Ann Appl Sport Sci, 11(04): e1193, 2023.
http://www.aassjournal.com; e-ISSN: 2322–4479; p-ISSN: 2476–4981. 10.61186 /aassjournal.1193

ORIGINAL ARTICLE

The Comparison of Changes in Pulmonary Function and Respiratory Muscle Strength in Young Adults According to the Abdominal Breathing Exercise Methods

[1]Min-Su Kim, [2]Sam-Ho Park, [2]Myung-Mo Lee*

[1]Department of Physical Therapy, Graduate School, Daejeon University, Republic of Korea. [2]Department of Physical Therapy, Daejeon University, Republic of Korea.

Submitted March 02, 2023; Accepted in final form May 04, 2023.

ABSTRACT

Background. The recent pandemic caused by COVID-19 is showing high awareness and social interest in respiratory diseases. The unexpected decline in pulmonary function significantly affects the deterioration of functional activities of daily living and quality of life. **Objectives.** The purpose of this study was to compare changes in pulmonary function and respiratory muscle according to diaphragm breathing exercise methods. **Methods.** The study consists of 33 healthy young adults in a cross-sectional design used. All three breathing methods were performed at intervals of at least 2 days. The order of intervention was randomly assigned (crocodile breathing, DNS breathing, abdominal breathing using an inspirometer). Pulmonary function (Forced Vital Capacity, Forced Expiratory Volume in one second, Forced Expiratory Volume at 1sec/ Forced Vital Capacity, Peak Expiratory Flow, Maximal Voluntary Ventilation) and respiratory muscle strength (MIP, MEP) were evaluated, using Micro Quark (Cosmed) and Micro RPM (Carefusion). **Results.** In the result of the pulmonary function test, there was no difference in FVC, FEV1, and FEV1% among the three respiratory exercises ($p<0.05$). However, in PEF and MVV, there were significant differences. In the result of the respiratory muscle strength test (MIP, MEP) with Mircro RPM, there were significant differences between the Incentive spirometer group and the crocodile group ($p<0.05$). **Conclusion.** Crocodile breathing can improve pulmonary function and respiratory muscle strength better than the group using Spirometers. Therefore, crocodile breathing helps strengthen the respiratory muscles of normal adults and improves pulmonary function.

KEYWORDS: ***Breathing Exercise, Diaphragm Breathing, Pulmonary Function Test, Respiratory.***

INTRODUCTION

Respiration is a series of processes in which oxygen is ingested and carbon dioxide is exhaled through the airways, and it is divided into inhalation in which air enters the lungs, and exhaled in which air in the lungs is discharged to the outside (1). A normal adult breathes 12 to 16 times per minute, and the respiratory system of the human body plays a role in the ventilation-perfusion exchange between the air and blood surrounding the lungs, and at the same time is achieved by respiratory muscles and neurological control (2).

Respiration occurs by repetition of inhalation and exhalation, and an inhalation causes the contraction of the diaphragm to increase intra-abdominal pressure and lower the intra-abdominal pressure. During strong inspiration, the diaphragm and external intercostal muscles, as well as the respiratory auxiliary muscles, the sternocleidomastoid muscle, scalene muscle, and

*. Corresponding Author:
Myung-Mo Lee, Ph.D.
E-mail: mmlee@dju.kr

trapezius muscle are required, to increase intra-abdominal pressure (3). Exhalation is caused by the relaxation of the diaphragm, and strong exhalation is caused by conscious contraction of the abdominal muscles.

Contrary to strong inhalation, strong exhalation increases intrathoracic pressure and contracts the ribs through the action of the rectus abdominis, transeversus abdominis, external oblique, and intercostal muscles (4, 5). Breathing methods can be divided into diaphragm breathing and abdominal breathing. In diaphragm respiration, the main movement of the rib cage changes the area of the lungs, and abdominal respiration is respiration in which the contraction of the diaphragm is the main action. Diaphragm breathing also is an effective breathing method for learning and exercising to stabilize the trunk and improve pulmonary function (6).

Chronic obstructive pulmonary disease (COPD), one of the representative respiratory diseases, is characterized by a decrease in expiratory volume accompanied by dyspnea, chronic cough, and sputum. As the disease progresses, symptoms gradually worsen and daily life is affected, so early detection and rehabilitation are important to prevent progression as a chronic condition (7). Diaphragm breathing is effective in improving dyspnea in COPD patients, and diaphragm breathing has been suggested as a breathing method that can increase lung volume along with chest expansion and effectively remove secretions accumulated in the airways (8).

In addition, as a traditional breathing exercise method to enhance cardiopulmonary function in patients with COPD and cardiopulmonary disease, breathing exercises using an incentive spirometer (9), pursed lip breathing (10), and lower lip expansion breathing (11). To perform correct diaphragm breathing, it is necessary to consciously contract the diaphragm, train the breathing pattern, and provide accurate feedback on diaphragm breathing (7, 12). Diaphragm breathing in parallel with functional exercise has a positive effect on not only respiratory function but also functional movement improvement and pain reduction (13).

Respiratory exercise using an incentive spirometer is a widely used method in general respiratory rehabilitation to reduce pulmonary ventilation and pulmonary complications (14). By actively using the diaphragm and inspiratory auxiliary muscles, which are the prime movers of the inspiratory muscle, feedback on the volume and flow of air during inhalation can be provided in real-time, thereby increasing the patient's concentration in participating in breathing exercises.

Dynamic neuromuscular stabilization (DNS) is an exercise method applied based on the developmental kinematics-based motor development process from birth to the onset of walking (15). DNS breathing is introduced by combining DNS exercise and diaphragm breathing, and posture, joint centering, and breathing patterns are presented from a neurodevelopmental point of view (16). When the DNS breathing exercise was applied to a male student with poor posture, it was found to be effective in preventing the risk of inappropriate posture as well as improving respiratory function (16).

Crocodile breathing is a diaphragm breathing technique performed in a prone position. It is possible to give subjective feedback on the movement of the boat by pushing the floor by itself, and it can also be applied to breathing resistance exercises by using the body weight as resistance (17). Crocodile breathing was effective in reducing pain, muscle tone, and stiffness in patients with low back pain, and was reported to be effective in activating core muscles (18).

The increase in fine dust concentration and smoking populations due to industrialization is leading to a high prevalence of various lower respiratory tract diseases. Moreover, the recent pandemic caused by COVID-19 is showing high awareness and social interest in respiratory diseases. The unexpected decline in pulmonary function significantly affects the deterioration of functional activities of daily living and quality of life. Therefore, in this study, we applied the incentive spirometer, DNS breathing exercise, and the crocodile breathing method, which emphasized abdominal breathing, to adults in their twenties, and compared the effects of the functional breathing exercise method on pulmonary function and respiratory muscle strength and suggested clinical usefulness.

MATERIALS AND METHODS

Participants. 153 healthy adults in their twenties enrolled in the University D were recruited for this study. Subject selection criteria were those who did not have musculoskeletal pain in the extremities in daily life, those with a VAS score of less than 3, those who had not been exposed to respiratory or neurological diseases, those who had or contracted COVID-19 within the last month, and those who had been tested in the middle of the experiment. Factors that could negatively affect the results of this study, such as those who gave up on the program and those whose FEV1% was less than 70, were excluded as conditions. After explaining the purpose and procedure of the experiment to all subjects, consent was obtained to participate in the experiment. Only those who voluntarily indicated their intention to participate in the questionnaire and signed the questionnaire were included. To prevent the spread of COVID-19, all subjects were checked for fever and symptoms before the study (Figure 1).

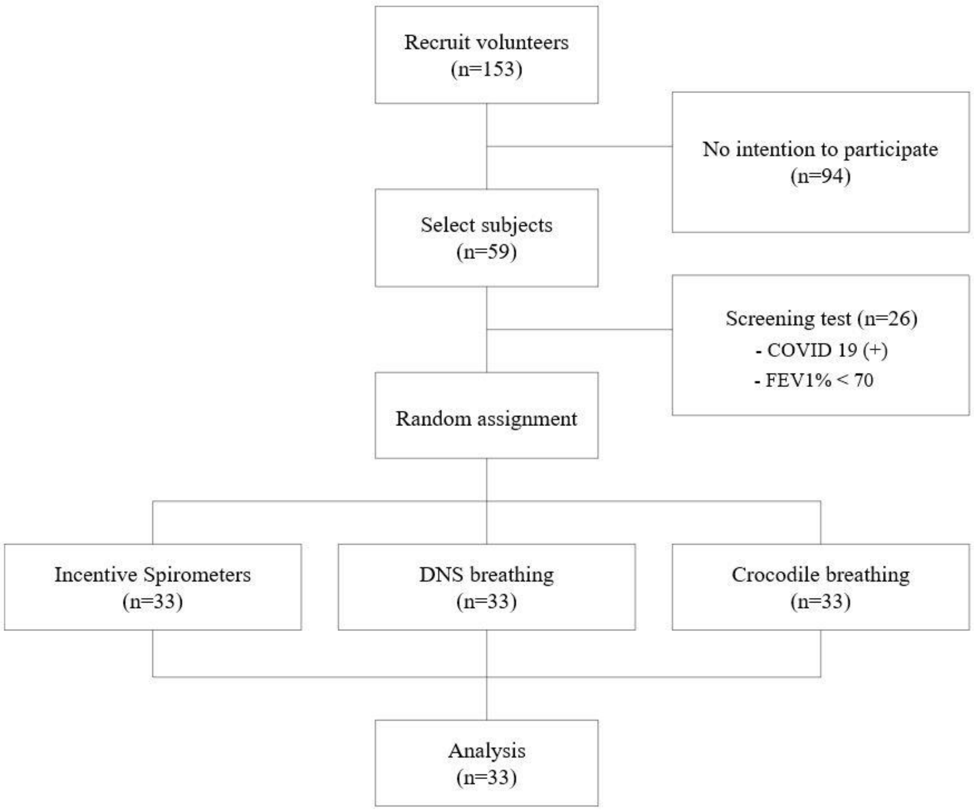

Figure 1. Flow chart of this study

Procedures. This study was conducted from March to June 2022 as a cross-sectional study. Those who did not intend to participate in the study (n=94), those who were quarantined as positive for COVID-19 during the study period, or those who were less than 1 month after the quarantine was lifted (n=23), FEV1% <70% (n=3), 33 subjects were selected.

Subjects applied incentive spirometer breathing exercise, DNS breathing exercise, and crocodile breathing exercise in random order, and after 10 minutes of rest after breathing exercise, pulmonary function test and the respiratory muscle strength test were performed. Each intervention was applied at intervals of 3 days to minimize the carryover effect according to the exercise method.

Interventions. Before the intervention, all subjects received prior exercise on abdominal breathing so that when the intervention was applied, diaphragm breathing could be performed concurrently. Each breathing exercise intervention was conducted for 15 minutes under the guidance of one trained examiner, and the subject was performed with an intensity within 15 points of a rating of perceived exertion (RPE). During the intervention, if there were complaints of difficulty in performing breathing exercises, dizziness, vomiting, anemia, etc., it was stopped or re-applied after providing sufficient rest according to the intention of the participant.

Incentive spirometer. The incentive spirometer is a breathing exercise tool widely distributed to patients with respiratory diseases to strengthen the inspiratory muscles. In this study, a flow-oriented incentive spirometer (Teleflex, USA) and a volume-oriented incentive spirometer (Hyupsung Medical, Republic of Korea) were used to strengthen the inspiratory muscles in parallel with abdominal breathing. The flow spirometer is a breathing exercise tool that provides feedback on the inspiratory rate by sequentially floating three spheres placed in each cylinder by the sucked airflow rate during inspiration. Subjects performed fast and strong inspiratory breathing exercises to raise as many spheres as possible by diaphragm breathing after closing their noses (Figure 2-A).

A flow spirometer is a breathing exercise tool used to increase the maximum inspiratory capacity while inhaling at a constant rate. It provides feedback on the inspiratory rate and total inspiratory capacity. Subjects covered their noses and performed abdominal breathing to achieve maximum inspiratory capacity at a constant rate. Respiratory exercise using each induced spirometer was adjusted to be performed 25 to 30 times for 7 minutes, and 1 minute was provided as a rest period in between (Figure 2-B).

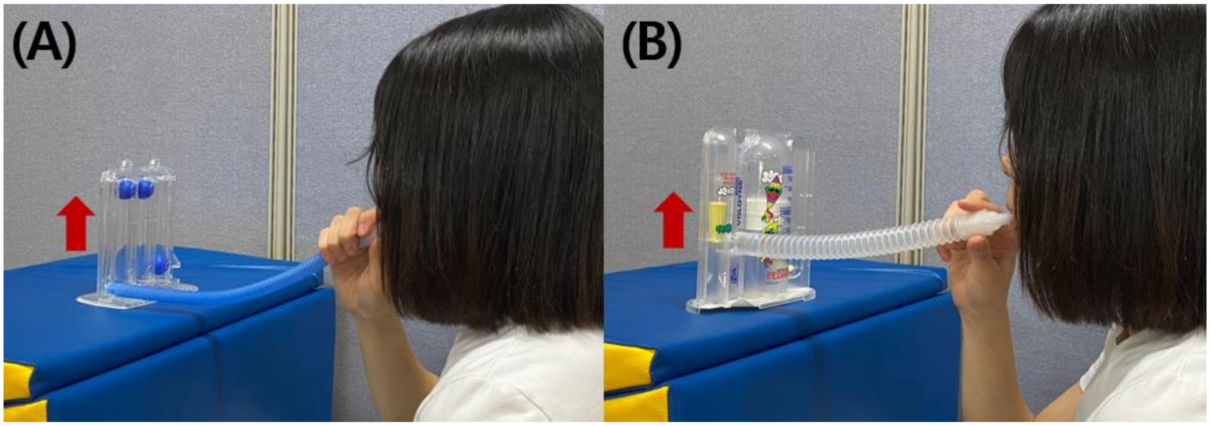

Figure 2. (A) Flow-oriented incentive spirometer. (B) Volume-oriented incentive spirometer.

DNS breathing. The purpose of DNS respiration was to improve the stability of the core by applying the abdominal respiration method to the exercise method applied based on the children's motor development process. In this study, step-by-step breathing exercise was applied in the hook lying position (Figure 3-A), the dead bug position (Figure 3-B), and the half-kneeing position (Figure 3-C) with the knee bent at 45 degrees. While maintaining the posture, the subject was asked to breathe in, hold, and exhale at a ratio of 1:1:2 by abdominal breathing, and to exhale slowly using abdominal pressure through pursed lip breathing did. It was adjusted so that 15-20 breaths could be applied for 4 minutes for each step, and a rest period of 1 minute was provided between steps.

Crocodile breathing. Crocodile breathing is a breathing method performed in a prone position with your stomach on the floor, and you can focus on the contraction of the abdominal muscles at the same time as the contraction of the diaphragm. A step-by-step breathing method was applied to provide accurate feedback and stimulation for breathing exercises. In the first step, a pillow was placed under the lower abdomen to focus on abdominal expansion due to diaphragm contraction during inhalation, and a soft weight ball (3.3lb, Theraband) was placed on the lower back to provide resistance (Figure 4-A). In step 2, the pillow was removed and resistance was provided only with a soft weight ball (Figure 4-B), and in step 3, only the lower abdominal muscles could be focused without using tools (Figure 4-C). The subjects placed their hands next to their faces and performed breathing exercises in a prone position on the bed. As with the DNS breathing method, inhalation, hold, and exhalation were performed at a ratio of 1:1:2. During inhalation, the focus was placed on the rise of the lower abdomen along with the expansion of the lower abdomen, and during exhalation, the air was slowly exhaled using abdominal pressure through closed lip breathing. It was applied to allow 15 to 20 breaths for 4 minutes for each step, and a break of 1 minute was provided between steps.

Outcome measures. Pulmonary function. Micro Quark (Cosmed, Italy) was used for the pulmonary function test according to the intervention method. According to the pulmonary function test guidelines of the American Thoracic Society, the subject sat on a chair without a back, straightened his back, covered his nose, and then breathed through the mouth according to the examiner's instructions. Forced vital capacity (FVC), forced expiratory volume at 1 second (FEV1), Forced expiratory volume in 1 sec/forced vital capacity (FEV1%) and peak expiratory flow (PEF) values were used as data. For the evaluation of ventilation according to the intervention method, the value was recorded after evaluating the Maximum Voluntary Ventilation (MVV) for 1 minute. The pulmonary function test recorded the highest value after three measurements, and a 10-minute rest period was provided between the tests.

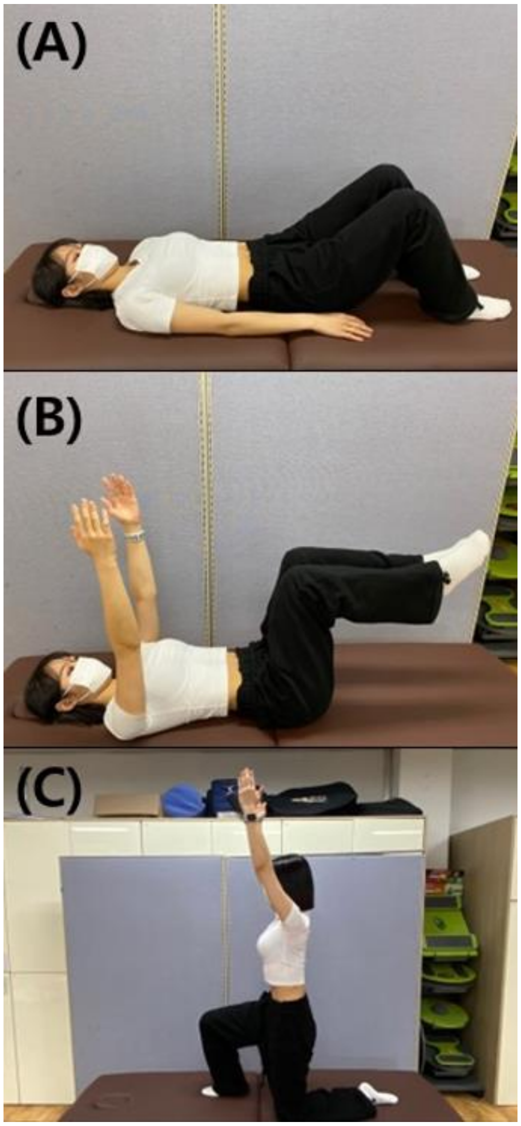

Figure 3. DNS breathing exercise methods

Muscle strength. Changes in respiratory muscle strength according to the breathing exercise method were measured using Micro RPM (Carefusion, San Diego, CA, USA). Micro RPM is a device that indirectly indicates the force of the muscles involved in respiration by measuring the pressure generated during inhalation and exhalation. In this study, maximal inspiratory and maximal exhalation pressures were measured as maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP), respectively, and the unit of measurement was recorded as a pressure value in cmH2O. Subjects held the mouthpiece in their mouth in the same posture as the lung function test and performed maximal inhalation and maximal exhalation. At this time, intraoral pressure was used to prevent excessive contraction or swelling of the cheeks, and the compensatory action between the shoulder and trunk was minimized and the use of abdominal breathing was instructed. Respiratory muscle strength was measured three times, and the highest value was recorded. All evaluations were performed by one inspector who understood the inspection method and was competent.

Statistical analysis. The data collected in this study were analyzed through the SPSS ver.19.0 (SPSS Inc, Chicago, II, USA). The general characteristics of the study subjects were technically analyzed, and normality was tested using the Shapiro-Wilk test. One-way Analysis of Variance was performed to confirm the difference in the dependent variable according to the abdominal breathing method, and the Bonferroni correction method was used as a post hoc test. The statistical significance level was set as a=0.05.

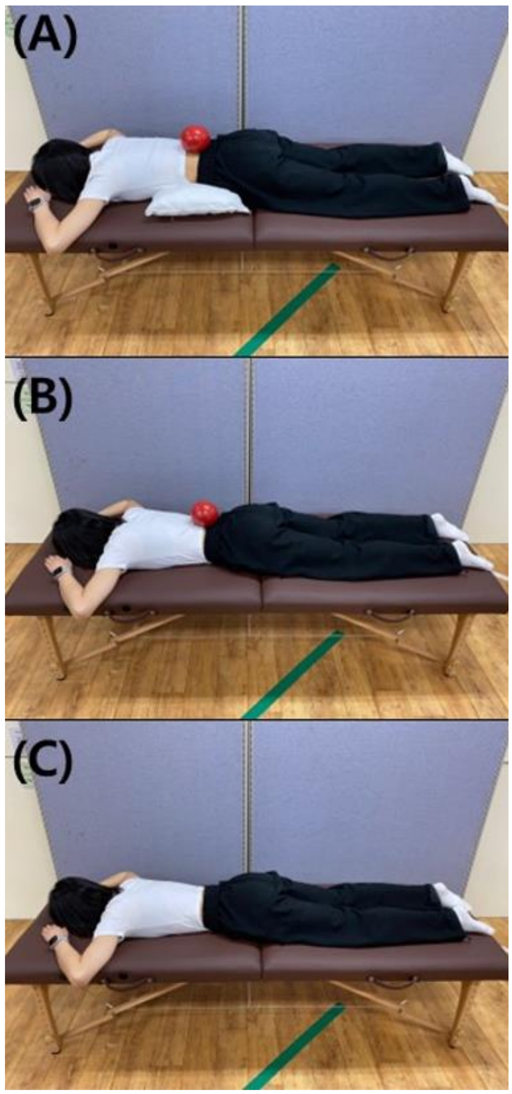

Figure 4. Crocodile breathing exercise methods

RESULTS

Characteristics of the subject. The general characteristics of the subjects participating in this study were Table 1.

Pulmonary function, respiratory muscle strength comparison. Table 2 shows the results of the pulmonary function test and respiratory muscle strength evaluation according to the intervention method.

As a result of the pulmonary function test, there was no statistically significant difference between the conditions in FVC, FEV1, and FEV1%. PEF and

MVV were highest in the order of crocodile breathing, DNS breathing, and incentive spirometer, and there was a statistically significant difference according to condition ($p<0.05$). As a result of the post hoc test, there was a significant improvement in crocodile breathing compared to the spirometer ($p<0.05$). As a result of measuring respiratory muscle strength, both MIP and MEP were highest in the order of crocodile breathing, DNS breathing, and incentive spirometer, and there was a statistically significant difference according to the conditions ($p<0.05$). As a result of the post-hoc test, there was a statistically significant improvement in crocodile breathing compared to incentive spirometer respiration ($p<0.05$).

Table 1. General characteristics of subjects (Mean ± SD)

Variables	N=33
Sex (male/female)	17/16
Age (years)	20.97±1.90
Height (cm)	169.00±7.79
Weight (kg)	63.70±12.37

Table2. Comparison Pulmonary function, Respiratory muscle strength (n=33)

	Incentive Spirometers	DNS breathing	Crocodile breathing	F
Pulmonary function				
FVC (L)	3.48±.85[a]	3.48±.86	3.52±.86	.031
FEV1 (L)	2.91±.67	2.95±.68	2.95±.69	.042
FEV1/FVC (%)	84.18±6.72	85.30±5.48	84.36±5.59	.337
PEF (L/s)	5.25±1.71	5.95±1.85	6.39±1.86[†]	3.274[*]
MVV (L/min)	93.91±24.23	102.39±27.45	111.53±33.54[†]	3.117[*]
Respiratory muscle strength				
MIP (cmH2O)	63.68±22.50	72.84±24.97	82.56±30.35[†]	4.30[*]
MEP (cmH2O)	64.48±26.96	75.63±26.40	86.92±31.88[†]	5.10[*]

[a]Mean±SD, *FVC*: forced vital capacity, *FEV1*: forced expiratory volume in one second, *PEF*: peak expiratory flow, *MVV*: maximum voluntary ventilation, *MIP*: maximum inspiratory pressure, *MEP*: maximum expiratory pressure.
[*]$p<0.05$, [†]significant difference compared with Spirometer

DISCUSSION

This study was conducted to investigate the immediate changes in the functional breathing method emphasizing diaphragm breathing on the pulmonary function and respiratory muscle strength of normal adults in their 20s. As a result, it was confirmed that the crocodile breathing method using diaphragm breathing was effective in improving MVV, PEF, MIP, and MEP. Clinically, inspiratory muscle strengthening exercise is applied to strengthen the respiratory function of patients with airway obstruction and restrictive ventilation problems. In addition, diaphragm breathing emphasizing the contraction of the diaphragm, the main inspiratory muscle, is being applied to stabilize and strengthen the core along with various functional movements.

The incentive spirometer is widely used in the field of respiratory rehabilitation as an inspiratory exercise tool to reduce or prevent postoperative pulmonary complications and improve lung motor function (15). Through the cylinder inside the spirometer, it provides visual feedback according to the flow rate and flow rate during forced inhalation. Dilates the alveoli by holding the breath for several seconds after a forced inhalation. It also improves ventilation in tidal volume and facilitates sputum excretion. Eltorai et al. (19) said that breathing exercise applied with an induced spirometer is effective in improving pulmonary function in elderly people with mild cognitive impairment. Sum et al. (20) reported that breathing exercises using a flow-oriented incentive spirometer in patients with traumatic rib fractures had a significant improvement in the spirometry index.

Repetitive breathing exercise using an incentive spirometer is effective in strengthening the inspiratory muscles. For effective inspiratory muscle strengthening, accurate breathing pattern exercises using the diaphragm should be preceded. Efficient breathing patterns should be learned by minimizing the use of assistive muscles and promoting the use of the diaphragm. In particular, in the case of the elderly or patients, since they are not used to breathing using the diaphragm, it is necessary to use an incentive spirometer for respiratory rehabilitation or to teach a breathing pattern using the diaphragm before exercise. It was reported that the COPD group, in which the induced spirometry and breathing exercise were combined, had a positive effect on quality of life and arterial blood gas test, but no significant change in spirometry index (9). It is difficult to use the diaphragm in patients with COPD using an incentive spirometer. Nevertheless, it is considered that the education on the correct use of the barrier and the application of exercise using it were insufficient. Despite the effectiveness and purpose of the incentive spirometer, several previous studies do not describe the specific method of using the spirometer. In this study, accurate diaphragm breathing patterns were pre-educated for normal adults in their 20s, and after that, while using the spirometer, the focus was on inspiratory muscle strengthening exercises using the diaphragm.

DNS breathing is a breathing method aimed at improving the stability of the core by applying diaphragm breathing to various application postures of the child's motor development process. Recently, it has been applied to patients with low back pain to stabilize the core and improve the function of the abdominal muscles to reduce pain and improve function. Ha and Lee's (21) research compared the effects of exercise for core stabilization and diaphragm breathing exercise for adults in their 20s. As a result of his study, the reported that there was an improvement in respiratory function in both the core stabilization group and the diaphragm, breathing group, but there was no significant difference between the groups. Stephens et al. (18) reported that when archers were trained to strengthen respiratory muscles and core stabilization exercises were combined, they were effective in improving breathing and balance abilities. Park and Lee (22) reported that respiratory resistance exercise combined with lumbar stabilization exercise was more effective in reducing pain, improving psychological stability, and improving motor and breathing functions, compared to the group applying only lumbar stabilization exercise. Oh et al. (13) reported that when abdominal draw-in exercise and breathing resistance exercise were combined with low back pain in women, there was a decrease in back pain and functional limitation and an improvement in thickness and pulmonary function during diaphragm contraction.

All of the above studies show that the intervention combined with breathing exercises focused on diaphragm contraction was effective in reducing pain and improving function more effectively than applying functional movements for core stabilization alone. This is because, when the action of the muscles used for postural stabilization is combined with breathing exercises focused on the diaphragm and abdominal muscles, it causes greater activation of the core muscles. In our study, participants applied breathing exercises focusing on diaphragmatic contraction as well as postural stabilization in the hook lying position, the dead bug position, and the half-kneeing position with the knees bent at 45 degrees; and showed improved values in PEF, MVV, MIP, and MEP than breathing exercises using an incentive spirometer, but it was not statistically significant.

Patients with low back pain are characterized by high muscle activity and hypertonicity around the waist due to the instability of the abdominal muscles. It can be confirmed that crocodile breathing focused on diaphragm contraction is a breathing method that can contribute to lumbar stabilization by strengthening the abdominal muscles and reducing hypertonicity around the waist. As a result of our study, PEF, MVV, MIP, and MEP showed the highest values after crocodile breathing was applied, and there was a statistically significant improvement compared to respiratory intervention using an incentive spirometer. It is thought that crocodile respiration focused on diaphragm contraction contributed to the contractility of the muscles around the abdomen and the flexibility and strengthening of the erector spinae muscle, leading to the improvement of lung function and respiratory muscle strength. It is true that the crocodile breathing method, in which the body weight is reflected as resistance during breathing, has a stronger resistance than the other two breathing methods. Ha and Lee (21) presented a study result showing that in young adults, the change in the lung capacity index was more pronounced according to the size of resistance rather than accurate feedback on diaphragm contraction. According to the study results, if the subject has a sufficient awareness of the diaphragm contraction, core strengthening exercise combined with strong breathing resistance may be suggested as a more effective intervention method.

This study examines the changes in pulmonary function and respiratory muscle strength according to the functional resistance breathing exercise method. It was confirmed that the effective breathing method is the crocodile breathing method while comparing the lung capacity index obtained according to each exercise method. However, although it was aimed at adults who can perform abdominal breathing relatively easily, it is judged that future research is necessary to apply it to the elderly who cannot perform abdominal breathing well or patients with weakened cardiorespiratory function.

The limitations of this study are: First, during the study, several people excluded from the study due to a positive COVID-19 test occurred. Second, since it was conducted on normal adults in their twenties, it cannot be generalized to all patients. Third, due to movements requiring high-intensity movements during the respiratory intervention, it was not possible to prepare standards for movement awareness and exercise intensity by performing the intervention under the same conditions without considering the physical characteristics of each subject.

When diaphragm breathing is applied in a future follow-up study, if the breathing intervention is modified, intensity control, and interest factors for exercise are supplemented, it is believed that it can be used as an effective method to improve pulmonary function and respiratory muscle strength according to the diaphragm breathing exercise method.

CONCLUSION

This study was conducted to investigate changes in pulmonary function and respiratory muscle strength in adults in their 20s through three diaphragm breathing exercises. Based on the results, it was concluded that the crocodile breathing method was more effective than the incentive spirometer and DNS breathing method for improving pulmonary function and respiratory muscle strength. Through the results of this study, it was found that crocodile breathing had a positive effect on pulmonary function and respiratory muscle strength than the group that incentive spirometer and DNS breathing. These results show that crocodile breathing is recommended for patients who want to improve pulmonary function and respiratory muscle strength.

APPLICABLE REMARKS

- This study finds that they compare changes in pulmonary function and respiratory muscle according to diaphragm breathing exercise methods.
- It was concluded that the crocodile breathing method was more effective than the incentive spirometer and DNS breathing method for improving pulmonary function and respiratory muscle strength.

ACKNOWLEDGMENTS

This work was supported by a grant from the National Research Foundation of Korea (NRF) funded by the Korean government (MSIT) (No. 2022R1C1C101350111).

AUTHORS' CONTRIBUTIONS

Study concept and design: Min-Su, Kim, Myung-Mo Lee. Acquisition of data: Min-Su, Kim, Sam-Ho Park, Myung-Mo Lee. Analysis and interpretation of data: Min-Su, Kim, Myung-Mo Lee. Drafting of the manuscript: Min-Su, Kim. Critical revision of the manuscript for important intellectual content: Sam-Ho Park, Myung-Mo Lee. Statistical analysis: Myung-Mo Lee. Administrative, technical, and material support: Myung-Mo Lee. Study supervision: Myung-Mo Lee.

CONFLICT OF INTEREST

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

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