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ORIGINAL ARTICLE

Effects of Inspiratory Muscle Training on Respiration and Balance in Patients with Stroke: A Pilot Randomized Controlled Trial

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PURPOSE: Respiratory function can be adversely affected after a cerebrovascular accident. This study aimed to determine whether inspiratory muscle training (IMT) changes the respiration and balance abilities of patients with stroke.

METHODS: Twelve patients with stroke were randomly assigned to the study (n=6) and control (n=6) groups. The study and control groups received IMT and general physical therapy, respectively for 6 weeks, five times a week for 30 min/day. Inspiratory and expiratory functions and balance were measured pre- and post-evaluation.

RESULTS: After IMT intervention, the weight distribution ratio (WDR) for balance ability measurement was significantly decreased ($p<.05$), and the maximum inspiratory pressure (MIP), maximum inspiratory flow rate (MIFR), maximum inspiratory capacity (MIC), peak expiratory flow (PEF), forced expiratory volume in 1 second (FEV_1), and limits of stability (LOS) were significantly increased in the study group ($p<.05$). A comparison of the study and control groups revealed statistically significant differences in MIP ($p<0.01$), MIFR ($p<.01$), MIC ($p<.05$), PEF ($p<.05$), FEV_1 ($p<.05$), WDR ($p<.01$), and LOS ($p<.05$).

CONCLUSIONS: This study suggests that IMT is a useful and effective exercise intervention for patients with stroke.

Key words: Stroke, Inspiratory muscle training, Respiration, Balance

INTRODUCTION

Stroke is a disease that is accompanied by a variety of neurological symptoms, with decreased and lost brain function due to cerebral blood vessel hemorrhage or infarction [1]. Stroke affects not only the muscles of the arms and legs but also the respiratory muscles [2,3]. Patients with stroke show weakness of the respiratory muscles [3,4] and decreased movement of the paralyzed diaphragm [5,6]. The cardiopulmonary function in patients with stroke is reduced due to the weakening of the respiratory muscles and decreased chest movement [7].

The diaphragm is a significant muscle involved in respiration, and due to its anatomical structure, it attaches to the ribs and lumbar vertebrae, contributing to the stabilization and movement of the spine [8,9]. The constriction of the diaphragm increases the intra-abdominal pressure and synergizes with the pelvic floor and abdominal muscles to increase the trunk stability [10]. Impaired respiratory muscles can lead to decreased core stability required for normal balance and mobility [11,12].

Inspiratory muscle training (IMT) involves breathing exercises using a pressure threshold device to strengthen the muscles involved in breathing. IMT is easy to apply, and is considered relevant in the rehabilitation exercise [13]. IMT gradually overloads inspiratory muscles and the resulting change in maximum inspiratory pressure (MIP) may reveal morphological adaptation of these muscles [14]. MIP is often reported as an outcome measure used to quantify the efficacy of such interventions

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[15].

IMT is reported to improve performance in daily living activities in heart disease [16,17] and lung disease [18,19], which have inspiratory muscle weakness. Cho et al. [20] reported that IMT is effective for respiratory function, walking endurance, and fatigue symptoms, including changes in muscle structure, and can be beneficial as an exercise program in patients with stroke.

IMT on postural stability and balance have been shown in a previous study [21]; if the respiratory muscle is strengthened, respiratory muscle fatigue is reduced, and exercise capacity is improved [14]. Since the respiratory muscles respond to training similarly to other skeletal muscles, the respiratory muscles must be trained just as the arm and leg muscles are trained in patients with stroke [22]. IMT is performed based on the principles of overload, specificity, and reversibility, which are the basic principles of skeletal muscle strengthening [23]. IMT improves lung function by applying resistance to the inspiratory muscle and causing an additional effect on the respiratory muscle endurance for more efficient use of the respiratory muscle in daily life activities [13].

A general stroke rehabilitation program that focuses only on physical and functional recovery is insufficient to improve a patient's respiratory function [24]. Therefore, programs, including respiratory interventions, can be effective in improving the function of patients with stroke [25]. Currently, various studies are being conducted on IMT for respiratory function recovery in patients with stroke. However, few studies have been conducted on IMT for the improvement of balance ability along with respiratory function recovery.

Therefore, this study aimed to investigate whether IMT changed the respiration and balance ability of patients with stroke.

METHODS

1. Participants

A total of 12 patients with stroke who were hospitalized in Seongnam-si, Gyeonggi-do were included in this study. The patients were randomly assigned into the study and control groups. The study was conducted for 6 weeks from February 2022, 5 times a week for 30 min/day. The inclusion criteria were as follows:

(1) Persons diagnosed with stroke;

(2) A person who can walk independently for >30 m (walking aids allowed);

(3) Those with no history of cardiovascular or respiratory problems; and

(4) Those with a score of 24 or higher on the Korean version of the Mini-Mental State Examination (MMSE-K).

The purpose of the study was explained to all participants, informed consent was obtained, and the study was conducted after obtaining approval from the U1 University Institutional Review Board (approval number: U1IRB2022-03).

2. Intervention

The intervention of the study group was modified and devised by following the protocol of Sutbeyaz et al. [26] The study participants started treatment in a sitting position on a height-adjustable treatment table. The pelvis was maintained in a neutral position by tilting it forward and backward. The torso was erected in a vertical line against gravity to induce extensor muscle contraction. IMT was performed using POWERbreathe K5 (International Ltd., Warwickshire, UK). Intra-rater intra-class correlation coefficients (ICCs) ranged from 0.959 to 0.986. Inter-rater ICC values were 0.933 to 0.985 [27]. A nose plug was worn, and a personal mouthpiece was placed in close contact with the mouth to prevent air leakage. After maximizing the residual volume in the lungs, the participants were instructed to breathe in rapidly and strongly. The training time was 30 minutes in total, which included 15 minutes of posture setting, 5 minutes of training per set, and 5 minutes of rest for two sets. The intensity was gradually increased from 40% of the MIP (auto mode, very light) to 60% (auto mode, moderate) [26]. This suggests that improvement in performance following IMT requires an intensity of training that increases MIP [28]. The intervention was conducted for 6 weeks, 5 times a week for 30 min/day. The method was demonstrated to the participants before training, and the study was conducted following full familiarization with the method. For the intervention of the control group, general physical therapy, including neurodevelopment treatment and joint movement, stretching, and strength exercises, was performed.

3. Measurement

1) Inspiratory function test

Inspiratory function test was performed using POWERbreathe K5 (International Ltd., Warwickshire, UK). MIP (cmH_2O), maximum inspiratory flow rate (MIFR, liters/sec), and maximum inspiratory capacity (MIC, liters) were measured.

The participants performed an inhalation function test program with a personal mouthpiece in a comfortable sitting position. The method

was demonstrated to the participants before training, and evaluation was performed following full familiarization with the method.

2) Expiratory function test

Expiratory function tests were performed using a spirometer (Microlife PF-200, Switzerland) to determine the peak expiratory flow (PEF, liters/min) and forced expiratory volume in 1 second (FEV_1, liters). The participants were asked to sit comfortably, put a spirometer in their mouth, inhale as much as possible, and subsequently exhale as hard as possible. The test was conducted three times, and the average value was calculated.

3) Balance test

The weight distribution ratio (WDR) and limits of stability (LOS) in the standing position were measured using a BioRescue Platform (Rm Ingenierie, Rodez, France). After the participants stood on the platform barefoot and stood still for 1 minute, the WDR of the paralyzed and nonparaplegic sides was measured. The amount of change was measured using the difference in WDR between both legs as an absolute value.

To measure the LOS, the task indicated on the screen was performed. Following the arrows appearing on the screen, the center of gravity was voluntarily moved as much as possible. During the measurement, the feet should not fall off the floor, and if the feet fell off the ground, the values were remeasured.

Data collection was performed three times, and the average value was used. The effect on muscle fatigue was minimized by providing a 3-minute rest period for each measurement.

4. Statistical analysis

The results of this study were analyzed using the statistical program SPSS (ver. 18.0). A chi-square test and an independent sample t-test were used to test the homogeneity between the two groups. The Wilcoxon signed-rank test was conducted for before and after comparison within a group, and the Mann-Whitney U test was performed for a comparison between the study and control groups. The results for each item were presented as mean ± standard deviation, and the statistical significance level (α) was set to .05.

RESULTS

1. General characteristics of the participants

No statistically significant difference in the general characteristics of the study and control groups was noted. The general characteristics of the participants are presented in Table 1.

2. Comparison of the inspiratory function

After the IMT intervention in the study group, the MIP significantly increased from 35.40 ± 7.65 to 52.69 ± 9.80 cmH_2O ($p < .05$). Moreover, the MIFR significantly increased from 1.88 ± 0.58 to 3.11 ± 0.56 L/sec ($p < .05$). The MIC also significantly increased from 1.00 ± 0.19 to 1.34 ± 0.25 L ($p < .05$). Upon comparison of the study and control groups, statistically significant differences in MIP ($p < .01$), MIFR ($p < .01$), and MIC ($p < .05$) were observed (Table 2).

3. Comparison of expiratory function

After the IMT intervention in the study group, the PEF was significantly increased from 271.67 ± 72.58 to 378.72 ± 54.55 L/min, and the FEV_1 increased significantly from 1.48 ± 0.37 to 2.11 ± 0.18 L ($p < .05$). Upon comparison of the study and control groups, statistically significant differences in the PEF and FEV_1 values were observed ($p < .05$) (Table 3).

Table 1. General characteristics of the participants

Variables	Study group (n = 6)	Control group (n = 6)	χ^2/t	p
Gender (male/female, %)	3/3 (50/50)	3/3 (50/50)	.000	1.000
Paretic side (right/left, %)	3/3 (50/50)	3/3 (50/50)	.000	1.000
Diagnosis (ICH/IS, %)	3/3 (50/50)	3/3 (50/50)	.000	1.000
Age (yr)	50.33 ± 14.10[a]	48.00 ± 17.09	.258	.802
Height (cm)	165.83 ± 7.89	167.50 ± 9.52	-.330	.748
Weight (kg)	60.47 ± 7.75	62.32 ± 12.72	-.304	.767
Duration (months)	16.17 ± 4.62	15.17 ± 3.92	.404	.695
MMSE-K (score)	29.00 ± 1.27	29.17 ± 0.75	-.277	.787
BMI (kg/m^2)	21.94 ± 1.33	21.99 ± 2.25	-.050	.961

[a]Mean ± standard deviation.
ICH, intracerebral hemorrhage; IS, ischemic stroke; MMSE-K, Mini-Mental State Examination-Korean version; BMI, body mass index.

Table 2. Comparison of the inspiratory function within and between groups

Variables	Study group (n=6)		Control group (n=6)		z	*p*
	Pre	Post	Pre	Post		
MIP (cmH_2O)	35.40±7.65[a]	52.69±9.80*	35.90±5.64	38.97±4.92*	-2.722	.006**
MIFR (L/sec)	1.88±0.58	3.11±0.56*	1.93±0.42	2.05±0.41*	-2.722	.006**
MIC (L)	1.00±0.19	1.34±0.25*	1.34±0.52	1.25±0.36	-2.242	.025*

MIP, maximum inspiratory pressure; MIFR, maximum inspiratory flow rate; MIC, maximum inspiratory capacity.
[a]Mean±standard deviation.
*$p<.05$, **$p<.01$.

Table 3. Comparison of the expiratory function within and between groups

Variables	Study group (n=6)		Control group (n=6)		z	*p*
	Pre	Post	Pre	Post		
PEF (L/min)	271.67±72.58[a]	378.72±54.55*	272.50±50.31	298.56±77.56*	-2.242	.025*
FEV_1 (L)	1.48±0.37	2.11±0.18*	1.70±0.77	1.79±0.91	-2.402	.016*

PEF, peak expiratory flow; FEV_1, forced expiratory volume in 1 second.
[a]Mean±standard deviation.
*$p<.05$, **$p<.01$.

Table 4. Comparison of BRP within and between groups

Variables	Study group (n=6)		Control group (n=6)		z	*p*
	Pre	Post	Pre	Post		
WDR (%)	19.45±10.25[a]	5.44±1.76*	13.53±4.44	11.82±4.64	-2.722	.006**
LOS (cm^2)	27.20±5.36	43.42±10.18*	36.43±30.07	40.36±30.76*	-2.082	.037*

BRP, BioRescue Platform; WDR, weight distribution ratio; LOS, limits of stability.
[a]Mean±standard deviation.
*$p<.05$, **$p<.01$.

4. Comparison of balance ability

After the IMT intervention in the study group, the WDR significantly decreased from 19.45%±10.25% to 5.44%±1.76% ($p<.05$), and the LOS significantly increased from 27.20±5.36 to 43.42±10.18 cm^2 ($p<.05$). Comparison of the study and control groups showed statistically significant differences in the WDR ($p<.01$) and LOS ($p<.05$) (Table 4).

DISCUSSION

This study was conducted on the effects of IMT on respiration and balance in patients with stroke. Twelve patients diagnosed with stroke were randomly classified into a study group and a control group.

One of the key components in stroke rehabilitation is IMT, which is mainly aimed at maintaining and restoring the pulmonary function [29]. IMT is one of the methods used to increase the respiratory muscle strength [30]. Pozuelo-Carrascosa et al. [22] reported that respiratory muscle strengthening was effective in improving the lung function parameters, exhalation and inhalation muscle strength, and walking ability in patients after stroke.

Sutbeyaz et al. [26] reported that a 6-week IMT program improved the function of the inspiratory muscle in patients with stroke. In a 9-week study conducted on patients with stroke, Britto et al. [31] reported that the inspiratory muscle exercise group showed improvement in MIP and endurance. Chen et al. [16] reported that in a study conducted on 21 patients with stroke, a difference in the MIP was noted compared with the control group when IMT was applied. Furthermore, Aydoğan et al. [32] showed statistically significant changes in the respiratory function and respiratory muscle variables in the group to which IMT was applied, and the MIP value significantly increased compared with that in the control group.

After the IMT intervention in this study, the MIP, MIFR, and MIC were significantly increased in the study group ($p<.05$). Comparison of the study and control groups showed statistically significant differences in MIP ($p<.01$), MIFR ($p<.01$), and MIC ($p<.05$). MIP is a direct measure of the inspiratory muscle strength and may detect respiratory muscle weakness before changes in the pulmonary function test [33]. As a

result, increasing the strength of the weakness of the inspiratory muscles through targeted training should increase their maximal force producing capacity, resulting in more activation of the diaphragm and thus increased MIP [34].

These results suggest that the respiratory muscle function of patients with stroke is improved by the IMT program conducted in this study.

Moreover, a study by Sutbeyaz et al. [26] showed that FEV1 and PEF were improved by the IMT program. Kim et al. [7] stated that in a study conducted on 20 patients with stroke, respiratory movements were statistically significant in FEV_1 and PEF compared with those in the control group.

Lower FEV_1 levels are associated with increased stroke risk and stroke recurrence rate [35]. Previous studies have shown that FEV1 is improved through IMT, suggesting that respiratory exercise may help reduce stroke recurrence [7].

PEF is reduced by approximately one-third in patients with stroke compared with that in healthy older adults [36]. Improved PEF values reflect an increase in muscle strength, reduce the risk of respiratory infections, and show improvement in expiratory function [26].

In this study, after the IMT intervention, the PEF and FEV_1 were significantly increased in the study group ($p<.05$). When compared with the control group, a statistically significant difference in the PEF and FEV_1 ($p<.05$) was observed. These results indicate that the expiratory function of patients with stroke was improved by the IMT program conducted in this study.

Jung et al. [37] reported that in patients with stroke, IMT improved the respiratory function and increased the trunk control and motor ability. In addition, Aydoğan et al. [32] stated that IMT for patients with stroke is an effective physical therapy program that contributes to the improvement of trunk control, balance, breathing, and functional ability. The results of this study are consistent with those of previous studies.

In this study, the WDR for balance ability measurement was significantly decreased ($p<.05$), and the LOS was significantly increased ($p<.05$). Comparison between the study and control groups showed statistically significant differences in the WDR ($p<.01$) and LOS ($p<.05$). The diaphragm, the primary inspiratory muscle, is one of the trunk stabilizers; impaired respiratory muscle activation in patients with stroke can reduce the trunk stability and mobility [12]. Previous study reported that the respiratory muscles play roles in trunk stability by covering the lower trunk and by increasing abdominal pressure, and respiratory muscle functions may also be negatively affected when the trunk muscles are weakened [38]. The IMT conducted in this study led to an improvement in the muscle strength of the respiratory muscles, including the diaphragm, in patients with stroke, which contributed to the stability of the trunk and improved the static and dynamic balance.

The respiratory functions and respiratory muscle strength of individuals with stroke were reported to be lower than healthy individuals [3]. After stroke, there may be alterations to the viscoelastic properties of muscles, causing contracture of the paralyzed side, in addition to rigidity of the thorax, which restrict with the biomechanical functioning of the thorax and may lead to loss of performance of the respiratory function and trunk [39]. Despite its clinical importance, few studies have been conducted on IMT for the improvement of balance ability along with respiratory function recovery.

This study has some limitations. First, as a preliminary study, it is difficult to generalize the results of the study due to the small sample size. We believe that despite the fact that the sample size was too small for generalization, the results provide a significant starting point for the future measurement of the relationship between IMT on respiration and balance in patients with stroke. Therefore, the results of this study must be confirmed with a larger sample size. Second, during the study period, it was difficult to control the participants' daily activities and other physical activities and interventions in rehabilitation. Lastly, the study period is short; therefore, a long-term perspective is needed.

CONCLUSION

In conclusion, IMT conducted in this study showed positive changes in the improvement of respiration and balance ability of patients with stroke. This study has limitations in providing statistical significance due to the small sample size. However, when comparing the amount of change before and after the IMT intervention, a significant level of change is found. Future randomized controlled studies incorporating IMT of individuals after stroke with large sample size would provide insight into the effectiveness and clinical relevance of this intervention. This suggests that the IMT conducted in this study is a useful and effective therapeutic intervention for health care in patients with stroke. Furthermore, this will serve as a basis for further research in the future.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

AUTHOR CONTRIBUTIONS

Conceptualization: WN Chang; Data curation: KB An; Formal analysis: KB An; Funding acquisition: KB An, HJ Jeon and WN Chang; Methodology: HJ Jeon; Project administration: HJ Jeon; Visualization: WN Chang; Writing-original draft: KB An; Writing-review & editing: HJ Jeon and WN Chang.

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