteristics of study participants

Parameters	IMTG (n=11)	CG (n=12)
Age (years)	69.7 (6.8)	71.6 (7.9)
Weight (kg)	65.2 (12.2)	63.1 (10.9)
Height (cm)	163.8 (10.6)	165.9 (6.8)
Disease duration (months)	392.0 (59.6)	435.6 (66.4)
MMSE-K	25.6 (1.4)	26.1 (1.3)
Gender	Male	6 (55%)
	Female	5 (45%)
Cause of disease	Cerebral infarction	7 (64%)
	Cerebral hemorrhage	4 (36%)
Affected side	Right	5 (45%)
	Left	6 (55%)

Values are mean (SD); MMSE-K: Mini-Mental State Examination Korea; IMTG: inspiratory muscle training group; CG: control group

Balance ability was measured using the Berg balance scale<sup>17</sup>).

IBM SPSS ver. 18.0 software was used for statistical analysis. Normality was confirmed using the Kolmogorov-Smirnov test. Between-group comparisons were performed using an independent t-test. Within-group comparisons were performed using a paired t-test, to compare dependent variables. The level of statistical significance was set at  $\alpha = 0.05$ .

## RESULTS

The IMT group showed a significant increase in the FVC after the intervention (from 1.6 to 2.03 L;  $p < 0.05$ ). The control group also showed a significant increase (from 1.86 to 1.99 L;  $p < 0.05$ ). There was a significant difference in the increased FVC value ( $p < 0.05$ ) between the experimental and control group. The experimental group showed a significant increase in the FEV1 after the intervention (from 1.32 L to 1.67 L;  $p < 0.05$ ). The control group also showed an increase (from 1.58 L to 1.71;  $p < 0.05$ ). There was a significant difference between the experimental and control group in a comparison of the FEV1 ( $p < 0.05$ ), and the increased value of the FEV1. The PEF increased significantly in the experimental group (from 3.14 to 3.83 L;  $p < 0.05$ ), but not in the control group (from 4.53 to 4.87 L;  $p > 0.05$ ).

The thickness of the TA significantly increased from 0.36 cm to 0.41 cm in the experimental group ( $p < 0.05$ ), and from 0.27 cm to 0.31 cm in the control group ( $p < 0.05$ ). The thickness of the IO significantly increased from 0.33 cm to 0.35 cm in the experimental group ( $p < 0.05$ ), and from 0.25 cm to 0.27 cm in the control group ( $p < 0.05$ ).

The balance ability score significantly increased from 30.09 to 32.64 in the experimental group ( $p < 0.05$ ), and from 27.50 to 29.42 in the control group ( $p < 0.05$ ) (Table 2).

## DISCUSSION

The purpose of this study was to evaluate the effects of IMT on lung function, deep abdominal muscle thickness, and balance ability in stroke patients after 6 weeks of training.

Exercise to improve respiratory function is the most important factor in therapeutic interventions because it affects the functional recovery of stroke patients. The IMT group showed significant improvement in balance, TA and IO thickness, FVC, FEV1, and PEF ( $p < 0.05$ ). Compared to the control group, the IMT group seemed to be significantly more efficient in terms of increasing FVC and FEV1 ( $p < 0.05$ ). This result is similar to the result reported by Sutbeyaz et al.<sup>5</sup>, who assigned 45 subacute stroke patients into IMT and control groups. In their study, lung function, recovery status, activities of daily living, and quality of life were performed for 6 weeks, six times a day for 30 minutes during the week. The breath-training group revealed significant differences in FVC and FEV1, but no significant difference in PEF. Jung et al.<sup>18</sup> demonstrated that IMT with abdominal electronic stimulation improved pulmonary function in chronic stroke patients. According to the National Institute for Clinical Excellence, the FVC/FEV1 ratio is an important indicator for diagnosing chronic obstructive pulmonary disease when the value is lower than 60% (normal is approximately 80%). In this study, IMT and control groups were not statistically significantly different in all the comparisons. This result could be useful in determining whether lung function in stroke patients with restrictive ventilation disorders had improved during the course of IMT.

Breathing is movement of air in and out of the lungs in response to volume changes in the thoracic diaphragm, followed by the intercostals, rectus abdominis, TA, and multiple accessory muscles. According to previous research, application of chest expansion resistance exercises by a therapist is recommended if the environment and conditions are appropriate for enhancement of chest expansion capacity and maximal inspiratory pressure in elderly people<sup>19</sup>. In the FVC, the TA and intercostals are used to exert pressure on the lower ribs by bending the torso and inducing deep breathing with the lifted diaphragm<sup>20</sup>.

**Table 2.** Comparison of lung function and balance abilities within and between groups

Parameters	Values				Change values	
	IMTG (n=11)		CG (n=12)		IMTG (n=11)	CG (n=12)
	pre	post	pre	post	post-pre	post-pre
FVC (L)	1.6 (0.8)	2.0 (0.7)**	1.9 (0.7)	2.0 (0.6)*	0.4 (0.3)	0.1 (0.2)*
FEV <sub>1</sub> (L)	1.3 (0.7)	1.7 (0.7)**	1.6 (0.6)	1.7 (0.5)*	0.4 (0.3)	0.1 (0.2)*
PEF(L/s)	3.1 (2.0)	3.8 (2.0)*	4.5 (2.5)	4.9 (2.2)	0.7 (0.9)	0.3 (0.7)
FEV <sub>1</sub> / FVC (%)	83.8 (16.3)	81.6 (10.7)	86.1 (12.8)	85.5 (7.5)	0.4 (0.7)	0.2 (0.9)
TA (cm)	0.4 (0.2)	0.4 (0.2)*	0.3 (0.1)	0.3 (0.1)*	0.1 (0.0)	0.0 (0.0)
IO (cm)	0.3 (0.1)	0.4 (0.1)*	0.3 (0.1)	0.3 (0.1)*	0.0 (0.0)	0.0 (0.0)
BBS (scores)	30.1 (10.9)	32.6 (11.1)***	27.5 (10.0)	29.4 (9.7)***	2.5 (1.0)	1.9 (1.0)

Values are mean (SD), \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

AP: anteroposterior; ML: mediolateral; PSD: postural sway distance; IMTG: I group; CG: control group; FVC: forced vital capacity; FEV<sub>1</sub>: forced expiratory volume in 1 second; PEF: peak expiratory flow; FEV<sub>1</sub>/FVC: forced expiratory volume in 1 second/forced vital capacity; TrA: transverse abdominis; IO: internal oblique; BBS: Berg Balance Scale

According to our results, the significant increase in thickness of the deep abdominals indicates that strengthening exercises affect muscle contraction. No statistically significant difference was observed in a comparison between the groups.

Increased inspiratory muscle fatigue can lead to respiratory and nonrespiratory fatigue of the upper spine<sup>21</sup>). Fatigue is conveyed through the blood flow to the extremities and reflected in the plantar flexor muscles before the onset of inspiratory fatigue<sup>22</sup>). Blood flow to the extremities is reduced because of inspiratory muscle fatigue but can be improved by IMT. In addition, IMT for the diaphragm and scalene can help stabilize thoracic mobility, and contributes to chest balance and transfer abilities<sup>23</sup>). Bosnak et al.<sup>8</sup>) applied IMT at 40% resistance of PEF training in 16 patients out of an experimental group of 30 patients with heart disease for 6 weeks. The quality of life, lung function, balance, and quadriceps strength significantly improved. Lucinda et al.<sup>24</sup>) studied subjects who performed IMT at home for 10 weeks. There were significant differences in balance, functional stair, sit-to-stand, and 6-minute walking tests between IMT and control groups.

Based on these results, we conclude that IMT training could be useful in improving lung function in stroke patients with restrictive lung disease. Rehabilitation using conservative physical therapy plus respiratory exercise could be a useful intervention for stroke patients in clinical settings. Further research is needed to develop a new IMT program that improves balance ability and adds evaluation of trunk activities. IMT can affect quadriceps strength in stroke patients. Studies on IMT should also be based on scientific evidence for balance training and improvement of exercise performance.

## REFERENCES

- 1) Martins SC, Friedrich MA, Brondani R, et al.: Thrombolytic therapy for acute stroke in the elderly: an emergent condition in developing countries. *J Stroke Cerebrovasc Dis*, 2011, 20: 459–464. [[Medline](#)] [[CrossRef](#)]
- 2) Dean E, Frownfelter D, Wong WP, et al.: Cardiovascular/cardiopulmonary physical therapy sinks or swims in the 21st century: addressing the health care issues of our time. *Phys Ther*, 2000, 80: 1275–1278. [[Medline](#)]
- 3) Estenne M, Gevenois PA, Kinnear W, et al.: Lung volume restriction in patients with chronic respiratory muscle weakness: the role of microatelectasis. *Thorax*, 1993, 48: 698–701. [[Medline](#)] [[CrossRef](#)]
- 4) Moodie L, Reeve J, Elkins M: Inspiratory muscle training increases inspiratory muscle strength in patients weaning from mechanical ventilation: a systematic review. *J Physiother*, 2011, 57: 213–221. [[Medline](#)] [[CrossRef](#)]
- 5) Subbeyaz ST, Koseoglu F, Inan L, et al.: Respiratory muscle training improves cardiopulmonary function and exercise tolerance in subjects with subacute stroke: a randomized controlled trial. *Clin Rehabil*, 2010, 24: 240–250. [[Medline](#)] [[CrossRef](#)]
- 6) Britto RR, Rezende NR, Marinho KC, et al.: Inspiratory muscular training in chronic stroke survivors: a randomized controlled trial. *Arch Phys Med Rehabil*, 2011, 92: 184–190. [[Medline](#)] [[CrossRef](#)]
- 7) St Croix CM, Morgan BJ, Wetter TJ, et al.: Fatiguing inspiratory muscle work causes reflex sympathetic activation in humans. *J Physiol*, 2000, 529: 493–504. [[Medline](#)] [[CrossRef](#)]
- 8) Bosnak-Guclu M, Arikan H, Savci S, et al.: Effects of inspiratory muscle training in patients with heart failure. *Respir Med*, 2011, 105: 1671–1681. [[Medline](#)] [[CrossRef](#)]
- 9) Babcock MA, Pegelow DF, McClaran SR, et al.: Contribution of diaphragmatic power output to exercise-induced diaphragm fatigue. *J Appl Physiol* 1985, 1995, 78: 1710–1719. [[Medline](#)]
- 10) Minoguchi H, Shibuya M, Miyagawa T, et al.: Cross-over comparison between respiratory muscle stretch gymnastics and inspiratory muscle training. *Intern Med*, 2002, 41: 805–812. [[Medline](#)] [[CrossRef](#)]
- 11) Borg GA: Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*, 1982, 14: 377–381. [[Medline](#)] [[CrossRef](#)]
- 12) Enright S, Chatham K, Ionescu AA, et al.: Inspiratory muscle training improves lung function and exercise capacity in adults with cystic fibrosis. *Chest*, 2004, 126: 405–411. [[Medline](#)] [[CrossRef](#)]
- 13) Fry DK, Pfalzer LA, Chokshi AR, et al.: Randomized control trial of effects of a 10-week inspiratory muscle training program on measures of pulmonary function in persons with multiple sclerosis. *J Neurol Phys Ther*, 2007, 31: 162–172. [[Medline](#)] [[CrossRef](#)]
- 14) Liebenson C: Spinal stabilization training. *J Bodyw Mov Ther*, 1997, 1: 87–90. [[CrossRef](#)]
- 15) Stetts DM, Freund JE, Allison SC, et al.: A rehabilitative ultrasound imaging investigation of lateral abdominal muscle thickness in healthy aging adults. *J Geriatr Phys Ther*, 2009, 32: 60–66. [[Medline](#)] [[CrossRef](#)]
- 16) Hodges PW, Richardson CA: Contraction of the abdominal muscles associated with movement of the lower limb. *Phys Ther*, 1997, 77: 132–142, discussion 142–144. [[Medline](#)]
- 17) Blum L, Korner-Bitensky N: Usefulness of the Berg Balance Scale in stroke rehabilitation: a systematic review. *Phys Ther*, 2008, 88: 559–566. [[Medline](#)] [[CrossRef](#)]

- 18) Jung JH, Shim JM, Kwon HY, et al.: Effects of abdominal stimulation during inspiratory muscle training on respiratory function of chronic stroke patients. *J Phys Ther Sci*, 2014, 26: 73–76. [[Medline](#)] [[CrossRef](#)]
- 19) Kim CB, Yang JM, Choi JD: The effects of chest expansion resistance exercise on chest expansion and maximal respiratory pressure in elderly with inspiratory muscle weakness. *J Phys Ther Sci*, 2015, 27: 1121–1124. [[Medline](#)] [[Cross-Ref](#)]
- 20) Kendall FP, McCreary EK, Provance PG: *Muscle: testing and function*, 4th ed. Baltimore/London: Williams & Wilkins, 1993.
- 21) Poole DC, Richardson RS: Determinants of oxygen uptake. Implications for exercise testing. *Sports Med*, 1997, 24: 308–320. [[Medline](#)] [[CrossRef](#)]
- 22) McConnell AK, Lomax M: The influence of inspiratory muscle work history and specific inspiratory muscle training upon human limb muscle fatigue. *J Physiol*, 2006, 577: 445–457. [[Medline](#)] [[CrossRef](#)]
- 23) Bergh A: The effect of passive thoracic flexion-rotation movement on the total static compliance of the respiratory system and respiratory responses in ventilated patients. Diss. Stellenbosch: University of Stellenbosch, 2007.
- 24) Pfalzer L, Fry D: Effects of a 10-week inspiratory muscle training program on lower-extremity mobility in people with multiple sclerosis: a randomized controlled trial. *Int J MS Care*, 2011, 13: 32–42. [[Medline](#)] [[CrossRef](#)]