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# Comparison of the Effects of Two Different Stretching on Shoulder Flexion Angle, Muscle Tone, and Thoracic Mobility in Subjects with Short Latissimus Dorsi Muscle

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## Abstract

This study aimed to compare the effects of two latissimus dorsi muscle (LD) stretching exercises on the shoulder joint flexion angle, LD muscle tone, and thoracic mobility in subjects with short LD. This was a cross-sectional and randomized controlled trial. The study included 28 subjects with a short LD. Participants showing a range of shoulder flexion of <170° in the LD length test were identified as having a short LD. The subjects were randomly assigned to either Group 1 (shoulder abduction + contralateral trunk side bending) or Group 2 (shoulder abduction + shoulder external rotation). LD muscle tone and stiffness were measured using Myoton PRO. Thoracic mobility of the middle part was measured using a circular tape measure. Both groups 1 and 2 showed significantly increased range of shoulder flexion and middle thoracic mobility, and the LD muscle tone of the distal and lower parts and LD muscle stiffness of the distal parts decreased significantly after interventions ($p<.05$). In the comparison between groups, no significant differences were noted in all dependent variables. Therefore, this study suggests that both LD stretching exercises can be effective in increasing the range of shoulder flexion, reducing LD muscle tone and stiffness, and improving chest mobility.

**Key Words:** Latissimus dorsi; Muscle tone; Stretching; Thoracic mobility

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## Ⅰ. Introduction

The latissimus dorsi muscle (LD) is directly attached to the back of the sacrum, posterior iliac crest, back fascia, 8th to 12th ribs, inferior angle of the scapula, and spinous processes of the 7th to 12th thoracic vertebrae. It attaches indirectly to the spinous process of the lumbar vertebra through the muscle fibers of the LD traveling laterally above the axillae, twists once before attaching to the distal attachment point, and reaches the floor of the intertubercular groove of the humerus (Gerling and Brown, 2013; Huberty et al., 2018; Kendall et al., 2005; Muscolino, 2013). The main function of this muscle is to extend, adduct, and rotate internally the humerus (Bogduk et al., 1998); however, as a muscle attached from the 8th rib to the 12th rib, it controls breathing and generates the pressure necessary for breathing, while the chest wall and trunk are fixed. It also contributes to lateral flexion of the trunk and extension of the lumbar spine (Goel et al., 1993; Guzik et al., 1996; McGill and Norman, 1986; Potvin et al., 1991; Schultz and Andersson, 1981).

The LD has a long lever arm extending from the humerus to the lumbar fascia, and as it generates tension on the lumbar fascia, it can also affect lumbopelvic movement (Huberty et al., 2018). When the LD is shortened, it directly stresses the lumbar fascia and may cause back pain by creating an anterior tilt of the pelvis and excessive extension of the lumbar region (Dongre and Sharma, 2008). In addition, when the humerus is internally rotated due to shortening of the LD, the greater tubercle of the humerus could be located under the coracoacromial ligament. Subsequently, it might reduce the subacromial space (Hawkins and Kennedy, 1980; Valadie et al., 2000; Yamamoto et al., 2009). This decrease in space causes pinching of the supraspinatus muscle, biceps brachii muscle long tendon, subacromial capsule, and shoulder joint capsule during arm elevation (McFarland et al., 1999; Michener et al., 2003). Therefore, increased internal rotation of the humerus due to shortness or stiffness of the LD can lead to shoulder complex dysfunction and musculoskeletal pain.

Static stretching exercises are a typical method for treating shortened LD. Static stretching exercises are widely used clinically to increase the range of motion of a joint by directly stretching the LD and increasing the resistance to stretching. Commonly, LD stretches are commonly performed with a combination of shoulder abduction and contralateral trunk flexion (Turgut et al., 2018). The lower part of the LD significantly increases when contralateral trunk flexion is performed, and the combination of contralateral trunk rotation and contralateral trunk flexion, and contralateral trunk rotation effectively stretches all parts of the LD according to previous studies (Asayama et al., 2021). However, this method causes excessive rotation and bending of the trunk, making it difficult to apply in early rehabilitation, and may cause discomfort in breathing. In addition, excessive lateral bending of the trunk can increase lordosis of the lumbar region, and it may be difficult to bring about the elongation effect of the distal attachment point, which has a significant influence on the internal rotation of the humerus. Understanding a more effective LD stretching position without discomfort is important to prevent LD injuries and ensure an early return to competition after LD injuries.

Therefore, the purpose of this study was (1) to investigate changes in the shoulder joint flexion angle, LD muscle tone and stiffness, and thoracic mobility in two groups (shoulder joint abduction + contralateral trunk lateral flexion vs. shoulder joint abduction + lateral rotation). (2) The differences between the two groups were compared. The hypotheses of this study are as follows: (1) Shoulder joint flexion angle, LD muscle tone and stiffness, and thoracic mobility improved in both groups after intervention. (2) When comparing the two groups, significant differences were noted in the shoulder joint flexion angle, LD tone and stiffness, and thoracic cage mobility.

## Ⅱ. Materials And Methods

### 1. Participants

The subjects of this study were 28 adult males attending university B, located in Cheonan, Chungcheongnam-do. The passive shoulder joint flexion angle was measured on both arms, and the smaller one was selected as the final measurement side (12 patients on the right and 16 patients on the left). The 28 subjects were randomly assigned to 14 group 1 and 14 group 2 using the random number function of Microsoft Excel 2010. The criteria for selecting the study subjects were as follows: Adults aged 20 years or older, no neurologic or orthopedic problems, voluntarily consented after hearing the method and process of this study, and a passive shoulder joint flexion angle of <170° during the LD length test (Kwon et al., 2022). Among the subjects selected by consenting to this study, those with a history of having or suffering from cardiopulmonary disease, with a history of respiratory organ surgery, with or with a history of musculoskeletal disorders of the shoulder, and do not agree with this study procedure were excluded from this study. This study was approved by the Institutional Review Board of Baekseok University (BUIRB-202210-HR-026). Table 1. shows the general characteristics of the study subjects.

### 2. Research procedure

To confirm the shortening of the LD, the passive shoulder flexion angle was measured in the supine position, and subjects with a degree of <170° were selected. After selecting the subjects, the principal investigator explained the overall progress of the experiment to all subjects. After obtaining consent to participate in the research, the experiment was conducted. Height and weight were measured, followed by pre-measurements in the order of shoulder joint flexion angle, LD tone and stiffness, and thoracic mobility. Subsequently, two groups were selected using the random number function of Microsoft Excel 2010. Post-measurement was performed in the same order as pre-measurement immediately after all interventions were completed.

### 3. Measurement methods

#### 1) The LD length test (shoulder joint flexion angle measurement)

The shoulder joint flexion angle was measured

**Table 1.** General characters

| Variables | Group 1 (n=14) | Group 2 (n=14) |
|---|---|---|
| Age (yrs) | 23.71 ± 2.43[a] | 22.79 ± 1.42 |
| Height (㎝) | 176.07 ± 5.84 | 175.14 ± 5.10 |
| Weight (㎏) | 78.79 ± 11.70 | 70.18 ± 8.58 |
| Shoulder flexion Angles (°) | 160.43 ± 7.65 | 162.43 ± 5.36 |

[a]Mean±standard deviation

using a goniometer (Goniometer, Fabrication Enterprises Inc., USA) for the LD length test. The subject was in a supine position with the knee and hip joints flexed, soles of both feet placed flat on the treatment table, and participant's lumbar spine pressed toward the treatment table. A Mulligan belt was used to firmly fix the anterior superior iliac spine of the pelvis to the treatment table to prevent anterior tilting of the pelvis during the length test. Subjects were asked to notify the therapist if the belt was pulled too hard, as this meant that the participant's lumbar spine was lifted off the support, and the participant's pelvis was tilted anteriorly. The axis of movement of the goniometer for measuring the shoulder joint flexion angle was placed on the lateral side of the greater tubercle of the humerus and was marked with a pen. The stationary arm was placed parallel to the center of the axillary line, and the moving arm was placed parallel to the shaft of the humerus. The subject's thumb was pointed toward the ceiling to prevent internal rotation of the humerus, and the lumbar vertebrae were kept neutral to prevent an increase in lordosis. Then, the investigator fixed the goniometer with one hand, with the other hand, the subject's shoulder joint was flexed until additional movements occurred, such as when the subject's thumb pointed inward (Dawood et al., 2018). Measurements were taken three times, before and after the intervention, and the average value was used in the final data analysis.

2) Latissimus dorsi muscle tone and stiffness

The muscle tone and stiffness of the LD were measured using MyotonPRO (Myoton AS, Tallinn, Estonia). Muscle tone (F, Hz) is the resistance to passive stretching, which reflects reflex stimulation of the muscles. It is expressed in frequency (Hz) because it indicates vibration in a resting state (EMG at baseline) without voluntary muscle contraction. In addition, as a biomechanical characteristic of muscles, muscle stiffness (S, N/m), which is the magnitude of force required to cause tissue displacement, was measured (Schneider et al., 2015) In this study, the LD was measured in the prone position and divided into four parts. The LD is one of the largest muscles and divided into distal (near distal attachment part), upper (thoracic fibers), middle (lumbar fibers), and lower parts (iliac fibers): distal, three fingers outward from the axillary fold; upper part, the lower part of the inferior angle of the scapula at the level of the spinous process of the 8th thoracic vertebrae; middle part, the point where the horizontal axis of the spinous process of the 8th thoracic vertebra meets the line crossing the top of the ridge of the spinous process of the 1st lumbar vertebra and the iliac crest of the femur; lower part, the point where the horizontal axis of the level of the spinous process of the 8th thoracic vertebra meets the line crossing the apex of the ridge of the superior iliac spine and the iliac crest of the femur (McDonald et al., 2018). Vibration and noise, which are environmental factors that may affect measurements, were controlled and measured at an appropriate temperature (22 - 24℃) and humidity (45 - 60%). The subjects were instructed to relax during the measurements. During measurement, the muscle belly and measuring device were measured perpendicular to each other, and resonant vibration was allowed to occur. It was measured three times before and after the intervention, and the average value was used for the final data analysis. The higher the F and S values of myotons, the greater the soft tissue tension and muscle stiffness (Schneider et al., 2015). This measurement method shows reliability from very high reliability to excellent reliability, and from good reliability to high reliability (interclass correlation coefficient; 0.97 to 0.99) (Mullix et al., 2012).

#### 3) Thoracic mobility

To measure thoracic mobility, a circular tape measure (Hoechtmass, HIVER, Germany) was used. First, the subjects abducted both shoulders in an upright posture, and the examiner marked the xiphoid process with a pen to measure the mid-thoracic cage mobility and then placed a tape measure at the marked point to measure it. After placing a tape measure at the reference point and measuring the circumference of the middle of the thorax during rest, the circumference of the middle of the thorax at maximum inspiration was re-measured in the same way, and the difference between the circumference of the thorax at maximum inspiration and that of the chest at rest was derived for analysis (Miller et al., 2005). Measurements were taken three times before and after the intervention, and the average value was used in the final data analysis. A decrease in measured thoracic mobility indicates a decrease in lung elasticity. This measurement method is highly reliable and widely used in clinical practice (inter-class correlation coefficient: 0.80 - 0.91) (Bockenhauer et al., 2007).

### 4. Interventions

#### 1) Shoulder abduction + contralateral trunk bending in the sitting position (group 1)

After the subject sat on a chair without a backrest, the hip and knee joints were positioned at 90°. The proximal thigh was firmly secured with a belt to prevent the pelvis from rising when the LD was stretched. The shoulder on the tested side was maximally abducted, and the elbow was bent so that the forearm touched the head. Subsequently, the subject passively bent the trunk to the opposite side, and the investigator stretched the muscle by pressing the distal part of the subject's upper arm (Asayama et al., 2021). The intervention method was shown in Figure 1. Stretching exercises were performed at the maximum angle at which the subject did not feel discomfort or pain (Nakamura et al., 2011), and instructions were given to relax the body as much as possible between intervention and rest. A total of four sets of 30 s of maintenance and 10 s of rest were performed, and if the position of the trunk and pelvis could not be maintained, the values were excluded from the final analysis.

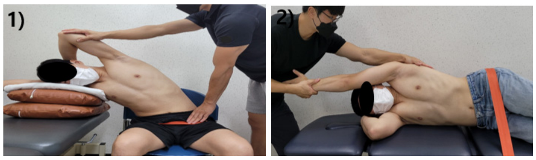


**Figure 1.** Two different stretching exercises of latissimus dorsi muscle; 1) shoulder abduction + contralateral trunk bending, 2) shoulder abduction + lateral rotation

#### 2) Shoulder abduction + lateral rotation in the side lying position (group 2)

The subjects were placed on their side on a treatment table, and their backs were placed against a wall to minimize trunk movement. To prevent the pelvis from lifting during stretching, the hip and knee joints were flexed at 90°. To prevent lateral bending of the trunk, one hand was placed on the axillary part of the subject's LD, and the other hand was placed on the wrist. While observing the movement of the subject's pelvis and trunk, the shoulder was rotated laterally and abducted until the LD stretch was felt (Kwon et al., 2022). The intervention method is shown in Figure 1.

Stretching exercises were performed at the maximum angle at which the subject did not feel discomfort or pain (Nakamura et al., 2011), and instructions were given to relax the body as much as possible between intervention and rest. A total of four sets of 30 s of maintenance and 10 s of rest were performed, and if the position of the trunk and pelvis could not be maintained, the value was excluded from the final analysis.

### 5. Statistical analysis

In this study, the collected data were analyzed using SPSS version 18.0 (SPSS Inc. Chicago, IL, USA). A paired t-test was conducted to verify whether there were pre- and post-differences in the shoulder joint flexion angle, muscle tone, and thoracic mobility. An independent t-test was used to compare the difference in values before and after the interventions, and the statistical significance level was set at 0.05.

## Ⅲ. Results

### 1. Intra-group comparison before and after intervention

In both intervention groups, the shoulder joint flexion angle and middle thoracic mobility

**Table 2.** Comparisons of dependent variables between pre and post interventions

| Variables | Group | | Pre[a] | Post[a] | $t$ | $p$ |
|---|---|---|---|---|---|---|
| Shoulder flexion angles (°) | 1 (n=14) | | 160.43±7.65 | 165.64±7.15 | −3.26 | .00* |
| | 2 (n=14) | | 162.43±5.36 | 168.50±5.08 | −4.37 | .00* |
| Muscle tone (F, ㎐) | 1 (n=14) | Distal | 12.01±.92 | 11.50±0.83 | 3.22 | .00* |
| | | Upper | 13.66±1.29 | 13.60±1.36 | 0.43 | .68 |
| | | Middle | 12.63±0.63 | 12.61±0.61 | 0.09 | .93 |
| | | Lower | 11.94±0.48 | 11.63±0.48 | 2.89 | .01* |
| | 2 (n=14) | Distal | 12.42±1.12 | 11.92±1.06 | 5.88 | .00* |
| | | Upper | 14.19±1.18 | 14.12±1.14 | 0.77 | .45 |
| | | Middle | 13.30±0.67 | 13.16±0.73 | 1.48 | .16 |
| | | Lower | 12.34±0.59 | 12.08±0,.70 | 2.58 | .02* |
| Muscle stiffness (N/m) | 1 (n=14) | Distal | 191.50±31.88 | 184.43±28.35 | 2.22 | .05* |
| | | Upper | 242.98±52.63 | 238.48±46.19 | 0.81 | .43 |
| | | Middle | 210.21±23.14 | 205.75±26.31 | 0.84 | .42 |
| | | Lower | 201.40±19.47 | 192.86±17.77 | 2.73 | .02* |
| | 2 (n=14) | Distal | 191.88±28.50 | 186.86±28.69 | 2.33 | .03* |
| | | Upper | 245.74±39.21 | 246.26±43.62 | −0.17 | .87 |
| | | Middle | 218.43±17.81 | 215.52±20.16 | 1.31 | .21 |
| | | Lower | 200.45±16.00 | 198.17±18.74 | 0.93 | .37 |
| Thoracic mobility (㎝) | 1 (n=14) | | 2.65±1.07 | 3.00±1.18 | −3.30 | .01* |
| | 2 (n=14) | | 3.94±1.24 | 4.09±1.14 | −2.46 | .03* |

[a]average ± standard deviation.
*$p<.05$
Group 1 refers shoulder abduction + contralateral trunk bending
Group 2 refers shoulder abduction + lateral rotation

significantly increased after each intervention. The muscle tone (F) in the distal and lower parts of the LD decreased significantly in both groups. Muscle stiffness (S) decreased significantly in the distal and lower parts in the group 1, and significantly decreased only in the distal parts in the group 2, and the results are shown in Table 2.

### 2. Intergroup comparison

In the comparison between the groups, no significant difference was noted in all dependent variables.

## Ⅳ. Discussion

This study was conducted to investigate the effects of two different stretching exercises applied to subjects with shortened LD on the shoulder joint flexion angle, muscle tone of the LD, and thoracic mobility. As a result, in both groups, shoulder joint flexion angle and middle thoracic mobility significantly increased, and muscle tone in the distal and lower parts of the LD significantly decreased after the intervention. As a result of comparing the differences values of pre and post intervention, no significant difference was noted between the two groups.

The shoulder joint flexion angles in both groups increased by 3.25% and 3.74%, respectively, compared with those before the intervention. The increase in the shoulder joint flexion angle after the intervention in both groups can be explained as follows. The major function of the LD is to extend, adduct, and rotate internally the humerus (Bogduk et al., 1998); however, it also contributes to lateral flexion of the trunk and extension of the lumbar spine (Goel et al., 1993, Guzik et al., 1996, McGill and Norman, 1986, Potvin et al., 1991, Schultz and Andersson, 1981). Accordingly, the LD is stretched during abduction of the shoulder joint and lateral flexion of the trunk on the opposite side, as in the group 1, and shoulder abduction and lateral rotation, as in the group 2. Static stretching in a posture in which the LD is stretched may cause viscoelastic changes in the muscle, improve the extensibility of the soft tissue, and increase the flexion angle of the shoulder joint (Dongre and Sharma, 2008, Huberty et al, 2018, Porterfield and DeRosa, 1991). Therefore, both groups would be effective in increasing the shoulder joint flexion angle in subjects with shortened LD.

The distal and lower muscle tone excluding the LD upper and middle parts, in both groups significantly decreased compared with that before the intervention. The reason why muscle tone and stiffness in the distal and lower parts of the LD significantly decreased in the group 1 was that the upper and middle parts of the LD were almost horizontal, whereas the distal and lower parts were close to vertical. Based on this, the upper and middle parts were effectively stretched by the opposite trunk rotation, and the distal and lower parts were effectively stretched by the opposite trunk lateral bending. Accordingly, as trunk rotation was not included in the group 1 method of this study, muscle tone and stiffness in the upper and middle regions, where muscle fibers are near horizontal, would not have been effectively reduced. The distal muscle tone and stiffness were significantly reduced, although contralateral trunk lateral flexion was not included in the group 2. The reason for this is that, unlike the group 1, the group 2 stretched while maintaining lateral rotation of the humerus. Therefore, the tone and stiffness at the distal attachment part of the LD would have increased, creating a greater stretching force in the region closer to the distal attachment part. In addition, the investigator placed a hand on the subject's trunk to prevent lateral flexion of the subject's trunk, which was close to the distal and inferior portions of the LD. This created a fixation point during stretching; accordingly, the distal and lower parts closer to the fixation point were stretched more effectively, and muscle tone and stiffness were significantly reduced. Previous studies have reported that sports injuries of the LD mainly occur in the axillary region, which is the distal part of the LD, as well as in the tendon and muscle-tendon junction. In addition, Donohue et al. (2017) and Celebi and Ergen (2013) reported that sports injuries of LD occur not only in the tendons and muscle–tendon junctions but also in the axillary region. This region corresponds to the distal part of the LD (Çelebi and Ergen, 2013, Donohue et al., 2017). Therefore, interventions 1 and 2 are recommended for relaxation of the shortened distal and lower parts of the LD.

The middle thoracic mobility of the group 1 and 2 increased by 13.21% and 3.81%, respectively, compared with that before the intervention. In a study by Kim et al. (2014), mobility of the middle part of the thorax significantly increased as a result of performing thoracic spine mobilization exercises in healthy adults. Thoracic volume significantly increased as a result of performing respiratory muscle stretching exercises for patients with chronic obstructive pulmonary disease (Minoguchi et al., 2002). The reason for such a result can be explained as follows. First, the LD is connected to the back fascia and provides compressive force to the ribcage during contraction. When the LD is stretched, the viscoelasticity of the connective tissue and muscle fibers increases, and the increased viscoelasticity decreases the muscle tone. Finally, the mobility of the thorax would have improved because of the decreased resistance surrounding the thorax. Second, intercostal muscles exist between the ribs to control rib movement. The posture of abducting the arm and bending the trunk in the upright sitting position in the group 1 and the posture of abducting and abducting the arms in the side-lying position in the group 2 can also induce stretching of the intercostal muscles. Improved flexibility of the intercostal muscles would have resulted in increased intercostal and mid-thoracic mobility, although its length was not measured in this study. A previous study also reported that thoracic mobilization exercises help improve flexibility of the chest wall and increase the length of intercostal muscles (Kim et al., 2014). Based on the results of this study, LD stretching exercises are recommended to improve mobility of the thorax in subjects with LD shortening.

Comparing the difference in values pre and post intervention, no significant difference was noted between the two groups. Regardless of discomfort, the most effective method to stretch the LD is to perform simultaneously shoulder joint abduction, flexion, lateral rotation, contralateral trunk flexion, and lumbar flexion. However, Group 1 involved abduction of the shoulder joint and lateral trunk flexion on the opposite side, and group 2 involved shoulder abduction and lateral rotation. In both groups, shoulder joint abduction, flexion, lateral rotation, contralateral trunk flexion, and lumbar flexion were not performed, and only two were applied; thus, a significant difference may not be noted between the two groups. Intervention 2 was introduced in this study because of the discomforts during LD stretching. The excessive rotation and bending of the trunk would cause the chest to collapse to one side, making breathing uncomfortable, and excessive lateral bending of the trunk in the early stages of rehabilitation could increase forward bending in the lumbar region. During the interventions, several subjects in group 1 complained of breathing discomfort and none of the subjects in group 2. According to the results of this study, there is no difference in the effectiveness of the two stretching methods. Therefore, the shoulder abduction with lateral rotation is recommended to improve shoulder joint flexion angle, LD muscle tone and stiffness, and thoracic mobility in early rehabilitation.

This study had several limitations. First, as the study subjects were limited to young adult males, generalizing the results of the study to all ages and sexes is unreasonable. Therefore, future studies targeting various age groups and sexes should be conducted. Second, only the subject's range of motion and muscle tone were evaluated, and no functional evaluation or discomfort were noted. This study could not confirm the clinical and long-term effects. Considering these limitations, further studies, including follow-up studies on the lasting effects and investigations of clinical effects in patients, are needed.

## Ⅴ. Conclusion

The purpose of this study was to compare two LD stretching exercises in subjects with LD shortening in terms of shoulder joint flexion angle, LD muscle tone and stiffness, and thoracic mobility. As a result of the study, shoulder joint flexion angle and thoracic mobility significantly increased in both groups, and muscle tone decreased significantly in the distal and lower parts of the LD. Therefore, this study suggests that both LD stretching exercises can effectively increase the shoulder joint flexion angle, reduce muscle tone, and improve mobility of the mid-thoracic region in subjects with shortened LD.

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