Effects of Diaphragm Breathing Training Through Visual Feedback on Diaphragm Movement and Lung Function in Normal Women

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Purpose: This study aimed to investigate the effects of diaphragmatic breathing training with visual feedback on diaphragm movement and lung function in healthy women. **Methods:** A randomized controlled trial was conducted with the participation of 20 healthy college-aged women without any underlying physical conditions. The participants were randomly assigned into two groups: the intervention group that received diaphragmatic breathing training with visual feedback and the control group that underwent sham training without visual feedback. Diaphragmatics movement were assessed through respiratory motion analysis, and lung function was measured using spirometry before and after the training period. Data analysis included a paired t-test to compare within-group differences and an independent t-test to compare the effects between the two groups. **Results:** In both groups, diaphragmatic movement significantly increased after the intervention ($p<.05$). In addition, the intervention group that received visual feedback exhibited significant improvements in forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), and diaphragm movement ($p<.05$). However, the control group without visual feedback demonstrated only a significant increase in diaphragm movement ($p<.05$). Furthermore, the intervention group showed a significantly greater increase in FVC than the control group. **Conclusion:** This study reveals that incorporating visual feedback into diaphragmatic breathing training can effectively enhance diaphragmatic movement and improve lung function in healthy women. These findings suggest the potential benefits of visual feedback in optimizing the benefits of diaphragmatic breathing exercises. These results have implications for respiratory rehabilitation, stress reduction, and overall well-being in the general population. More studies are recommended to explore the long-term effects of diaphragmatic breathing training with visual feedback and its application in clinical populations with respiratory disorders.

Key words: Visual Feedback, Diaphragmatic, Breathing, Function, Movement

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Ⅰ. Introduction

The respiratory system is a crucial physiological component responsible for facilitating respiration in the human body. It comprises various structures, including the nose, trachea, bronchi, and lungs, which play a vital role in the exchange of oxygen and carbon dioxide. Respiratory diseases primarily affect the bronchial and pulmonary structures, as well as organs involved in respiration such as the nasal cavity, pharynx, larynx, trachea, bronchi, lungs, rib cage, and diaphragm. These conditions often manifest through symptoms such as coughing, sputum production, dyspnea, chest pain, and hemoptysis(Wheeldon, 2023).

Restrictive pulmonary diseases, characterized by reduced lung volumes compared to healthy individuals, lead to diminished lung capacity, inspiratory capacity, and total lung capacity. These conditions result from decreased lung extensibility, causing chronic underinflation and permanent pulmonary restriction(Naji et al., 2006). In contrast, obstructive pulmonary diseases obstruct normal airflow by narrowing or blocking the bronchial airways. Exhalation becomes more challenging than inspiration in these cases, resulting in increased functional residual capacity and residual volume. Common symptoms observed in patients with restrictive and obstructive pulmonary diseases include dyspnea, chronic cough, tachypnea, anxiety, unintended weight

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loss, and impaired respiratory function (Salhi et al., 2010).

Individuals with limited inspiratory capacity often benefit from training interventions aimed at strengthening the inspiratory muscles. Inspiratory muscle training has been associated with notable reductions in blood pressure, improvements in cardiovascular health, enhanced cognitive function, and increased physical activity levels(Kang et al., 1998).

Among the inspiratory muscles, the diaphragm assumes a prominent role(Jeon et al., 2010). Its contraction and descent during inhalation create additional space within the thoracic cavity, facilitating optimal lung expansion. Furthermore, the movement of the diaphragm influences the surrounding musculature and contributes to the maintenance of proper spinal alignment.

The primary objective of inspiratory muscle strengthening training is to enhance diaphragmatic function by promoting abdominal or diaphragmatic breathing during inhalation. This form of training has demonstrated efficacy in improving respiratory function, cardiorespiratory capacity, daily activities, quality of life, alleviating dyspnea, and enhancing endurance. Breathing training incorporating visual feedback has emerged as a simple and cost-effective method. It not only stimulates interest and engagement during training but also facilitates efficient treatment. Visual feedback-based training fosters an active mindset, promotes goal achievement, and enhances adherence to the training protocol(So et al., 2012). Numerous previous studies have reported positive effects of visual feedback, including improved respiratory muscle strength, exercise capacity, and quality of life in patients with chronic obstructive pulmonary disease who underwent breathing strengthening exercises with the aid of visual feedback equipment(Koppers et al., 2006; Lee et al., 2014).

Despite the considerable research on visual feedback, limited attention has been given to its impact on diaphragm movement. Specifically, studies investigating changes in diaphragmatic motion following breathing training that incorporates real-time ultrasound imaging as visual feedback are scarce. Ultrasound imaging offers advantages in terms of rapid and efficient measurement of diaphragm movement, providing insights into muscle activation patterns and changes in thickness during respiratory cycles(Baldwin et al., 2011). Previous studies employing ultrasonography technology have actively explored the application of real-time feedback for retraining purposes(Kwon et al., 2011).

Furthermore, it is worth noting that adult women, who predominantly engage in thoracic breathing patterns and underutilize diaphragmatic breathing, often exhibit lower respiratory function compared to men(Enright et al., 2006).

Therefore, the primary objective of this study is to investigate the effectiveness of visual feedback in improving diaphragm movement and respiratory function in adult women. Specifically, we aim to compare the acute effects of diaphragmatic breathing exercise with and without visual

Ⅱ. Methods

1. Participants

This study involved a total of 20 healthy adult female students, aged between 20 and 25 years, recruited from S University in Asan City. Prior to their participation, all subjects received comprehensive explanations regarding the study's objectives and methodology. Only individuals without any respiratory-related diseases were eligible to participate, and informed consent was obtained from all participants. Exclusion criteria included individuals who had undergone surgery within the past 3 months, individuals with a medical history, diagnosis, or family history of anemia or orthostatic hypotension, and individuals with known or suspected cardiopulmonary conditions. Ethical approval for the study was obtained from the Institutional Review Board (IRB) of Sunmoon University. Detailed information regarding the experiment's purpose and research methods was provided to all subjects, and their characteristics are presented in Table 1.

Table 1. General characteristics of participants (n=20)

	Visual feedback (n=10)	Non-Visual feedback (n=10)
Age (year)	20.7±0.15	20.4±0.51
Height (cm)	161.6±1.88	162.5±1.12
Weight (kg)	54.1±1.95	56.3±2.15
Smoking	1	2

* Mean ± Standard Deviation

2. Experiment Procedures

The experimental procedures were conducted with the participants in a supine position. The diaphragmatic breathing training method involved specific steps: inhalation through the nose, elevation of the ribs, and protrusion of the abdomen. During inhalation, the diaphragm was contracted, causing the organs in the abdominal cavity to descend into the pelvic cavity. Inhalation was performed with pursed lip breathing, focusing on expanding the abdomen. During exhalation, participants released the force from their abdomen and expelled air with a deep breath. The lower ribs, abdomen, and diaphragm were then returned to their original positions, pushing the organs in the pelvic cavity upward. This diaphragmatic breathing technique activated the muscles from the diaphragm to the pelvic floor, ensuring spinal stability.

1) Non-Visual Feedback

The group without visual feedback performed diaphragmatic breathing exercises without visual observation of the abdomen. The visual aspect of the ongoing breathing process was completely obstructed, and if necessary, an eye patch was utilized to prevent visibility of abdominal movement.

2) Visual Feedback

The group with visual feedback assumed a supine position and placed a water bottle on their abdomen. One hand held the base of the water bottle, anchoring it to the abdomen, while the other hand was placed on the chest to monitor chest movement. Visual feedback was provided by observing the movement of the water bottle cap.

3. Measurements

1) Diaphragm and Intercostal Movement Distance (Ultrasound)

To measure the changes in diaphragm movement before and after diaphragmatic breathing exercises, a B-mode ultrasound imaging technique was employed using a round probe (eZono® 3000). The participants were positioned in a supine posture with their hip and knee joints flexed, and the area between the 8th and 9th ribs was scanned using the ultrasound probe positioned perpendicular to the body. For optimal visualization of the diaphragm during a single breath, the probe was positioned horizontally in the intercostal space between the lower ribs(Epelman et al., 2005). Measurements were performed on the right side of the body three times, and the average value was calculated from these repeated measurements. The use of ultrasound for measuring diaphragm motion has been demonstrated to exhibit high intra-measurement reliability, with a correlation coefficient (r) of 0.99(figure 1).

2) Lung Capacity(Spirometer)

Lung capacity measurements, including vital capacity, pulmonary ventilation, forced vital capacity (FVC), forced expiratory volume per second (FEV_1), and peak expiratory volume (PEF), were performed using a spirometer. Prior

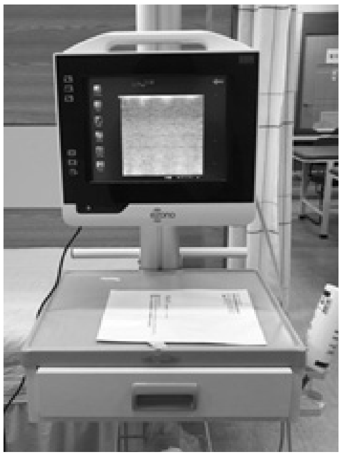

Fig 1. ultrasonography

Fig 2. Spirometer

to the measurements, the subjects were provided with a comprehensive explanation of the experiment's objectives and methodology.

During the measurement procedure, all participants were seated in an upright position and instructed to hold the spirometer's mouthpiece firmly. They were then directed to take 3 to 4 normal breaths, followed by a forceful inhalation, and subsequently exhale as forcefully and completely as possible within a 6-second timeframe. To ensure accurate measurements, participants were given 1 or 2 practice attempts with the spirometer to familiarize themselves with the procedure.

FVC, FEV_1, and PEF were measured three times for each participant, and the average values were used for subsequent analysis. To mitigate the potential impact of fatigue, a 1-minute rest period was provided between each measurement. The respiratory data were recorded accordingly(figure 2).

4. Data Analysis

Statistical analysis was conducted using SPSS version 24.0. Normality was assessed through the Shapiro-Wilk test to ensure the normal distribution of data. Independent t-tests were performed to examine the homogeneity of the subjects' general characteristics. Inter-group comparisons were analyzed using independent t-tests, while paired t-tests were employed for intra-group comparisons. The statistical significance level was set at a 95% confidence level.

Ⅲ. Results

In the group that received visual feedback, there were significant increases in Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), and diaphragm movement (p<.05). These findings suggest that the application of visual feedback during diaphragmatic breathing exercise had a positive impact on respiratory function, as indicated by improvements in FVC, FEV_1, and diaphragm movement.

On the other hand, in the non-visual feedback group, only the movement of the diaphragm showed a significant increase (p<.05). This suggests that the diaphragmatic breathing exercise alone, without the aid of visual feedback, primarily affected the diaphragm movement.

The results revealed a statistically significant difference in FVC between the group that received visual feedback

Table 2. Comparison of pulmonary function

		Visual feedback	Non-Visual feedback	t	p
FVC	PRE	2.28±.82	3.31±.37	−1.64	0.06
	POST	3.37±.64	3.35±.39	0.08	0.17
	Difference	0.53±.42	0.03±.17	3.39	0.02
	t	−3.91	−0.77		
	p	0.00	0.45		
FEV_1	PRE	2.07±.50	2.41±.52	−1.44	0.78
	POST	2.58±.48	2.84±.53	−0.51	0.49
	Difference	0.51±.60	0.30±.75	0.67	0.87
	t	−2.65	−1.27		
	p	0.02	0.23		
PEF	PRE	43.75±1.12	43.90±1.85	−0.22	0.34
	POST	4.02±1.35	3.65±2.05	0.23	0.94
	Difference	0.27±1.67	−0.48±.93	−0.52	0.07
	t	-0.51	0.16		
	p	0.61	0.87		

*p<0.05, mean ± standard deviation, FVC: Forced vital capacity, FEV_1: Forced expiratory volume in 1 second, PEF: Peak expiratory flow

Table 3. Comparison of diaphragm movement

		Visual feedback	Non-Visual feedback	t	p
Diaphragm (cm)	PRE	0.98±.68	1.29±1.12	−0.74	0.36
	POST	1.62±.95	1.70±1.15	−0.16	0.54
	Difference	0.64±.62	0.41±.35	1.01	0.08
	t	−3.24	−3.62		
	p	0.01	0.00		

*$p<0.05$, mean ± standard deviation

and the non-visual feedback group. This indicates that the application of visual feedback during diaphragmatic breathing exercise had a greater impact on improving FVC compared to the exercise without visual feedback.

Overall, these findings suggest that diaphragmatic breathing training with visual feedback can lead to significant improvements in FVC, FEV_1, and diaphragm movement, while exercise without visual feedback primarily enhances diaphragm movement. The incorporation of visual feedback in diaphragmatic breathing exercises may be an effective approach to optimize respiratory function in normal women.

Ⅳ. Discussion

This study aimed to compare the acute effects of diaphragmatic breathing exercise on FVC, FEV_1, PEF, and diaphragm movement, according to the application of visual feedback, in a group of 20 healthy adult women. The results of the study showed that in the group to which visual feedback was applied, there were significant increases in FVC, FEV_1, and diaphragm movement, while PEF showed a non-significant increase. In the group without visual feedback, there were increases in FVC, FEV_1, and PEF, but they were not statistically significant. Only the movement of the diaphragm showed a significant improvement in this group. Furthermore, there was a significant difference in FVC between the group with visual feedback and the group without visual feedback.

These findings are consistent with previous studies which suggest that providing visual feedback enhances the correct contraction of the diaphragm, improves the diaphragmatic breathing pattern, and increases efficiency(Nam et al., 2017; Kim and Hwang, 2008). Visual feedback also aids in the proper activation of deep muscles, resulting in improved muscle training efficiency(Baweja et al, 2011). The significant improvement in diaphragm movement observed when visual feedback was applied aligns with these previous findings. In this study, as inspiratory muscle training was primarily focused on the inspiratory muscles, it is assumed that there would be a greater increase in inspiratory capacity compared to when inspiratory training without feedback was provided. This study demonstrated similar results to the research conducted(Ramssok et al., 2016).

The significant improvement in FVC in the group with visual feedback can be attributed to the relationship between FVC and diaphragm movement during respiration, as described in a study(Nam et al., 2017). The smooth contraction of the diaphragm enhances respiratory control, coughing ability, and lung capacity. Therefore, the significant increase in diaphragm movement observed with visual feedback application likely contributed to the improvement in FVC. Furthermore, the improved FVC values in this study are attributed to the inspiratory training utilizing the diaphragmatic breathing technique, enabling participants to inhale a greater volume of air during inspiration. Similar results were reported in a study (Yun et al., 2016). In a previous study, similar to our research, it was observed that respiratory muscle training, both inspiratory and expiratory, improved pulmonary function in patients with neurological disorders. This aligns with the results of our current study, where inspiratory muscle training showed similar improvements(Lee et al., 2014).

However, this study observed some differences in results compared to previous research. The reason for this variance might be attributed to the simplified feedback training applied in our study, where hands were placed on the abdomen and chest to provide basic feedback on movement. This approach, compared to the real-time feedback used in previous studies(Nam et al., 2017), could have resulted in somewhat constrained outcomes.

In this study, a shorter training period was applied compared to previous research. It is anticipated that future studies will necessitate a long-term investigation of 4 weeks or more. The brief exercise duration in the current study is believed to be insufficient for inducing substantial changes in muscles and nerves. In this study, a shorter training period was applied compared to previous research. It is anticipated that future studies will necessitate a long-term investigation of 4 weeks or more. The brief exercise duration in the current study is believed to be insufficient for inducing substantial changes in muscles and nerves. Therefore, for future research, a more extended training duration for participants is deemed necessary. Future research should address the study's limitations, such as the small sample size, limited generalizability, and the necessity for long-term follow-up to assess the sustained effects of the intervention.

Ⅴ. Conclusion

Therefore, this study investigated the impact of diaphragmatic breathing exercises with and without visual feedback on lung function and diaphragm movement. The utilization of visual feedback resulted in notable enhancements in FVC, FEV_1, and diaphragm movement. In the absence of visual feedback, only diaphragm movement exhibited a significant improvement. Moreover, visual feedback proved more effective in enhancing FVC compared to non visual feedback. These findings suggest that visual feedback can augment the efficacy of breathing training, especially for individuals with compromised lung function in clinical contexts.

Reference

Baldwin CE, Paratz JD, Bersten AD. Diaphragm and peripheral muscle thickness on ultrasound: intra-rater reliability and variability of a methodology using non-standard recumbent positions. Respirology, 16(7);1136-1143, 2011.

Baweja HS, Patel BK, Neto OP, et al. The interaction of respiration and visual feedback on the control of force and neural activation of the agonist muscle. Hum Mov Sci, 30(6);1022-1038, 2011.

Epelman M, Navarro OM, Daneman A, et al. M-mode sonography of diaphragmatic motion: description of technique and experience in 278 pediatric patients. Pediatr Radiol, 35(7);661-667, 2005.

Enright SJ, Unnithan VB, Heward C, et al. Effect of high-intensity inspiratory muscle training on lung volumes, diaphragm thickness, and exercise capacity in subjects who are healthy. Phys Ther, 86(3);345-354, 2006.

Jeon YJ, Oh DW, Kim KM, et al. Comparison of the effect of inhalation and exhalation breathing exercises on pulmonary function of patients with cervical cord injury. Phys Ther Korea, 17(1);9-16, 2010.

Kang SW, Na YM, Baek SK, et al. Clinical implications of inspiratory muscle training in patients with duchenne muscular dystrophy, Ann Rehabil Med, 22(2);361-368, 1998.

Kim JH, Hwang BY. Comparison of diaphragm movement between patients with left hemiplegia and right hemiplegia. J Korean Bobath Assoc, 13(1);20-25, 2008.

Koppers RJ, Vos PJ, Boot CR, et al. Exercise performance improves in patients with COPD due to respiratory muscle endurance training. Chest. 129(4);886-892, 2006.

Kwon NH, Lee HO, Park DJ. The use of real time ultrasound imaging for feedback during abdominal hollowing. J Korean Soc Phys Med, 6(3);303-310, 2011.

Lee HY, Cha YJ, Kim K. The effect of feedback respiratory training on pulmonary function of children with cerebral palsy: a randomized controlled preliminary report. Clin Rehabil, 28(10);965-971, 2014.

Naji NA, Connor MC, Donnelly SC, et al. Effectiveness of pulmonary rehabilitation in restrictive lung disease. J Cardiopulm Rehabil, 26(4);237-243, 2006.

Nam SJ, Shim JH, Oh DW. Effects of Diaphragmatic Breathing Training Using Real-time Ultrasonography on Chest Function in Young Females With Limited Chest Mobility. Phys Ther Korea, 24(2);27-36, 2017.

Ramsook AH, Koo R, Molgat-Seon Y, et al. Diaphragm

Recruitment Increases during a Bout of Targeted Inspiratory Muscle Training. Med Sci Sports Exerc, 48(6);1179-1186, 2016.

Salhi B, Troosters T, Behaegel M, et al. Effects of pulmonary rehabilitation in patients with restrictive lung diseases. Chest, 137(2);273-279, 2010.

So MW, Heo HM, Koo BS, et al. Efficacy of incentive spirometer exercise on pulmonary functions of patients with ankylosing spondylitis stabilized by tumor necrosis factor inhibitor therapy. J Rheumatol, 39(9);1854-1858, 2012.

Wheeldon A. The respiratory system and associated disorders. Br J Nurs, 32(13);613-619, 2023.

Yun HS, Kim SY, Jeon HJ, et al. The effect of transverse abdominal muscle contraction with visual feedback on lung function in healthy adults. Journal of Korean Society of Integrative Medicine, 4(2);23-28, 2016.