



Original Article

Effect of trapezius muscle strength on three-dimensional scapular kinematics

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Abstract. [Purpose] This study aimed to investigate the effect of trapezius muscle isometric strength on three-dimensional scapular kinematics in asymptomatic shoulders. [Subjects and Methods] Thirty asymptomatic subjects were included to the study. Isometric strengths of the upper, middle, and lower trapezius muscle were measured using a handheld dynamometer. Three-dimensional scapular kinematics was recorded by an electromagnetic tracking device during frontal and sagittal plane elevation. For each muscle, the cut-off value for muscle strength was determined with the upper bound of the 95% confidence interval, and Student's t-test was used to compare the scapular kinematics between subjects with relatively weaker or stronger trapezius muscles. [Results] Shoulders with stronger upper trapezius muscles showed greater upward scapular rotation at 30°, 60°, 90°, and 120° of elevation in the frontal plane. Shoulders with stronger middle trapezius had greater scapular upward rotation at 90° of elevation in the frontal plane. Shoulders with stronger lower trapezius showed greater scapular posterior tilt at 90° of elevation in the sagittal plane. [Conclusion] This study's findings showed that isometric strength of the trapezius muscle affects upward scapular rotation and posterior tilt in asymptomatic shoulders. Therefore, trapezius muscle strength should be assessed and potential weakness should be addressed in shoulder rehabilitation programs.

Key words: Shoulder, Scapula, Kinematics

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INTRODUCTION

During arm elevation, the scapula moves toward internal or external rotation, upward rotation, and posterior tilt¹. It is widely accepted that the wide range of mobility in the shoulder has been associated with scapular mobility and stability². Dynamic scapular position and orientation has been associated with many factors such as thoracic posture, capsule-ligamentous soft tissue tightness, and lack of neuromuscular control^{3, 4}. Tate et al.⁵ previously reported that scapular position affects optimal elevation strength. Because of the importance of providing appropriate scapular mobility and stability, researchers have recently been investigating the factors affecting scapular position and orientation.

Complex scapular motion is controlled by many scapular muscles, which were previously defined as force couple muscles¹. Force couple muscles create coordinated and synchronized rotational scapular movements⁶. The three-dimensional (3-D) scapular kinematic properties occur as a result of a balanced force production of the upper, middle, and lower trapezius muscles as well as the serratus anterior⁶⁻⁸. At the same time, this proper scapular orientation enables proper function and optimal performance of the shoulder complex during sports- or occupation-related activities^{9, 10}. Many researchers^{2, 11} have suggested that weakness in one or more scapular muscles may reveal muscular imbalance and altered scapular kinematics. In addition, scapular muscle imbalance has been suggested as a contributing factor to shoulder pain¹². Electromyographic studies on muscular activation imbalances have reported that subjects with shoulder pain have increased activation levels of the upper trapezius^{13, 14}. Neuromuscular properties such as timing and recruitment of the trapezius muscle are confirmed

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factors affecting scapular position and orientation^{13, 15}); however, the specific effect of strength has not been elucidated.

Investigating the effect of scapular muscle performance on 3-D scapular kinematics during shoulder elevation may enable the enhancement of our comprehensive knowledge about scapular behavior in healthy shoulders and may further provide a basis for clinical evaluation methods and biomechanical considerations in shoulder rehabilitation. Therefore, the aim of the study was to investigate the effect of trapezius muscle isometric strength on 3-D scapular kinematics in asymptomatic shoulders. We hypothesized that 3-D scapula position and orientation would differ in subjects with relatively weaker or stronger trapezius muscles.

SUBJECTS AND METHODS

This single group study was performed at Hacettepe University, Department of Physiotherapy and Rehabilitation, Ankara, Turkey. The institutional review board approved the study protocol, and all subjects were informed about the nature of the study and signed a consent form.

A total of 30 asymptomatic subjects including 20 male and 10 female subjects with a mean age of 25 ± 1.5 years and mean body mass index of 24 ± 2.5 kg/m² were included in the study. The inclusion criteria for participation were no limitation in shoulder range of motion, no prior shoulder surgery or injury, and no signs of impingement on clinical examination. Subjects were excluded if they had any known systemic or neurological disorders, regularly performed repetitive shoulder movements related to occupational or sports activities, or had a body mass index >30 kg/m². The same physiotherapist with 5 years of clinical experience performed all of the measurements. For strength testing, the method suggested by Michener et al was used¹⁶. Isometric strengths of the upper, middle, and lower trapezius muscle were measured by a handheld dynamometer (Baseline®, USA). A “make test” muscle test was performed in the specific midrange position of the scapula to optimize the length-tension relationship of the specific muscle and obtain the maximum isometric contraction¹⁷. The specific scapular position for the upper trapezius was scapular elevation, that for the middle trapezius was scapular retraction, and that for the lower trapezius was scapular adduction and depression.

Three-dimensional kinematic data including internal-external rotation, upward-downward rotation, and anterior-posterior tilt for the scapula were collected via a Flock of Birds (Ascension Technologies Inc., Burlington, VT, USA) electromagnetic tracking device. This system was interfaced with the Motion Monitor software program (Innovative Sports Training Inc., Chicago, IL, USA). This method of measuring 3-D scapular kinematics was previously validated by comparing data obtained from skin sensors to those obtained from acromion-fixed sensors that were similar, especially at <120° of elevation¹⁸. The participants stood with their arms relaxed while the specific bony landmarks on the thorax (C7, T8, T12, jugular notch, xiphoid process), scapula (trigonum spine scapula, inferior angle, posterior acromial angle, and coracoid process), and humerus (lateral and medial epicondyle) were digitized to create an anatomically based local coordinate system. The International Society of Biomechanics standard protocol was followed to define the segmental axes and to convert the local coordinate system into angular rotations, using the Euler angle sequence¹⁹. All participants performed three repetitions of a full overhead arm elevation in the sagittal and frontal plane, using the wooden frame as a guide at a speed matching the 60 bpm tone of a metronome.

Data for scapular orientation at 30°, 60°, 90°, and 120° of humerothoracic elevation were obtained for each repetition. The scapular orientation values at each humerothoracic elevation angle were then averaged across the three repetitions. For each muscle, the cut-off value for strength was determined with the upper bound of the 95% confidence interval (CI). Subjects were assigned to the groups according their strength values being higher or lower than the cut-off value specified for the particular tested muscle. Statistical comparisons of the data were analyzed with two-way analysis of variance to compare scapular internal-external rotation, upward-downward rotation, and anterior-posterior tilt separately between the groups with relatively weaker or stronger trapezius muscles. The type 1 error level was set at 95%.

RESULTS

In general, although some variations were observed, the scapula moved toward internal rotation, upward rotation, and posterior tilt during shoulder elevation. The mean and 95% CI of isometric strength obtained from all subjects was 21.9 (20.5–23.7) kg for the upper trapezius, 12.3 (11.4–13.2) kg for the middle trapezius, and 12.8 (11.8–13.8) kg for the lower trapezius.

Comparisons showed that shoulders with stronger upper trapezius (n=19) showed greater upward scapular rotation at 30° ($F_{1, 28}=7.77$, $p=0.009$; mean difference: 4.9°), 60° ($F_{1, 28}=10.15$, $p=0.004$; mean difference: 6.9°), 90° ($F_{1, 28}=8.76$, $p=0.006$; mean difference: 7.4°), and 120° of elevation ($F_{1, 28}=5.2$, $p=0.03$; mean difference: 7.9°) in the frontal plane compared to shoulders with relatively weaker upper trapezius (n=11). Comparisons showed that shoulders with a stronger middle trapezius (n=19) have greater upward scapular rotation at 90° of elevation ($F_{1, 28}=4.88$, $p=0.03$; mean difference: 5.9°) in the frontal plane compared to shoulders with a relatively weaker middle trapezius (n=11). Comparisons also showed that shoulders with a stronger lower trapezius (n=21) showed a greater scapular posterior tilt at 90° of elevation ($F_{1, 28}=5.13$, $p=0.03$; mean difference: 5.2°) in the sagittal plane compared to shoulders with a relatively weaker lower trapezius (n=9). Intergroup comparisons revealed no significant differences in internal-external scapular rotation ($p>0.05$).

DISCUSSION

The current study investigated the effect of trapezius muscle isometric strength on 3-D dynamic scapular kinematics in asymptomatic shoulders. The comparisons revealed that isometric strength of the trapezius muscle affects scapular upward rotation and posterior tilt.

The differences in scapular rotations were specific to the tested muscle, humeral movement plane, and humerothoracic elevation angle. First, weakness in the upper and middle trapezius mostly affected upward scapular rotation; in contrast, weakness in the lower trapezius affected scapular posterior tilt, and muscular strength had no effect on internal-external scapular rotation. This specific response may occur as a result of anatomical attachment on the scapula and the angle of pull of each muscle^{7, 20}. The majority of research on trapezius function demonstrated that all parts of the trapezius muscle can create upward rotation²¹. However, it was also shown that the upper and middle fibers of the trapezius muscle could elevate the clavicle^{1, 20}. Second, some variation was observed, and the differences in scapular rotation were not consistent across all tested humeral movement planes. In particular, weakness in the lower trapezius revealed less posterior tilt when the humeral elevation was performed only in the sagittal plane. Ludewig et al.²² compared the motion of shoulder complex during multi-planar humeral elevation and reported that the scapula was more internally rotated when the humerus was located in the sagittal plane. Thus, the length-tension relationship of the lower trapezius may be more effective when the humerus is located in the sagittal plane; however, further studies are needed in this area. Third, comparisons between shoulders that had relatively stronger trapezius muscles revealed differences in scapular kinematics mostly at the mid-range of humerothoracic elevation. This range of motion was previously described as the range in which the scapular control is mostly dependent on muscular activation rather than passive structures²³. Therefore, trapezius muscle strength can be accepted as an important factor in maintaining scapular position during functional arm movements.

The findings of this study showed that trapezius muscle weakness resulted in decreased upward scapular rotation and posterior tilt. This relative weakness of the trapezius muscle may contribute to asymptomatic scapular dyskinesis, but further studies are needed with more focus on contribution of the muscle weakness to other shoulder dysfunctions. However, the pattern of changes in scapular kinematics was in a similar direction as previously reported in altered kinematics of several shoulder disorders^{3, 24}. In particular, the lack of appropriate scapular upward rotation and posterior tilt during arm elevation would negatively affect the width of the subacromial space²⁵. Therefore, strengthening of all parts of the trapezius muscles should be integrated into shoulder rehabilitation programs from the early stage whenever possible.

The current study has some limitations. The findings of this study are limited to the trapezius muscle and reflect an asymptomatic young population that does not regularly participate in occupational or sports activities related to repetitive shoulder movements and that was considered to have normal scapular motion during shoulder elevation. However, we believe that comparisons of scapular kinematics in the shoulders with relatively stronger or weaker trapezius muscles provide important baseline information to guide future research. Future studies should investigate the effect of eccentric force coupling muscle strength on different populations with shoulder disorders.

In conclusion, this study showed that the isometric strength of the trapezius muscle affects upward scapular rotation and posterior tilt in asymptomatic shoulders. Therefore, trapezius muscle strength should be assessed and potential weaknesses should be addressed during shoulder rehabilitation programs.

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