



Original Article

Effects of stretching the scalene muscles on slow vital capacity

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Abstract. [Purpose] The purpose of this study was to examine whether stretching of the scalene muscles would improve slow vital capacity (SVC). [Subjects and Methods] The subjects of this study were 20 healthy female students to whom the study's methods and purpose were explained and their agreement for participation was obtained. The SVC was measured using spirometry (Pony FX, COSMED Inc., Italy). The intervention used was stretching of the scalene muscles. Stretching was carried out for 15 min, 10 times at per each portion of scalene muscles: the anterior, middle, and posterior parts. [Results] Expiratory vital capacity (EVC) and tidal volume (Vt) noticeably increased after stretching. However, there were no changes in any of the SVC items in the control group. [Conclusion] This study demonstrated that stretching of the scalene muscles can effectively improve SVC. In particular, we confirmed that stretching of the scalene muscles was effective in increasing EVC and Vt, which are items of SVC.

Key words: Slow vital capacity, Stretching, Scalene muscle

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INTRODUCTION

The energy required for the cell survival is produced through the energy metabolism process, during which oxygen and nutrients react. Therefore, the lungs that supply oxygen are important for maintaining and improving health¹⁾. However, lungs movement is dependent on that of surrounding structures. In particular, movement of the thorax causes movement of the pulmonary function because the lungs are attached to the thorax. When the thorax expands, the intrapulmonary pressure becomes lower than the atmospheric pressure, leading to inhalation; when the thorax contracted, the intrapulmonary pressure becomes higher than the atmospheric pressure, leading to exhalation²⁾. Contraction of the diaphragm has the greatest effect on the reduction of intrapulmonary pressure, but the expansion and contraction of the thorax also influence pulmonary function. Therefore, to enhance pulmonary function, functions of the major respiratory muscles that directly expand the thorax and the respiratory support muscles that help thoracic expansion by lifting the thorax need to be improved. Major respiratory muscles include the diaphragm, intercostal muscles, and abdominal muscles³⁾ that are involved in resting respiration⁴⁾. Respiratory support muscles include the sternocleidomastoid (SCM), scalene, trapezius, pectoralis major, pectoralis minor, and anterior serratus⁵⁾, which are involved in deep, forced breathing⁴⁾. Therefore, if neck muscles are not easily controllable or the joint range of motion is limited, not only the neck movement but also the thoracic movement become limited, which weaken respiratory function⁶⁾. In relation to this, Legrand et al.⁷⁾ conducted an experiment on dogs and verified that the movement of SCM and scalene, which are respiratory support muscles, lowered intrapulmonary pressure. In particular, they reported that the movement of the scalene had greater action compared to SCM. The SCM appears to have greater effect on thoracic movement because it is attached to the clavicle and sternum, whereas the scalene muscles are attached to the first and second ribs⁸⁾. In agreement with this, Han et al.⁹⁾ also reported that stretching exercises for the neck muscles partially improve pulmonary function. Furthermore, Han et al.¹⁰⁾ reported improved pulmonary function as a result of stretching

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exercise of the SCM and scalene and strengthening exercise for the neck muscles in patients with allergic rhinitis. Likewise, Cho et al.¹¹⁾ also reported improved pulmonary function with neck muscle stretching and cervical joint motion exercises in stroke patients implanted with a tracheotomy tube. However, as reported in the study by De Troyer and Kelly¹²⁾, the SCM and scalene are not involved in resting respiration; on the other hand, Legrand et al.⁷⁾ reported that the scalene muscles could be involved in resting respiration. The scalene muscles consist of the anterior, middle, and posterior muscles. The anterior scalene is attached to the two-third of the medial point of the first rib and the middle scalene is attached to the superior surface of the first rib. Thus, the anterior and middle scalene muscles lift the first rib. The posterior scalene is attached to the dorsal surface of the second rib; thus, it lifts the second rib⁸⁾. Therefore, if the length of the scalene becomes shorter, the extent of the lift of the thorax becomes smaller during inhalation, which can decrease the extent of reduction of intrapulmonary pressure, thereby decreasing inhalation volume. Furthermore, during exhalation, the lowering of the thorax can be hindered, which decreases the extent of exhalation, thereby reducing the total ventilation volume. Nevertheless, studies investigating the correlation between the scalene muscles and pulmonary function are very rare. In particular, no study has been conducted on the correlation between scalene muscles and resting vital capacity. Therefore, in this study, the possibility that the relaxation of the scalene muscles can improve slow vital capacity (SVC) was investigated.

SUBJECTS AND METHODS

The subjects of this study were 20 female students in their 20s who were attending 'S' University in Busan. None of them had a past medical history of diseases of the nervous system, musculoskeletal system, or cardiovascular system that could have affected the results of this experiment. The subjects were randomized into an experimental group of 10 subjects and a control group of 10 subjects who received no treatment. All subjects were informed of the purpose and methods of the study beforehand and voluntarily agreed to participate. This study complied with the ethical standards of the Declaration of Helsinki, and written informed consent was obtained from all subjects.

Before applying stretching exercise to the scalene muscles, SVC of every subject was measured using a digital spirometer (Pony FX, COSMED Inc., Italy) with subjects sitting upright on a chair. They were instructed to straighten their waist and shoulder, spread their feet at shoulder width, and at right angle to the ground. Then, they were instructed to block their nose with a nose clamp and slightly bite into a mouth piece of the measuring instrument. When ready, they were instructed to inhale slowly to the maximum when the start message appeared on the monitor while breathing as usual and then exhale slowly to the maximum, and to breathe as usual. Three measurements were taken, and the average values were used for analysis.

After pulmonary function was measured, stretching exercises for the scalene were performed, in the order of the middle, anterior, and posterior scalene. While manual stretching exercises of the middle scalene, in the starting position, subjects were instructed to bend their neck laterally in the opposite direction. Then, the practitioner standing behind the subject pressed the shoulder with one hand while touching one side of the head and applied a lateral load with the other hand. For the manual stretching exercise of the anterior scalene, in the same position, the subject was instructed to bend the neck laterally in the opposite direction, direct the eyes upwards, and slightly bend the neck posteriorly. In this position, the practitioner standing behind the subject pressed the shoulder with one hand while touching one side of the head and applied a load with the other hand laterally and posteriorly. For manual stretching exercises of the posterior scalene, in the starting position, the subject was instructed to bend the neck forward and then laterally in the opposite side, and to look to the side and downward. The practitioner standing behind the subject pressed and fixed the shoulder with one hand while touching one side of the head and applied a lateral load with the other hand. For this manual stretching exercise, a hold-relax technique that involved holding for 6 s, followed by relaxing for 4 s was applied, for a total of 10 times. When one exercise was completed, a 5-s resting time was given. The total duration of manual stretching exercise was about 15 min. In the experimental group, the SVC was measured again after scalene muscle stretching. In the control group, the SVC was measured again after resting in the sitting position on a chair for 15 min, without treatment.

The data were analyzed using the IBM SPSS Statistics for Windows (ver. 21.0), and the significance level was set as $\alpha=0.05$. First, a test of normality was performed with the Shapiro-Wilk test. As the normality condition was satisfied, parametric statistical analysis was performed in this study. To examine homogeneity between the experimental and control groups before the experiment, an independent t-test was performed. Then, a paired t-test was performed to examine changes in SVC between the experimental and control groups.

RESULTS

Differences in the general characteristics and SVCs of the experimental and control groups before the intervention are listed in Table 1. Regarding general characteristics, the ages of subjects in the experimental and control groups were 21.3 and 21.6 years; the heights were 163.0 cm and 162.6 cm; and the weights were 60.2 kg and 57.3 kg, respectively. For SVC, the expiratory vital capacities (EVCs) of the experimental and control groups were 3.1 L and 2.9 L; expiratory reserve volumes (ERVs) were 1.2 L and 1.2 L; inspiratory reserve volumes (IRVs) were 1.3 L and 1.2 L; VE was 15.6 L and 14.3 L; and tidal volume (Vt) were 0.7 L and 0.6 L, respectively. There were no significant differences between the two groups in other items.

The effects of stretching on SVC are shown in Table 2. In the experimental group, EVC ($p<0.05$) and Vt ($p<0.05$) showed

Table 1. Differences in general characteristics and slow vital capacities between the experimental and control groups before intervention

| Variables | Experimental | Control |
|--------------------------------|--------------|-------------|
| Age (years) | 21.3 ± 0.7 | 21.6 ± 0.5 |
| Height (cm) | 163.0 ± 5.8 | 162.6 ± 3.7 |
| Weight (kg) | 60.2 ± 8.2 | 57.3 ± 7.3 |
| Expiratory vital capacity (l) | 3.1 ± 0.3 | 2.9 ± 0.3 |
| Expiratory reserve volume (l) | 1.2 ± 0.2 | 1.2 ± 0.2 |
| Inspiratory reserve volume (l) | 1.3 ± 0.3 | 1.2 ± 0.3 |
| Minute ventilation (l) | 15.6 ± 6.6 | 14.3 ± 6.4 |
| Tidal volume (l) | 0.7 ± 0.2 | 0.6 ± 0.2 |

Table 2. Differences in slow vital capacities between the experimental and control groups before intervention

| Variables | Group | Pre-stretching | Post-stretching |
|--------------------------------|---------------|----------------|-----------------|
| Expiratory vital capacity (l) | Experimental* | 3.1 ± 0.3 | 3.3 ± 0.3 |
| | Control | 2.9 ± 0.3 | 2.9 ± 0.3 |
| Expiratory reserve volume (l) | Experimental | 1.2 ± 0.2 | 1.3 ± 0.3 |
| | Control | 1.2 ± 0.2 | 1.2 ± 0.3 |
| Inspiratory reserve volume (l) | Experimental | 1.3 ± 0.3 | 1.2 ± 0.3 |
| | Control | 1.2 ± 0.3 | 1.1 ± 0.4 |
| Minute ventilation (l) | Experimental | 15.6 ± 6.6 | 17.2 ± 7.1 |
| | Control | 14.3 ± 6.4 | 16.5 ± 7.5 |
| Tidal volume (l) | Experimental* | 0.7 ± 0.2 | 0.8 ± 0.4 |
| | Control | 0.6 ± 0.2 | 0.6 ± 0.3 |

*p<0.05

a significant increase after stretching. On the other hand, ERV and VE increased and IRV decreased after stretching, but the differences were nonsignificant. In the control group, VE and Vt increased, ERV and IRV decreased, and EVC did not change.

DISCUSSION

Inspiratory and expiratory volumes are influenced by the degree of contraction and relaxation of the diaphragm²⁾. However, the roles of respiratory support muscles that lift the thorax can also influence ventilation volume. De Troyer and Kelly¹²⁾ electrically stimulated the respiratory support muscles originating from the neck of dogs, examined changes of the thorax and found that the volume of the thorax increased. Muza et al.¹³⁾ also verified that lung volume increases when electric stimuli are applied to the SCM of dogs. These results clearly show that the SCM and scalene which are respiratory support muscles are involved in pulmonary function. In relation to this, Wilson and De Troyer^{14, 15)} assumed that the muscles involved in the respiratory system could be involved in the expansion of the chest wall. In particular, because the contracting power of the muscles involved in inhalation is the driving force behind the opening of the respiratory tract, muscle mass, the maximal active muscle tension per unit cross-sectional area, and fractional changes in muscle length per unit volume increase of the relaxed chest wall influence the expansion of the respiratory tract¹⁶⁾. In other words, if the inspiratory main and support muscles have many muscular fibers, a large muscular contraction force per unit area, and a large change in muscle length per unit time, the pressure expanding the respiratory tract and the inhalation volume increase. Therefore, if the SCM and scalene have a large volume, a large muscular contraction force per unit area, and a large change in muscle length per unit time, the thorax is lifted to a greater extent and the inhalation volume increases. In this regard, Han et al.¹⁷⁾ also noted that forward head posture could reduce vital capacity, possibly because of weakness of the accessory respiratory muscles. This means that respiratory function is related to the functions of the SCM and scalene muscle. To verify this, Legrand et al.⁷⁾ examined changes in the length of the SCM and scalene while manually injecting external air into dogs to expand their lungs. As a result, they found that the SCM and scalene both became short, and the scalene in particular became shorter. Furthermore, when muscular contraction was induced by stimulating the two muscles, the rib cage significantly moved toward the head and the alveolar pressure decreased. Consequently, the more the lengths of the SCM and scalene changed per unit volume, the more the alveolar pressure lowered. This result experimentally confirmed that the ventilation volume through thoracic expansion increases when the SCM and scalene maintain reasonable lengths and the contraction and relaxation are normal. In line with

this, the results of the present study show that the Vt and EVC increased in the SVC. An increase in Vt means that inspiratory and expiratory volumes increase. The Vt increased because the stretching of the scalene increased its length, which increased changes in the contracting muscle length per unit time and accelerated the lifting of the thorax, and the intrathoracic pressure became lower as a result. Likewise, the EVC increased because the scalene was relaxed and the descent of the thorax during exhalation became larger, further increasing intrathoracic pressure. In addition, Han et al.¹⁷⁾ also mentioned that forward head posture could reduce vital capacity, possibly because of weakness of the accessory respiratory muscles.

The results of this study verified that stretching of the scalene improves Vt and EVC, and this has positive effects on increased SVC. Hence, stretching of the scalene should be included in the programs for improvement of respiratory functions.

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