



Original Article

Strength and muscle activity of shoulder external rotation of subjects with and without scapular dyskinesis

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Abstract. [Purpose] This study aimed to clarify the relationship between scapular dyskinesis and shoulder external rotation strength and muscle activity. [Subjects and Methods] Both shoulders of 20 healthy males were evaluated. They were classified into 19 normal, 8 subtly abnormal, and 13 obviously abnormal shoulders using the scapular dyskinesis test. Subtly abnormal shoulders were subsequently excluded from the analysis. Shoulder external rotation strength and muscle activity (infraspinatus, serratus anterior, upper, middle, and lower trapezius) were measured in 2 positions using a handheld dynamometer and surface electromyography while sitting in a chair with shoulder 0° abduction and flexion (1st position), and while lying prone on the elbows with the shoulders elevated in the zero position (zero position). The strength ratio was calculated to quantify the change in strength between the positions (zero position / 1st position). [Results] In the obviously abnormal shoulder group, the strength in the 1st position was significantly stronger, the strength ratio was significantly smaller, and the serratus anterior in the zero position showed significantly lower activity than the normal shoulder group. [Conclusion] In shoulder external rotation in the zero position, in obviously abnormal shoulders, the serratus anterior is poorly recruited, weakening the shoulder external rotation strength.

Key words: Scapular dyskinesis, Zero position, Serratus anterior

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INTRODUCTION

Highly repetitive overhead sports activities such as baseball pitching and tennis serves cause upper extremity injuries. These injuries result in a decline in performance and longtime absence from sport participation, so prevention is highly important. Shoulder external rotation muscle weakness is a causative factor of shoulder injuries¹⁻³⁾. Therefore, many authors have emphasized the need to enhance shoulder external rotation muscle strength and endurance during rehabilitation and conditioning programs^{1,2)}. We previously reported that shoulder external rotation strength was maintained regardless of the shoulder elevation angle in the scapular plane, and that scapular posterior tilting by the serratus anterior (SA) might generate shoulder external rotation torque and maintain shoulder external rotation strength⁴⁾.

The scapular dysfunction called scapular dyskinesis⁵⁾ involves alteration of the static scapular position or dynamic scapular motion. It has been suggested to be another risk factor of upper extremity injuries, and has been reported to be related to various shoulder pathologies⁶⁾. Scapular dyskinesis seems to cause an unstable basis of rotator cuff, and decline in the scapular posterior tilting force of the SA. Thus, scapular dyskinesis affects shoulder external rotation strength and muscle activity, especially in the zero position.

Recently, scapular motion was analyzed using an electromagnetic tracking device^{7,8)}. However, this expensive instrument cannot often be used in the clinical practice because of its cost. The visual assessment of scapular motion by McClure et al.⁹⁾

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does not require the use of expensive instruments, and its reliability and validity have been confirmed. Scapular dyskinesis judged by visual assessment shows alterations of scapular kinematics^{10, 11)} and muscle activity¹¹⁾ in shoulder elevation. Therefore, this assessment method could be utilized in clinical practice after the relationship between scapular dyskinesis and shoulder function has been clarified. Thus, the purpose of this study was to clarify the relationship between scapular dyskinesis and shoulder external rotation strength and muscle activity using visual scapular assessment.

SUBJECTS AND METHODS

The subjects were 20 male volunteers (mean age of 24.4 ± 3.1 years, height of 173.2 ± 5.2 cm, and weight of 66.4 ± 7.3 kg) who had no previous history of cervical or shoulder injury or pathologies in the preceding 6 months, had negative Neer impingement and Hawkins impingement test results, and had no rotator cuff tenderness. Both shoulders of each participant were tested, a total of 40 shoulders. Each shoulder was classified according to whether scapular dyskinesis was present or not. The pectoralis minor length¹²⁾ and shoulder horizontal adduction angle, abnormalities of which can cause scapular dyskinesis, were measured as soft tissue flexibility assessments. Ethical approval for this study was obtained from the Ethics Committee of Gunma University (approval code 15-79). This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all the participants, and their rights were protected.

The scapular dyskinesis test⁹⁾, a visual scapular motion assessment, was used to classify scapular motion. The participants were instructed to perform 5 consecutive repetitions of bilateral, active, and weighted shoulder flexion and shoulder abduction using dumbbells while their scapular motion was videotaped from the posterior using a digital camera (EX-FC150, CASIO COMPUTER CO., LTD, Tokyo, Japan). The weight of the dumbbell was set according to body weight, 1.4 kg (3 lb) for those weighing less than 68.1 kg (150 lb), and 2.3 kg (5 lb) for those weighing 68.1 kg or more. The participants were asked to simultaneously elevate their arms overhead as far as possible to a 3 s count, and then to lower them to a 3 s count paced by a metronome. The videotaped scapular motion was classified into normal, subtly abnormal, or obviously abnormal shoulders using the scale presented in Table 1. The subtly abnormal shoulders were excluded, and a comparative analysis of the normal and obviously abnormal shoulders was performed.

For measurement of the shoulder external rotation strength, a handheld dynamometer (μ -Tas MF-01, ANIMA Corp., Tokyo, Japan) was used with a fixed belt. The measurements were performed in 2 positions as illustrated in Fig. 1: 1) sitting in a chair with shoulder abduction and flexion at 0°, elbow flexion at 90°, and forearm pronation/supination in the neutral position (1st position); 2) lying prone on the elbows with the shoulder elevated at the humeral shaft axis roughly in alignment with the scapular spine (zero position). The measurements were performed for 5 s and repeated three times. Before the measurements, the subjects were asked to avoid compensatory movements during shoulder external rotation. When the subjects performed compensatory movements, the measurements were stopped and restarted after a rest period. The strength ratio was calculated to quantify the change in shoulder external rotation strength between the 1st position and the zero position (strength in the zero position / 1st position).

For electromyography (EMG), surface EMG (BioLog DL-3100, S&ME, Inc., Tokyo, Japan) was used, with a sampling rate of 1,000 Hz. The target muscles were the infraspinatus (IS), SA, upper trapezius (UT), middle trapezius (MT), and lower trapezius (LT). Surface electrodes (DL-141 active electrode; S&ME Inc., Tokyo, Japan) were applied parallel to each of the muscle fibers after appropriate skin preparation. The electrode positions were as described in a previous study¹³⁻¹⁵⁾. For the IS, the electrode was placed two fingerbreadths inferior to the center of the spina scapulae. For the SA, the electrode was placed on the midaxillary line at the level of the inferior angle of the scapula. For the UT, the electrode was placed midway between the spinous process of the seventh cervical vertebra and the posterior tip of the acromion process along the line of the trapezius. For the MT, the electrode was placed midway along the horizontal line between the root of the spine of the scapula and the third thoracic spine. For the LT, the electrode was placed midway between the spinous process of the seventh

Table 1. Scapular dyskinesis test: rating scale

Rating scale
Each test movement (flexion and abduction) rated as
a) Normal motion: no evidence of abnormality
b) Subtle abnormality: mild or questionable evidence of abnormality, not consistently present
c) Obvious abnormality: striking, clearly apparent abnormality, evident on at least 3/5 trials
Final rating is based on combined flexion and abduction test movements.
Normal: Both test motions are rated as normal or 1 motion is rated as normal and the other as having subtle abnormality.
Subtle abnormality: Both flexion and abduction are rated as having subtle abnormalities.
Obvious abnormality: Either flexion or abduction is rated as having obvious abnormality.

This rating scale is reproduced from McClure et al.⁹⁾

DISCUSSION

For overhead sports athletes, shoulder external rotator muscle weakness is a risk factor of shoulder injury¹⁻³). We previously reported that shoulder external rotation strength was maintained regardless of shoulder elevation angle in the scapular plane, and that scapular posterior tilting by the SA might generate shoulder external rotation torque and maintain shoulder external rotation strength⁴). In this study, we studied the relationship between the scapular dysfunction called scapular dyskinesis and shoulder external rotation strength and muscle activity.

The shoulder external rotation strength of the obviously abnormal shoulder group was stronger than that of the normal shoulder group in the 1st position, but no significant difference was observed between the groups in the zero position. The muscle ratio was significantly smaller in the obviously abnormal shoulder group. That is, shoulder external rotation strength declined more in obviously abnormal shoulder group than in the normal shoulder group when the position changed from the 1st position to the zero position. In the comparison of the muscle activities, the obviously abnormal shoulder group showed significantly lower SA activity. Moreover, the IS showed higher activity in the obviously abnormal shoulder group, but the difference was not significant. As mentioned above, we previously reported that shoulder external rotation strength was maintained regardless of shoulder elevation angle in the scapular plane, and that the SA is important in the shoulder elevated position. In shoulder elevation motion, the relationship between scapular dyskinesis and muscle activity has been clarified. Specifically, scapular dyskinesis was reported to show higher muscle activity of the UT^{11, 16}) and lower activity of the SA and LT¹⁶). Considering the result of our study, in shoulder external rotation in the zero position, in scapular dyskinesis, recruitment of the SA is poor, weakening the shoulder external rotation strength. These results reveal the negative effects of scapular dyskinesias on shoulder external rotation function. A difference was not observed in the comparison of shoulder external rotation strength in the zero position. This indicates that evaluation of shoulder external rotation strength in various positions is important. Various training methods have been reported to improve the SA^{15, 17-19}). Another study reported improvement of the supraspinatus and IS strength by the rehabilitation of the scapular muscle²⁰). These findings emphasize the importance of the scapular muscle in shoulder external rotation. Therefore, the effect of scapular muscle training on shoulder injury prevention should be investigated in future studies.

In baseball pitching and tennis serve motions, the greatest exertion of shoulder external rotation strength is needed from ball release (ball impact) to the follow-through phase. Pappas et al.²¹) reported that the maximum shoulder internal rotation angular velocity in the acceleration phase of baseball pitching is 6,180 °/s, and recognized the importance of the shoulder external rotation muscles as braking muscles. Gandhi et al.²²) reported that the external rotation strength of baseball pitchers

Table 3. Shoulder external strength and muscle activities

	Normal shoulder group (n = 19)	Obviously abnormal shoulder group (n = 13)
Strength (N)		
1st position	80.6 (9.6)	90.2 (13.3) *
Zero position	74.8 (14.3)	72.8 (12.5)
Strength ratio	0.93 (0.16)	0.81 (0.14) *
Muscle activity (%MVC)		
1st position		
Infraspinatus	95.1 (20.2)	108.8 (18.4)
Serratus anterior	16.1 (12.3)	15.6 (7.3)
Upper trapezius	28.1 (17.1)	41.2 (27.2)
Middle trapezius	51.6 (26.3)	73.1 (37.7)
Lower trapezius	63.9 (28.5)	74.2 (27.5)
Zero position		
Infraspinatus	77.5 (19.9)	91.1 (21.3)
Serratus anterior	74.7 (28.9)	56.2 (15.5) *
Upper trapezius	19.4 (14.4)	21.5 (18.5)
Middle trapezius	33.8 (20.6)	35.9 (16.8)
Lower trapezius	57.5 (18.4)	57.2 (25.9)

Means (standard deviation); * p < 0.05; 1st position: sitting position, shoulder 0° abduction and 0° flexion position; zero position: prone (on elbows) position with the humeral shaft axis roughly in alignment with the scapular spine; strength ratio: the rate of muscle strength change = the strength in the zero position / 1st position

decreased after a game compared to before the game because of IS fatigue. In our study, IS showed higher activity in the obviously abnormal shoulder group than in the normal shoulder group, but the difference was not significant. During shoulder external rotation in the zero position, the SA and IS may be considered to act as a co-muscle. In the obviously abnormal shoulder group, as the SA activity was lower, the IS activity may have been compensatorily higher. The shoulder injuries of overhead sports athletes are often caused by overuse. The obviously abnormal shoulder group may be prone to fatigue due to the high activity of the IS. Therefore, their shoulder external rotation strength will be weakened earlier, likely reducing their performance and increasing their risk of shoulder injury. However, these are speculative comments and the relationship between scapular dyskinesis and fatigue needs to be clarified in the future.

A limitation of this study was that it adopted an isometric task, although the shoulder external rotator is often needed in eccentric contraction in sports activities. Therefore, it is important to consider actual sports activities and to clarify their relationships with shoulder injuries. Through this study, we wish to contribute to the development of the preventive and rehabilitative strategies for the shoulder injuries of overhead sports athletes.

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