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Effects of pectoralis minor length on strength improvement and pain reduction during scapular reposition test

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Abstract. [Purpose] This study aimed to compare pain and shoulder elevation strength when scapular reposition test is applied to subclinical individuals with a short or long pectoralis minor. [Participants and Methods] Subclinical participants (n=34) with a positive impingement result on at least one of three tests were assigned to short (n=18) or long (n=16) pectoralis minor groups. Impingement tests were repeated with and without scapular reposition test. Visual analog scale was used to measure pain intensities under both conditions. Isometric shoulder elevation strength was measured by dynamometry. Two-way analyzes of variance and paired t-test were used to evaluate the effects of scapular reposition test in the two groups. [Results] The effects of pectoralis minor length on the frequencies of meaningful strength, pain reduction, and positive scapular reposition test result were evaluated. Repositioning reduced pain in both groups. In the short pectoralis minor group, shoulder elevation strength was significantly improved by scapular reposition test. A meaningful strength improvement and positive scapular reposition test result were reported more frequently in the short pectoralis minor group. [Conclusion] Consideration of pectoralis minor length and scapular reposition test results could aid the identification of factors contributing to scapular dyskinesis and related shoulder injuries, thereby enabling the selection of appropriate interventions.
Key words: Scapular reposition test, Pectoralis minor, Impingement

INTRODUCTION

Scapular dyskinesis, defined as a change in scapular position or motion, is one of several etiologic factors that cause shoulder joint pain[1]. Causes include a short pectoralis minor (PM)[2, 3]; thoracic kyphosis[4, 5]; pain[6]; changes in periscapular muscle activation[7]; or muscle fatigue[8, 9]. PM shortening occurs adaptively following the repetitive movements of the scapula or due to a consistently shortened PM[10, 11]. Adaptive PM shortening may increase passive tension results and reduce the subacromial space by restricting normal scapular motion, such as upward rotation, posterior tilt, and external rotation, during arm elevation[2]. Therefore, the resting length of the PM is emphasized when evaluating and treating shoulder lesions associated with scapular dyskinesis[12, 13].

Multiple tests are administered by physicians and clinicians to diagnose and assess shoulder dysfunction. Previous studies have suggested two symptom alternation tests the scapular assistance test and scapular retraction test are used to evaluate the effects of the passive correction of scapular dyskinesis on symptoms[14–16]. During the scapular assistance test, force is applied by an examiner to the scapular inferior angle to assist scapular upward rotation[17]. In contrast, when conducting the scapular retraction test, an examiner manually stabilizes the scapula in a retracted position[18]; when passive correction of the scapula reduces pain or increases shoulder elevation strength, results of this test are defined as positive.

However, recent studies have reported that excessive scapular retraction reduces shoulder elevation strength[19]. Tate et

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al.[20] proposed the scapular reposition test (SRT), which avoids excessive scapular retraction but emphasizes external rotation and posterior tilt. SRT is a clinical examination that confirms the presence of scapular dyskinesis by identifying changes in symptoms and strength during passive scapula repositioning. It is performed by using the hand and forearm of an examiner to reposition the scapula into external rotation and posterior tilt. Tate et al.[20] reported the frequencies of pain and shoulder elevation strength improvements during SRT in overhead athletes with or without impingement. In addition, Romkey et al.[21] measured shoulder elevation strength during SRT in professional pitchers with or without scapular dyskinesis. However, no study to date has investigated the effect of SRT on pain and shoulder strength in the ordinary individuals with scapular dyskinesis or sought to identify factors that contribute to scapula function. The purpose of this study was to examine the effect of PM resting length (a cause of scapular dyskinesis) on positive SRT results in subclinical individuals. We hypothesized that reduced pain, increased shoulder elevation strength, and a positive SRT result would be more common among individuals with a short PM.

PARTICIPANTS AND METHODS

Pilot data were collected from 10 participants who had at least one positive result for impingement when administered the Neer, Hawkins-Kennedy, and empty can tests. Data were used to determine a meaningful increase of the shoulder elevation strength and an objective cut point between the short and long PM groups. The averages of three measurements of the distance between the inferomedial aspect of the coracoid process and inferior aspect of the fourth rib at the sternum obtained using a tapeline were taken to indicate PM resting length. To determine the normalized PM length, the PM index (PMI) was calculated using the formula $\{[$PM resting length (cm)/participant height (cm)$] \times 100\}$[2]. Pilot data indicated a mean PMI of 7.49 and standard deviation (SD) of 0.4. Test-retest reliability for measurements of normalized joint torque for isometric shoulder elevation strength was demonstrated by an intraclass correlation coefficient (ICC) of 0.98. The standard error of measurement (SEM) for the normalized joint torque for isometric shoulder elevation strength was calculated by multiplying the SD by $\sqrt{(1-ICC)}$. A meaningful change in isometric shoulder elevation strength was defined as the minimal detectable change score at the 90% confidence interval (MDC90), which was calculated by multiplying the SEM by $1.64 \times \sqrt{2}$. The MDC90 value based on pilot data was 0.06 Nm/kg.

To detect a mean difference of 0.06 Nm/kg change in shoulder elevation strength during SRT with a statistical significance level of 0.05 and power of 80%, 14 participants per group were required. Power was calculated using the SD of 0.06 Nm/kg, which was obtained from the pilot data.

Initial identification of 80 volunteers was achieved using a flyer advertising the study at Daegu University, South Korea. The inclusion criterion was reported pain intensity of at least 1.4 cm on a visual analog scale (VAS) during one of three impingement tests (Neer, Hawkins-Kennedy, and the empty can tests), which is the minimal clinically importance difference reported in shoulder pain. Exclusion criteria were shoulder instability, defined as a positive result on one of two tests (the sulcus and apprehension tests); and a PMI within $\pm$ 1 SD of the mean score, which was determined using pilot data.

The primary investigator, who was a physical therapist with 7 years of experience in orthopedic manual therapy, performed tests evaluating impingement, shoulder instability, and PM length. Overall, 54 participants met the inclusion criterion, among whom none had experienced traumatic shoulder injury or cervical spine pain and all had a full range of shoulder elevation. Among these, 20 participants were excluded who did not meet the cutoff values for PMI group inclusion. The remaining 34 participants assigned to the long PM group (n=16) had a PMI >8.19 and those assigned to the short PM group (n=18) had a PMI <7.39. All participants read and signed a consent form, which was approved by the Daegu University Institutional Review Board (1040621-201511-HR-011-02), prior to study commencement.

The physical examination and SRT were performed by the primary investigator. Data collection, PMI calculations, and group classifications were performed by the second investigator, and thus, the primary investigator and participants were unaware of group classifications.

Pain intensity measurements were performed as a previous study in two steps[20]. First, pain was measured using a VAS rating obtained during the most painful impingement test (Neer, Hawkins-Kennedy, or empty can test) and side (if the subject was affected bilaterally) for each subject, as determined during the eligibility assessment. In the second step, the impingement test was repeated with the scapula manually stabilized using SRT, which was conducted by the examiner who repositioned the scapula into external rotation and posterior tilt using his hand and forearm[20]. Participants were asked to rate their pain again using the VAS.

A hand-held dynamometer (CommanderTM Muscle Tester; JTECH Medical, Midvale, UT, USA) was used to assess isometric shoulder elevation strength. It was fixed to a height adjustable rigid bar to eliminate measurement variations caused by differences in examiner force and stabilization. Shoulder strength measurements obtained using a hand-held dynamometer have been reported to have excellent inter- and intra-rater reliability in symptomatic and asymptomatic participants.

Shoulder elevation strength was measured with the subject standing in the empty can test position. Briefly, participants were asked to elevate the arm to 90° in the scapular plane (defined as 30° anterior to the frontal plane) with the thumb pointing down. The position of the participant and height of the dynamometer were adjusted such that the transducer was in contact with the ulnar styloid. Before measuring shoulder strength, all angular positions were confirmed using a goniometer. Participants were given a standardized description of the procedures used for shoulder strength testing. Each participant was evaluated on the side,

which produced pain during the impingement test or on the most painful side if they were affected bilaterally. To minimize the learning effect, strength testing was performed after 3 submaximal practice trials. A maximum trial was performed 3 times for 5 s under each condition with a 1 min rest between trials and 2 min rest between conditions (with or without SRT). The order of conditions was determined by a coin toss. The moment of shoulder elevation force was calculated using the distance between the acromion and ulnar styloid process. The mean peak force (N) of three trials was multiplied by this moment to determined joint torque (Nm). Joint torques (Nm) were normalized using the formula (joint torque [Nm] / subject mass [kg]).

The independent t and χ^2 tests were performed to compare participant characteristics between the short and long PM groups. The paired t-test was used to compare normalized joint torques of the two study groups (short and long PM) for the two conditions (with and without SRT). Mixed two-way analysis of variance (ANOVA) with two levels for each factor (SRT condition and PM group) was used to compare normalized joint torques and VAS pain scores. The χ^2 test was performed to compare frequencies of positive SRT and pain reduction between groups. Fisher's exact test was used to compare the frequencies of meaningful strength increases between groups. Statistical significance was set at $p<0.05$.

RESULTS

No significant differences were found between the characteristics of participants in the short and long PM groups, except for PMI (Table 1). Frequencies of meaningful improvements in pain and strength for each group are provided in Table 2. Frequencies of meaningful pain improvement in the short and long PM groups were 72.2% (n=13) and 50% (n=8), respectively, which were not significantly different (χ^2, p=0.183). Results of the two-way mixed ANOVA demonstrated a significant effect of SRT condition (p<0.001), but no significant interaction between group and SRT condition (p=0.089).

Normalized joint torques (Nm/kg) for isometric shoulder elevation with and without SRT are summarized in Table 3. In

Table 1. Characteristics of participants

	Short PM (n=18)	Long PM (n=16)
Gender		
Male	6	6
Female	12	10
Age (years)	23.77 ± 4.50	21.93 ± 3.53
BMI (kg/m^2)	21.85 ± 2.52	20.73 ± 1.56
VAS (cm)	4.27 ± 1.40	4.06 ± 1.38
PMI	7.07 ± 0.25	8.45 ± 0.32*

Data for gender are numbers of participants (n); all other data are means ± standard deviations.
*Significant difference between groups (p<0.05).
BMI: body mass index; PM: pectoralis minor; PMI: pectoralis minor index; VAS: visual analog scale.

Table 2. Frequency of positive SRT results, defined as a meaningful pain reduction or strength improvement, by group

	Short PM (n=18)	Long PM (n=16)
Pain		
Decrease	13 (72.2%)	8 (50%)
No change	5 (27.8%)	8 (50%)
Strength		
Increase	12 (66.7%)	4 (25%)*
No change	6 (33.3%)	12 (75%)
Positive SRT result		
Positive	16 (88.9%)	8 (50%)*
Negative	2 (11.1%)	8 (50%)

*Significant difference between groups (p<0.05).
PM: pectoralis minor.

Table 3. Normalized joint torque for isometric shoulder elevation with or without SRT

	Without SRT (Nm/kg)	With SRT (Nm/kg)
Short PM (n=18)	0.36 ± 0.13	0.42 ± 0.13*
Long PM (n=16)	0.41 ± 0.19	0.43 ± 0.20

*Significant difference between groups p<0.05.
PM: pectoralis minor; SRT: scapular reposition test.

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the short PM group, SRT condition produced a significant increase in normalized joint torque for isometric shoulder elevation (p=0.026); this was not found the long PM group (p=0.468). Similarly, a significant inter-group difference was observed between frequencies of meaningful improvements in strength (χ^2, p=0.015), which was greater in the short PM group (66.7%; Table 2). Results of the two-way mixed ANOVA demonstrated a significant effect of SRT condition on normalized joint torques for isometric shoulder elevation (p=0.023), but no significant interaction between group and SRT condition (p=0.118).

A positive SRT result was defined as a strength improvement of >0.06 Nm/kg or a VAS pain improvement of >1.4 cm; frequencies of positive SRT results are shown in Table 2. A significant difference was observed between the two groups (χ^2, p=0.013), such that the frequency of a positive SRT result was greater in the short PM group (88.9%).

DISCUSSION

The current study was undertaken to compare the effects of SRT on pain and shoulder elevation strength in individuals with a short or long PM muscle and a positive impingement test. The results obtained partially supported our hypothesis. As expected, shoulder elevation strength was significantly increased in the short PM group but not in the long PM group, and a positive SRT result was observed more frequently in the short PM group.

During SRT, both groups exhibited a significant reduction in pain and 64.7% of participants exhibited a meaningful reduction; however, there were no significant difference between groups. During the impingement test without SRT, narrowing of the subacromial space resulted in pain reproduction due to direct compression of soft tissue[22]. Repositioning of the scapula increases the subacromial space and may reduce soft tissue compression, resulting in less pain. Seitz et al.[23] reported that manual assistance of scapular upward rotation and posterior tilt increased the subacromial space by between 1.7 and 2.1 mm. The subacromial space can also be increased using rigid taping to support the scapula, thereby increasing its posterior tilt and upward rotation[24]. The previous studies support the notion that scapula repositioning using SRT increases the subacromial space.

In the present study, 35.3% of the 34 study participants experienced no change in pain during the impingement test in SRT condition, which could be due to several reasons. In asymptomatic overhead athletes, the supraspinatus tendon of the dominant arm is 0.6 to 1.6 mm thicker than that of the non-dominant arm[25, 26]. Michener et al.[27] reported that the supraspinatus tendon was 0.6 mm thicker in participants with shoulder impingement syndrome than in matched normal controls; therefore, the thickness of soft tissue in the subacromial space was greater than the increase in subacromial space during SRT, resulting in a greater likelihood of pain reproduction due to compression. In a previous study, pain reproduction could result in rotator cuff tendon tension during the full can test, as occurs during the empty can test[28]; therefore, during an active examination such as the latter, an increase in tensile stress applied to the rotator cuff may result in the reproduction of symptoms. However, we did not measure thickness or tension of the rotator cuff tendon, and are unable to confirm the reason for our finding.

The MDC90 indicates the minimal change that is not caused by measurement errors. In the present study, the MDC90 of normalized shoulder elevation strength was 0.06 Nm/kg in subclinical participants. By contrast, Seitz et al.[23] reported an MDC90 of 0.07 Nm/kg in participants with or without shoulder impingement syndrome. We attribute this difference to the methods of measurement used: Seitz et al.[23] obtained measurements in the full can test position, whereas we used the empty can test position. Timmons et al.[29] reported that scapular internal rotation and anterior tilt were greater during the empty can test than during the full can test, and thus, differences between scapular kinematics during these two tests could have changed force generation by the rotator cuff.

In the short PM group, SRT increased isometric shoulder elevation strength significantly to 0.07 ± 0.12 Nm/kg, which was greater than the MDC90. Using the MDC90 threshold, 66.7% of individuals in the short PM group exhibited a meaningful increase in strength during SRT. During shoulder elevation, scapular posterior tilt and external rotation would have been smaller in the short than in the long PM group. This notion is supported by Borstad and Ludewig[2], who found that participants with a short PM demonstrated significantly less posterior tilt and more internal rotation of the scapula during shoulder elevation than those with a long PM. Altered scapular kinematics could shorten the rotator cuff and reduce the tension-generating capacity of these muscles during isometric shoulder elevation. We suggest during shoulder elevation with SRT that scapular posterior tilt and external rotation were increased in the short PM group and that restoration of normal scapular motion may have increased rotator cuff length at rest. Thus, the observed strength gain may have been the result of an increase in tension-generating capacity[30]. Our results concur with those of previous studies. Kibler et al.[18] found that the SRT, which similar to SRT, increased isometric shoulder elevation strength in participants with shoulder pain. Rather et al.[31] reported that isometric shoulder elevation strength of normal participants was significantly greater than that of participants with a chronic protracted shoulder.

Tate et al.[20] reported that SRT produced meaningful increases in strength of 26% and 29% in positive and negative impingement groups, respectively. This differs from our results because only 30% of their participants demonstrated scapular dyskinesis and MDC90 values were calculated from measured shoulder elevation forces. By contrast, we classified participants according to resting length of the PM and calculated the MDC90 values using normalized joint torque for isometric shoulder elevation strength. Thus, it is not possible to directly compare increases in shoulder elevation strength observed in the two studies.

During SRT, a reduction in pain or an increase in shoulder elevation strength (the definition of a positive SRT result) were

reported more frequently in the short PM group. We expect that members of the short PM group with a positive SRT result would require treatment aimed at stretching the PM or strengthening the lower trapezius and serratus anterior. Thus, we believe that SRT and PM rest length might be helpful for identifying impairments related to shoulder impingement syndrome and for selecting appropriate interventions.

The present study was conducted in a subclinical population without severe symptoms or functional limitation; therefore, our findings may not be applicable to patients with a shoulder disorder. Furthermore, we did not concurrently monitor subacromial space, rotator cuff tendon thickness and scapular kinematics, and thus, we were not able to establish the cause of a positive SRT result. We suggest that studies be conducted to evaluate these parameters during SRT in clinical populations.

In this study, pain was reduced during SRT regardless of PM resting length. Shoulder elevation strength increased only in the short PM group, and a positive SRT result was presented more frequently in this group than in the long PM group. Application of SRT and measurement of PM resting length may aid the identification of shoulder impingement syndrome associated with scapular dyskinesis and intervention decision making.

Conflict of interest

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

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