

The role of visual feedback in respiratory muscle activation and pulmonary function

HAN-KYU PARK, PT, MSc¹⁾, YEONG-JU KIM, PT²⁾, TAE-HO KIM, PT, PhD^{3)*}

¹⁾ Department of Physical Therapy, Graduate School of Rehabilitation Science, Daegu University, Republic of Korea

²⁾ Department of Physical Therapy, Graduate School of Clinical Pharmacy and Health, Kyungsung University, Republic of Korea

³⁾ Department of Physical Therapy, College of Rehabilitation Science, Daegu University: 201 Daegudae-ro, Jillyang, Gyeongsan, Gyeongbuk, Republic of Korea

Abstract. [Purpose] It is well known that visual feedback is an important factor contributing to balance and postural control. Nevertheless, there has been little discussion about the effects of visual feedback on pulmonary function. This study was conducted to investigate the role of visual feedback on respiratory muscle activation and pulmonary function. [Subjects and Methods] The subjects were 37 healthy adults who consented to participate in this study. The study measured the muscular activation of the trunk and pulmonary function according to the absence or presence of visual feedback. [Results] The results revealed significant changes in muscular activation and pulmonary function with the use of visual feedback. [Conclusion] These findings suggest that visual feedback may play a role in increasing respiratory muscle activity and pulmonary function.

Key words: Visual feedback, Respiratory muscles, Pulmonary function

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INTRODUCTION

The abdominal muscles are thought to both modulate and respond to changes in intra-abdominal pressure (IAP) with the diaphragm¹⁾. Currently, increases in IAP have been shown to occur as a reflex response to external stresses placed on the lumbar spine. Therefore, co-contraction of the abdominal muscles regulates IAP, fixes the trunk, and reduces the stress on the lumbar region²⁾. Moreover, cardiorespiratory activities may interrupt postural stability. In other words, when the respiratory demand increases, deeper and faster rib cage movements lead to greater postural sway. At this time, abdominal muscles contribute to postural stability and also contribute significantly to breathing³⁾. During periods of increased IAP such as in the case of breathing, in particular, anterolateral abdominal muscles and the diaphragm work to control changes in IAP⁴⁾. McGill et al.⁵⁾ reported that the trunk muscles are recruited to stabilize the lumbar spine and may assist in the mechanics of ventilation. Thus, the abdominal core muscles modulate changes in IAP, contribute to respiration, and provide trunk stability during changes in posture, walking, talking, and breathing⁶⁾. Indeed, abdominal muscles are thought to contribute to res-

piration, particularly when the oxygen demand is increased by maximal ventilation³⁾.

In general, trunk stability and postural control are dependent upon the integration of information from the proprioceptive, vestibular, and visual sensory systems. These three sensory systems have different operating frequency ranges that affect their influence on postural control in different situations. For example, extremely low frequencies of sway are best stabilized by vision. Somatosensation can assist in sensing a wide variety of movements. The vestibular system is thought to have a sensory threshold in a standing posture⁷⁾. The central nervous system uses two main postural strategies to maintain and restore balance. The first one, anticipatory postural adjustments (APAs), controls the position of the center of mass (COM) of the body by activating the trunk and leg muscles prior to a forthcoming body perturbation⁸⁾. The second, compensation postural adjustments (CPAs), serve as a mechanism of restoration of the position of the COM after a perturbation has already occurred. These two mechanisms have been shown to be effective in maintaining and restoring balance⁹⁾.

Vision plays an important role in the generation of APAs and increases postural stability¹⁰⁾. When people stand with their eyes closed or have vision problems, postural sway increases by 20–70%¹¹⁾. Vando et al.¹²⁾ suggests that postural control in normal healthy persons is highly related to the ability to access visual information. Poor vision can have powerful effects on balance and can cause postural changes, imbalance, and a decrease in motion in healthy adults⁶⁾. Many previous studies have focused on APAs or posture changes and imbalance. However, there is a lack of

*Corresponding author. Tae-Ho Kim (E-mail: ptkimth@daegu.ac.kr)

studies on using visual feedback to determine vital capacity. This study aimed to identify the role of visual feedback in changes in abdominal muscle activation, which largely affect stability, maintenance of posture, and vital capacity.

SUBJECTS AND METHODS

The subjects of this study were 37 healthy adults (18 males and 19 females). They were provided with a verbal explanation of the study method and purpose, and written informed consent was received from each subject. The characteristics of the subjects were as follows: age, 24.4 ± 2.1 years; height, 170.0 ± 8.5 cm; weight, 62.5 ± 9.8 kg. All the participants had normal vision, and individuals with musculoskeletal or nervous problems, lung diseases, or lower back pain and smokers were excluded. This study was approved by the Daegu University Institutional Review Board and in accordance with the ethical principles of the Declaration of Helsinki.

In this study, a spirometer (Spiropalm, A-M Systems, Carlsborg, WA, USA) was used to examine vital capacity. The measured variables were as follows: forced vital capacity (FVC) and maximum voluntary ventilation (MVV). Vital capacity was measured according to the guidelines of the American Thoracic Society¹³. This study was conducted with randomized trials, to avoid overlapping of results according to test sequence, on 2 different days with an interval of one day (in consideration of the subjects' muscle fatigue). Measurements were conducted in the same way. However, in the experiments without visual feedback, the researcher provided a sufficient explanation so that the subjects would better understand the experiment. In the case of experiments with visual feedback, the subjects were given a detailed explanation about the shapes of the graphs for FVC and MVV to ensure their understanding. This information was also displayed on a screen using a beam projector. The experiment methods were as follows: The subjects were asked to sit comfortably on a chair, and a researcher placed his hands on their shoulders (to reduce the compensation by the trunk). A clip was placed to prevent breathing through the nose. The subjects were then asked to breathe out through their mouth carefully while holding a mouthpiece to prevent air from leaking. For FVC measurement, the subjects were told to hold their heads slightly upwards while sitting upright, breathe in and out normally two or three times, and then breathe in deeply for 2 seconds. The subjects then were asked to breathe out as much air as possible for 6 seconds while maintaining an upright posture. For MVV measurement, the subjects were asked to breathe as quickly and deeply as possible at a ratio of 90–110 times/min for 12 seconds. An electromyograph (EMG) (TeleMyo DTS, Noraxon, Scottsdale, AZ, USA) was used to measure the muscle activities of the trunk. EMG data were band-pass filtered between 20 Hz and 400 Hz and filtered with a notch filter at 60 Hz. The sampling rate for the signals was set to 1,000 Hz. Collected data were analyzed after calculating root mean square (RMS) values. Reference voluntary contraction (RVC) was used for standardization of EMG. In this method, the muscle contraction of a particular movement was standardized relative to the RVC. Baseline EMG activity was recorded for 3

seconds in a sitting position before the measurements. EMG data for FVC were recorded for 6 seconds immediately after breathing in deeply for 2 seconds, and EMG data for MVV were recorded for 12 seconds while breathing in as deeply as possible. The average of three measurements was used to avoid biased results. Surface electrodes were attached to muscle fibers in a line as follows: in the case of the rectus abdominis (RA), 1 cm lateral from and 2 cm below the umbilicus; in the case of the internal abdominal oblique (IO), 2 cm medial from and 2 cm below the anterior superior iliac spine (ASIS), in the case of the external abdominal oblique (EO), along the line connecting the opposite pubic tubercle and the most inferior costal margin on the inferior margin in a diagonal direction¹⁴, and in the case of the sternocleidomastoid (SCM), over the muscle's belly¹⁵. Surface EMG electrodes were placed on the right side of the abdomen. In order to reduce skin resistance, excessive hair was removed from the skin, the corneum was removed by rubbing the skin with a piece of sandpaper, and the skin was cleaned with disinfectant alcohol. Three values were recorded, and the average value was used in the analyses. A five-minute rest was given after every trial to prevent muscle fatigue.

A paired t-test was conducted to examine the effects of respiratory muscle activation and pulmonary function with visual feedback. The significance level was set to $p < 0.05$ for the statistical analysis, and the collected data were analyzed using the SPSS 21.0 for Windows.

RESULTS

Comparison of respiratory muscle activation and pulmonary function according to use of visual feedback revealed that FVC, FEV₁, PEF, and MVV had increased with the use of visual feedback ($p < 0.05$) (Table 1). Activation of the SCM, RA, EO, and IO increased during both the FVC and MVV tests with the use of visual feedback ($p < 0.05$) (Table 2).

DISCUSSION

Vision collects information about the surrounding environment. It constantly provides the central nervous system with information about the location and movement of the body segments, and it helps to maintain balance¹⁰. Thus, measurements were conducted to determine how vision affects the abdominal muscles and whether or not it has any correlation with vital capacity.

The abdominal muscles act as respiratory muscles and play a significant role in stabilizing the trunk and controlling its balance, both of which are important in maintaining APAs¹⁶. Trunk stability is achieved through the cooperative contraction of both the flexor and extensor trunk muscles, which increases IAP. Because the spring force of the abdomen is created by increasing the IAP¹⁷, the trunk muscles can stabilize the spine, especially the lumbar spine, and affect ventilation¹⁸. Currently, the abdominal muscles are thought to affect vital capacity by forming functional kinetic chains with the diaphragm, multifidus, muscles surrounding the abdominal muscles, and pelvic floor muscles (PFMs)¹⁹. Kim and Lee²⁰ suggested that strengthening the abdominal

Table 1. Comparison of pulmonary function according to the absence or presence of visual feedback (N=37)

Variables	No feedback	Feedback
FVC	3.8±0.9 ^a	4.0±0.9*
FEV ₁	3.1±0.8	3.3±0.8*
PEF	6.6±2.5	7.1±2.4*
MVV (l/min)	130.6±43.0	140.2±43.4*

^aMean±SD. *p<0.05

FVC: forced vital capacity; FEV₁: forced expiratory volume in one second; PEF: peak expiratory flow; MVV: maximum voluntary ventilation

muscles would increase diaphragm activity and promote cooperative contraction of the muscles surrounding the abdominal muscles, which would result in increased IAP, thus affecting the pulmonary capacity. The correlation with vital capacity was also verified in studies that observed contraction of the PFM, diaphragm, and muscles surrounding the abdominal muscles resulting in an increase in the IAP²¹). It has also been suggested that abdominal muscles contract in cooperation with the diaphragm and increase the IAP to affect vital capacity²²). In a situation that requires a lot of oxygen, such as exercise, the abdominal muscles are incrementally activated. They contribute to modulation of the expiratory lung volume and expiratory flow and assist inspiration by regulating the length of the diaphragm. Furthermore, the abdominal muscles are broadly regarded as the principal muscles of active expiration and contribute to respiration²³). Previous studies have reported respiratory-related abdominal muscles activity thresholds for minute ventilation equal to or greater than before^{3, 23}).

This study confirmed that the use of visual feedback increased the overall vital capacity and activation of respiratory muscles in the subjects. The results showed increased activity of the abdominal muscles, particularly the IO muscle, which generally reacts in APAs in response to visual feedback. This muscle provides the spine with proper stability and protection around the lumbar region in the case of increased IAP. Unlike the other abdominal muscles, the IO is closely associated with changes in IAP¹⁶). Therefore, the abdominal muscles first contract for APAs in response to visual feedback and then contract to provide spinal stability in response to increased IAP caused by breathing. The results of this study showed a correlation with vital capacity. Therefore, the abdominal core muscles both provided spinal stability and acted as respiratory muscles by increasing the contraction when breathing increased. Drăgoi et al.²⁴) suggested that vital capacity and chest expansion were increased by the respiratory movement of the abdominal muscles and the diaphragm. Brown et al.²⁵) confirmed that both vital capacity and use of the respiratory muscles increased after the latter were trained. The present study also found that by using visual feedback, it was possible to increase vital capacity as well as the use of muscles surrounding the abdominal muscles. The results showed also increased activity of the SCM. The SCM is an important accessory muscle of inspiration and becomes active during ventilation at high lung volumes and elevated levels of inspiration work.

Table 2. Comparison of respiratory muscle activation according to the absence or presence of visual feedback (N=37)

Variables	No feedback	Feedback
Muscle activation of FVC (%RVC)	SCM 259.9±74.3 ^a RA 249.3±231.6 EO 347.8±82.7 IO 409.4±187.2	318.3±123.0* 285.0±261.1* 453.1±93.9* 523.8±336.6*
Muscle activation of MVV (%RVC)	SCM 762.2±272.3 RA 270.6±99.9 EO 446.1±93.7 IO 636.5±414.0	1,132.5±402.6* 363.9±203.5* 705.3±206.8* 746.0±605.9*

^aMean±SD. *p<0.05

SCM: sternocleidomastoid; RA: rectus abdominis; EO: external abdominal oblique; IO: internal abdominal oblique

So the results of this study confirmed that SCM recruitment was increased during FVC and MVV maneuvers²⁶). Shadgan et al.²⁷) also reported that the SCM is progressively activated when breathing increased. Consequently, the findings showed that visual feedback affected vital capacity by cooperative contractions of the respiratory muscles, which stabilized the body as APAs. However, the present study has the following limitation. Because the study was conducted to observe the immediate effects of visual feedback in normal adults, it did not identify the correlation of the effects of the intervention in patients. Therefore, further research should be conducted to identify increases in vital capacity and the strength of respiratory muscles through visual feedback training in patients with lung disease.

REFERENCES

- Ratnovsky A, Elad D, Halpern P: Mechanics of respiratory muscles. *Respir Physiol Neurobiol*, 2008, 163: 82–89. [Medline] [CrossRef]
- Allison GT, Kendle K, Roll S, et al.: The role of the diaphragm during abdominal hollowing exercises. *Aust J Physiother*, 1998, 44: 95–102. [Medline] [CrossRef]
- David P, Terrien J, Petitjean M: Postural- and respiratory-related activities of abdominal muscles during post-exercise hyperventilation. *Gait Posture*, 2015, 41: 899–904. [Medline] [CrossRef]
- Hodges PW, Sapsford R, Pengel LH: Postural and respiratory functions of the pelvic floor muscles. *NeuroUrol Urodyn*, 2007, 26: 362–371. [Medline] [CrossRef]
- McGill SM, Sharratt MT, Seguin JP: Loads on spinal tissues during simultaneous lifting and ventilatory challenge. *Ergonomics*, 1995, 38: 1772–1792. [Medline] [CrossRef]
- Talasz H, Kofler M, Kalchschmid E, et al.: Breathing with the pelvic floor? Correlation of pelvic floor muscle function and expiratory flows in healthy young nulliparous women. *Int Urogynecol J Pelvic Floor Dysfunct*, 2010, 21: 475–481. [Medline] [CrossRef]
- Redfern MS, Yardley L, Bronstein AM: Visual influences on balance. *J Anxiety Disord*, 2001, 15: 81–94. [Medline] [CrossRef]
- Massion J: Movement, posture and equilibrium: interaction and coordination. *Prog Neurobiol*, 1992, 38: 35–56. [Medline] [CrossRef]
- Aruin AS, Kanekar N, Lee YJ, et al.: Enhancement of anticipatory postural adjustments in older adults as a result of a single session of ball throwing exercise. *Exp Brain Res*, 2015, 233: 649–655. [Medline] [CrossRef]
- Mohapatra S, Aruin AS: Static and dynamic visual cues in feed-forward postural control. *Exp Brain Res*, 2013, 224: 25–34. [Medline] [CrossRef]
- Tomomitsu MS, Alonso AC, Morimoto E, et al.: Static and dynamic postural control in low-vision and normal-vision adults. *Clinics (Sao Paulo)*, 2013, 68: 517–521. [Medline] [CrossRef]
- Vando S, Haddad M, Masala D, et al.: Visual feedback training in young karate athletes. *Muscles Ligaments Tendons J*, 2014, 4: 137–140. [Medline]

- 13) American Thoracic Society: Standardization of Spirometry, 1994 Update. *Am J Respir Crit Care Med*, 1995, 152: 1107–1136. [[Medline](#)] [[CrossRef](#)]
- 14) Cram JR, Kasman GS, Holtz J: Introduction to surface electromyography. Gaithersburg: Aspen Publishers, 1998.
- 15) Wytrzązek M, Huber J, Lipiec J, et al.: Evaluation of palpation, pressure algometry, and electromyography for monitoring trigger points in young participants. *J Manipulative Physiol Ther*, 2015, 38: 232–243. [[Medline](#)] [[CrossRef](#)]
- 16) Silfies SP, Mehta R, Smith SS, et al.: Differences in feedforward trunk muscle activity in subgroups of patients with mechanical low back pain. *Arch Phys Med Rehabil*, 2009, 90: 1159–1169. [[Medline](#)] [[CrossRef](#)]
- 17) Panjabi M, Abumi K, Duranceau J, et al.: Spinal stability and intersegmental muscle forces. A biomechanical model. *Spine*, 1989, 14: 194–200. [[Medline](#)] [[CrossRef](#)]
- 18) Richardson CA, Jull GA: Muscle control-pain control. What exercises would you prescribe? *Man Ther*, 1995, 1: 2–10. [[Medline](#)] [[CrossRef](#)]
- 19) Akuthota V, Nadler SF: Core strengthening. *Arch Phys Med Rehabil*, 2004, 85: S86–S92. [[Medline](#)] [[CrossRef](#)]
- 20) Kim E, Lee H: The effects of deep abdominal muscle strengthening exercises on respiratory function and lumbar stability. *J Phys Ther Sci*, 2013, 25: 663–665. [[Medline](#)] [[CrossRef](#)]
- 21) Park HK: The effects of pelvic floor muscle contraction on pulmonary function and diaphragm activity. Unpublished master's thesis, Silla University, Busan, Republic of Korea, 2014.
- 22) Micheal S, Erik S, Udo S: Thieme-Atlas of Anatomy. New York: Thieme Stuttgart, 2006, pp 130–137.
- 23) Campbell EJ, Green JH: The behaviour of the abdominal muscles and the intra-abdominal pressure during quiet breathing and increased pulmonary ventilation; a study in man. *J Physiol*, 1955, 127: 423–426. [[Medline](#)] [[CrossRef](#)]
- 24) Drăgoi RG, Amaricai E, Drăgoi M, et al.: Inspiratory muscle training improves aerobic capacity and pulmonary function in patients with ankylosing spondylitis: a randomized controlled study. *Clin Rehabil*, 2015, [Epub ahead of print]. [[Medline](#)]
- 25) Brown PI, Johnson MA, Sharpe GR: Determinants of inspiratory muscle strength in healthy humans. *Respir Physiol Neurobiol*, 2014, 196: 50–55. [[Medline](#)] [[CrossRef](#)]
- 26) Mañanas MA, Jané R, Fiz JA, et al.: Study of myographic signals from sternomastoid muscle in patients with chronic obstructive pulmonary disease. *IEEE Trans Biomed Eng*, 2000, 47: 674–681. [[Medline](#)] [[CrossRef](#)]
- 27) Shadgan B, Guenette JA, Sheel AW, et al.: Sternocleidomastoid muscle deoxygenation in response to incremental inspiratory threshold loading measured by near infrared spectroscopy. *Respir Physiol Neurobiol*, 2011, 178: 202–209. [[Medline](#)] [[CrossRef](#)]