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Effects of Thorax Mobility Exercise on the Thorax Mobility, Breathing Pattern and Respiratory Capacity in Subject With Restricted Thorax Mobility: A Case Series

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Abstract

Objective : To investigate the effects of thorax mobility exercises on thorax mobility, breathing pattern, and respiratory capacity in subjects with restricted thorax mobility.

Methods : Thirteen subjects with restricted thorax mobility participated in this study. Measurement of thorax circumference using a tape measure (difference between inhalation and exhalation), breathing pattern (distance of rib cage elevation during breathing), and respiratory capacity was performed. Paired *t*-test was used to compare the thorax mobility, breathing pattern, and respiratory capacity between before and after thorax mobility excercise. Statiscal significance was set at .05.

Results : There were significant differences in thorax mobility and breathing pattern, but no significant difference in respiratory capacity ($p < .05$).

Conclusion : Based on the results of this study, thorax mobility exercise using the rib mobilization technique is considered to be a method that can improve thorax mobility and normalize abnormal breathing patterns that cause rib cage elevation.

Keywords : Breathing pattern, Respiratory capacity, Rib cage elevation, Rib mobilization technique, Thorax mobility

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Ⅰ. Introduction

The normal breathing pattern combines the downward movement of the diaphragm with the lateral expansion of the ribs caused by the intercostal muscles, which expands the thorax (or chest) space and enables efficient gas exchange (Neumann, 2002). The diaphragm muscle, which plays the most important role in breathing, moves down during inhalation to form a space for the lungs to expand. As the volume inside the thorax space increases, the internal pressure decreases, resulting in respiratory mechanics that allow outside air to enter the thorax. Afterwards, air is discharged to the outside by the elastic restoring force of the soft tissues constituting the lungs and chest, which were stretched during exhalation (caused by a decrease in space inside the thorax space and an increase in internal pressure) (Pacific Academy of Science, 2014). Therefore, if the mobility of the ribs and spine, which make up the thorax, is reduced, problems occur in normal breathing mechanics and activities (Chaitow et al., 2014).

Limitation of the mobility of the spine and ribs can occur due to abnormal body alignment and movements biased in a specific direction (Sahrmann, 2011). This causes a decrease in the movement of the thorax space, and the normal breathing pattern cannot be maintained, resulting in an abnormal breathing pattern that excessively raises the thorax and a decrease in breathing capacity (Libenson, 2007). Since these changes are factors that accelerate body alignment and muscle imbalance, therapeutic intervention is needed to restore normal movement of the diaphragm and ribs (Lee, 2018). Although trainings to restore abnormal breathing patterns and respiratory ability have been attempted, most of them are therapeutic interventions focused on restoring diaphragm function (Enright et al., 2006; Kang, 2014; Yamaguti et al., 2012). In order for the diaphragm to function normally, it is important to restore the normal muscle strength and mobilization ability of the diaphragm, but it is very important to first secure a space where the diaphragm can function (Lee, 2018). Therefore, securing the normal mobility of the ribs, which have the greatest influence on the mobility of the thorax, is the first step of treatment.

The purpose of this study was to investigate the effect of rib mobilization technique (thorax mobility exercise) on the thorax mobility, breathing pattern, and respiratory capacity in subjects with restricted thorax mobility. It was hypothesized that the rib mobilization technique would improve thorax mobility, breathing pattern, and respiratory capacity in subjects with restricted thorax mobility.

Ⅱ. Methods

1. Subjects

A total of 13 healthy adult (men = 9, women = 4) participated in the experiment. And, subject were informed of the purpose of our study and its possible hazards. All subjects confirmed their consent to participate by completing a research consent form. The subject selection criteria are as follows. First, those with restricted thorax mobility (the difference between chest circumference at maximum inhalation and at rest is 2.5 cm or less) (Moll & Wright, 1972). Second, those with reduced respiratory function (forced vital capacity [FVC] %) are 90% to 80% of the predicted normal value (Miller et al., 2005).

Table 1. Subject Characteristics (N = 13)

Characteristic	Total
Age (yr)	22.92 ± 1.50
Height (cm)	170.53 ± 4.72
Body mass (kg)	66.53 ± 10.78

Values are presented as *mean* ± standard deviation.

Third, those who do not have problems with the cardiovascular system, nervous system, or orthopedic. Fourth, subjects with a paradoxical breathing pattern with predominantly upper chest breathing were selected as study subjects. The general characteristics of the research subjects are as Table 1.

2. Instrumentation

1) Tape measure

A tape measure was used to measure the degree of thorax mobility (chest expansion) between inhalation and exhalation. As a method for measuring the degree of chest expansion or mobility, the tape measure method is a measurement method with very high reliability (intergrade correlation coefficient: 0.81~0.91). With the subject standing upright, the tape measure was placed horizontally across the junction between the xiphoid process and the sternum. After that, the maximum breath-in (inhalation) and maximum breath out (exhalation) were measured respectively (Figure 1). The degree of expansion of the chest was obtained by subtracting the measured value at maximum exhalation from the maximum inhalation value (Miller et al., 2005).

2) Measurement of respiratory capacity

In this study, the respiratory capacity was measured using Smart breathe air (Addable). For an accurate test, the participants who participated in the experiment were explained and educated about the measurement method and posture in advance. After breathing three times in a comfortable state, the subjects were instructed to perform maximal inhalation followed by maximal exhalation. A total of three measurements were made and the average value was used (Figure 2). To evaluate respiratory capacity, the measured variables were FVC, forced expiratory volume in 1 second (FEV1), and forced expiratory ratio (FEV1/FVC) was used as the measurement data.

Figure 1. Tape Measure

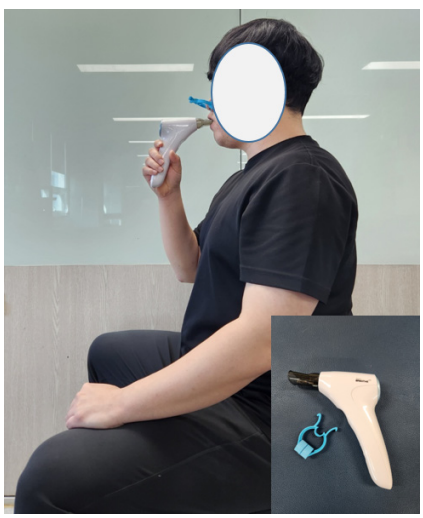

Figure 2. Measurement of Respiratory Capacity

3) Breathing pattern measurement

A reflective marker with a diameter of 1.5 cm was attached to the junction between the xiphoid process and the sternum while the subjects lay in a hook lying position. The degree of abnormal chest lift (thorax elevation), which occurs excessively during inhalation, was measured. Samsung Galaxy S22 mobile phone (Samsung Electronics) to measure chest lift distance (vertical movement distance) between inhalation and exhalation. A length-adjustable tripod was placed 1 m away from the side of the subject's torso (Figure 3). In order to measure the distance on the captured image, it is necessary to measure with a reference of a specific length. Therefore, the reference bar was placed at the same position as the marker (distance from the camera) to provide a criterion for measuring the moving distance of the marker attached to the sternum. The captured images were analyzed using Kinovea (V. 0.8.15; Kinovea) software.

3. Experimental procedure

Before and after applying the rib mobilization technique, the chest expansion range was measured using a tape measure, the respiratory capacity was measured using a respiration measuring machine, and the breathing pattern was measured. In the rib mobilization technique, while the subject is seated upright, the therapist places and fixes the hand (the lateral part of the second finger) under the part to be mobilized in the state of the subject's back-lateral position. Rib mobilization techniques are divided into methods for increasing exhalation (enhancing upward/outward/backward rotation of the ribs) and methods for increasing inhalation (enhancement of upward/outward/backward rotation). First, the mobilization technique to increase the anterior/lower/medial/anterior rotation of the ribs to increase exhalation is as follows. With the subject sitting upright, the therapist places and fixes the hand on the part to be mobilized in the state of the subject's back-side. While exhalation, the subject rotates the thorax in the opposite direction to the mobilized ribs. At this time, the therapist follows along with the movement of the thorax and continuously applies pressure to the ribs to be mobilized in the forward/downward/inward direction. While holding the breath at the end range of the rotation and holding it for 5 seconds, therapist applies a continuous mobilization technique to the targeted rib (Figure 4A). Second, the mobilization technique to increase the upper/outer/posterior rotation of the ribs to increase inhalation is as follows. Position and fix the hand on the lower rib to be mobilized while positioned on the postero-lateral side of the subject. While inhalation, the subject rotates the thorax in the direction in which the ribs are fixed. Hold subject's breath at the end range of the rotation and hold for 5 seconds (Figure 4B). The joint mobility technique was performed three times in the same form for each segment, and it was performed from the 11th rib to the 5th rib. The rib mobilization technique was applied in a

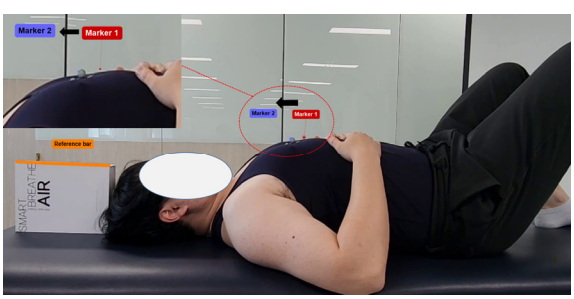

Figure 3. Breathing Pattern Measurement
Red marker = point during exhalation; Blue marker = point during inhalation.

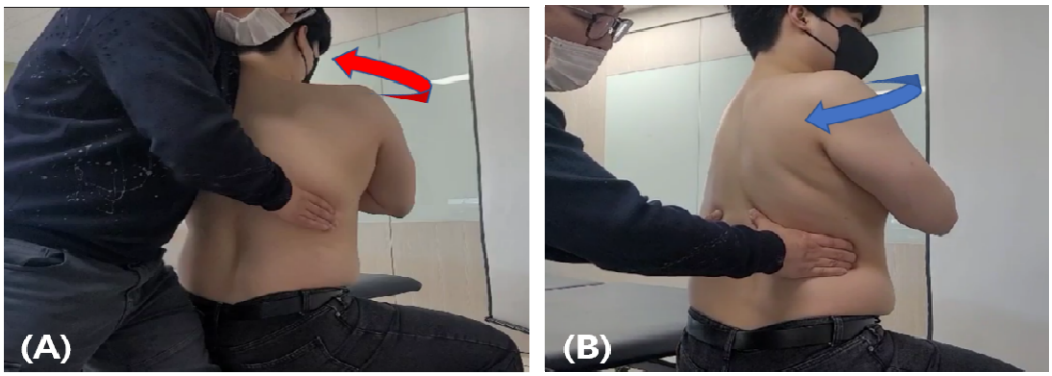

Figure 4. Thorax Mobility Exercise
Rib mobilization (A) to increase exhalation, (B) to increase inhalation.

painless range and intensity. The total treatment time for each subject was about 20 minutes.

4. Statistical analysis

Variables were normally distributed, as determined by Kolmogorov-Smirnov tests; thus, parametric statistics were used (p 〉 .05). Data of this study were expressed as mean ± standard deviation. Statistical analyses were performed using a SPSS ver. 23.0 (IBM Corp.). A paired t-test was used to compare changes in chest expansion, respiratory capacity, and breathing pattern before and after application of thorax mobility exercise (rib mobilization technique), and the statistical significance level was set at .05.

Ⅲ. Results

Before and after application of the rib mobilization technique, thorax mobility (chest expansion range) and breathing patterns (chest lift movement) showed significant differences (p 〉 .05), but respiratory capacity did not show significant differences (Table 2).

Ⅳ. Discussion

The purpose of this study was to investigate the effect of rib mobilization technique (thorax mobility exercise) on the thorax mobility, breathing pattern, and respiratory capacity in subjects with restricted

Table 2. Comparison of Variables Pre- and Post-Thorax Mobility Exercise

Variable		Condition		t	p-value
		Before rib mobilization	After rib mobilization		
Chest expansion (cm)		1.70 ± 0.87	4.27 ± 1.30	-7.04	.00*
Respiratory capacity	FVC (L)	3.07 ± 0.40	3.12 ± 0.43	-1.68	.12
	FEV1 (L)	2.84 ± 0.34	2.87 ± 0.35	-2.16	.05
	FEV1/FVC (%)	0.92 ± 0.34	0.92 ± 0.30	0.55	.60
Chest lift movement (cm)		2.38 ± 0.31	0.99 ± 0.36	8.57	.00*

Values are presented as *mean* ± standard deviation. *Asterisk indicates a statistically significant (p 〈 .05).
FVC = forced viatal capacity; FEV1 = forced expiratory volume in 1 second.

thorax mobility. The results of the study showed significant differences in chest expansion range and breathing pattern (chest lift movement) between before and after rib mobilization technique, but no significant change in respiratory capacity.

Breathing is a continuous process of inhalation and exhalation. During inhalation, external air is introduced into the lungs by forming negative pressure that expands the chest space through the expansion of the chest area composed of ribs and the up-down movement of the dome-shaped diaphragm. Gas exchange takes place. During exhalation, the increased chest space and the diaphragm, which contracted and moved downward, return to their original positions due to elastic restoring force, causing a decrease in space and an increase in internal pressure, and air is discharged to the outside (Pacific Academy of Science, 2014). Respiratory function is affected when the expansion capacity of the chest space composed of ribs is reduced (Lee, 2018). In order to compensate for the reduced respiratory capacity, respiratory accessory muscles are used excessively, resulting in an upper chest breathing method or a retrograde breathing method in which the upper chest is excessively lifted or raised (Libenson, 2007). Compared to normal breathing, upper chest breathing causes various problems such as reduced breathing efficiency (low gas exchange rate, frequent breathing rate) and excessive tension and pain in neck-shoulder muscles (scalenus and sternocleidomastoid muscles), and decreased thorax movement (expansion of the abdomen and lower chest) (Kisner & Colby, 2007; Page et al., 2009). Previous studies have shown that breathing training in various postures, diaphragm strengthening exercise, and biofeedback training using ultrasound and electromyography have the effect of improving breathing ability for subjects with abnormal breathing patterns (Enright et al., 2006; Kang, 2014; Yamaguti et al., 2012).

It emphasized that securing thorax mobility (movement of ribs and thoracic spine) is the most necessary therapeutic intervention in order for the diaphragm and intercostal muscles, which play a major role in breathing (inhalation and exhalation), to function normally and efficiently (Lee, 2018). Therefore, in this study, a rib mobilization technique was applied to improve the limited thorax mobility. As a method to improve thorax mobility, this study aimed to find out how the application of the rib mobilization technique affects not only thorax mobility, but also breathing patterns and respiratory capacity. The main results of this study investigating the effect of rib mobilization technique are as follows. First, chest expansion (thorax mobility) was improved compared to before rib mobilization. It was confirmed that thorax mobility could be improved even with treatment session for about 20 minutes. This secures a physical space for the diaphragm to function, enabling normal activity of the diaphragm. Therefore, it is recommended to apply rib cage mobilization for diaphragm strengthening or functional training. Second, there was a significant change in breathing patterns. Compared to before treatment, it was confirmed that the range in which upper chest lift occurs was significantly reduced using accessory muscles. It was confirmed that there was a change from the abnormal breathing pattern using accessory muscles to the normal breathing pattern using a diaphragm. It is believed that costo-diaphragmatic breathing can be induced through rib cage mobilization, in which expansion of the lower chest area and abdominal expansion can occur. Respiratory capacity did not change at a significant

level before and after rib mobilization technique. The reason is thought to be that alveolar extensibility was not changed by short-term therapeutic intervention (rib mobilization technique). Physical expansion of the chest space occurred with the rib mobilization technique, but an immediate change in the expandability of the internal alveoli. Therefore, it is thought that a study on the effect of diaphragm strengthening training and rib cage mobilization on respiratory capacity through therapeutic intervention for a certain period of time is necessary.

The limitations of this study are as follows. First, this study verified the effect of short-term therapeutic intervention using only the rib mobilization technique. Future studies will need to investigate changes that occur when therapeutic interventions that consider multifaceted factors that cause breathing problems are applied for a long period of time. Second, since the participants in the study were all young, there are limitations in generalizing the results of this study. In future research, studies targeting various age groups will be needed.

V. Conclusion

The purpose of this study was to investigate the effect of rib mobilization technique (thorax mobility exercise) on the thorax mobility, breathing pattern, and respiratory capacity in subjects with restricted thorax mobility. Based on the results of present study, we suggest thorax mobility exercise using the rib mobilization technique is considered to be a method that can improve thorax mobility and normalize abnormal breathing patterns that cause rib cage elevation.

Conflicts of interest

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

Acknowledgements

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국문초록

가슴 가동성 제한을 가지고 있는 대상자에게 가슴 가동성 운동이 가슴가동성, 호흡패턴 및 호흡량에 미치는 효과: 사례 시리즈

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목적 : 본 연구는 가슴 가동성 제한을 가지고 있는 대상자에게 가슴 가동성 운동이 가슴 가동성, 호흡 패턴 및 호흡 용량에 미치는 영향을 알아보고자 하였다.

연구방법 : 13명의 가슴 가동성 제한을 가진 남/녀 대상자를 대상으로 가슴 가동성 운동(갈비뼈 가동성 운동)을 시행하여 가슴 가동성, 호흡 패턴 및 호흡량에 어떠한 변화가 있는지를 알아보았다. 가슴 가동성 운동 전/후에 연구 참여 대상자의 가슴 가동성(들숨-날숨 간 가슴 확장 길이 측정), 호흡 패턴 형태(가슴 움직임 수직 이동거리 측정) 및 호흡량(forced vital capacity, forced expiratory volume in 1 second)을 측정하였다. 가슴 가동성, 호흡 패턴 및 호흡 용량을 비교하기 위하여 짝-검정을 사용하였다. 통계적 유의성 검정을 위한 유의수준은 .05였다.

결과 : 가슴 가동성과 호흡 패턴은 통계적으로 유의한 차이가 있지만, 호흡 용량은 유의한 차이가 없었다($p < .05$).

결론 : 본 연구의 결과를 토대로 갈비뼈 가동화 기법을 이용한 가슴 가동성 운동은 가슴 가동성 개선과 가슴 올림이 유발되는 비정상적인 호흡 패턴을 정상화시킬 수 있는 방법이라고 여겨진다.

주제어 : 가슴 가동성, 갈비뼈 가동화 기법, 갈비뼈 올림, 호흡 용량, 호흡 패턴