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Active Scapular Retraction and Acromiohumeral Distance at Various Degrees of Shoulder Abduction

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Context: Performing shoulder-abduction exercises with scapular retraction has been theorized to reduce the potential for shoulder impingement. However, objective data to support this premise are lacking.

Objective: To evaluate the influence of active scapular retraction on acromiohumeral distance (AHD) at 4 shoulder-abduction angles using real-time ultrasound.

Design: Cross-sectional study.

Setting: University laboratory.

Patients or Other Participants: Twenty asymptomatic individuals (10 men, 10 women; age = 22.9 ± 2.8 years, height = 169.3 ± 9.5 cm, mass = 65.5 ± 12.9 kg) were recruited.

Main Outcome Measure(s): Real-time ultrasound images of AHD were obtained during nonretracted and retracted scapular conditions at 0°, 45°, 60°, and 90° of shoulder abduction. A 2-factor analysis of variance with repeated measures was used to evaluate the influence of shoulder retraction on AHD across shoulder-abduction angles.

Results: A scapular-retraction condition × shoulder-abduction–angle interaction for AHD was found ($F_{3,57} = 4.56$, $P = .006$). The AHD was smaller at 0° (10.5 versus 11.2 mm, respectively; $t_{19} = 2.22$, $P = .04$) but larger at 90° (9.4 versus 8.7 mm, respectively; $t_{19} = -2.30$, $P = .04$) of shoulder abduction during the retracted than the nonretracted condition. No differences in AHD were observed between conditions at 45° ($t_{19} = 1.45$, $P = .16$) and 60° ($t_{19} = 1.17$, $P = .86$) of abduction.

Conclusions: The observed differences in AHD at 0° and 90° of shoulder abduction were small and did not exceed the established minimal detectable change for either angle. Our findings suggest that active scapular retraction during shoulder abduction has a minimal influence on AHD at 0° and 90° in healthy individuals. Further investigations are needed to determine whether scapular retraction influences AHD in individuals with subacromial impingement.

Key Words: subacromial space, ultrasound, rehabilitation, shoulder joint, exercise

Key Points

- Active scapular retraction during shoulder abduction had minimal to no influence on acromiohumeral distance in young, healthy individuals.
- The mechanism underlying improvements in shoulder symptoms from scapular exercises may not be related solely to improvements in acromiohumeral distance.
- Researchers should determine whether scapular-retraction exercises influence acromiohumeral distance in individuals with subacromial impingement syndrome.

Optimal functioning of the shoulder joint depends on proper positioning and movement of the scapula.[1–3] During upper extremity elevation, the scapula rotates upwardly, externally, or internally and tilts posteriorly.[3,4] This 3-dimensional pattern of scapular movement results in elevation of the acromion during shoulder elevation and is thought to help prevent impingement of the rotator cuff by maintaining the proper acromiohumeral distance (AHD).[5] Optimal scapular movement is also important for maintaining the optimal length-tension relationships of the rotator cuff and scapular muscles during glenohumeral motion.[6–9] During glenohumeral elevation, the rotator cuff muscles produce joint compression and minimize superior translation of the humeral head.[3,9,10] Minimizing superior humeral translation is thought to be important for maintaining the AHD and reducing the potential for rotator cuff impingement.[3,4,11]

The *AHD* is defined as the distance between the superior aspect of the humeral head and the inferior aspect of the acromion.[3,12] It varies from 10 to 15 mm in asymptomatic individuals at rest[13,14] and decreases to 5 to 6 mm at 90° of passive shoulder abduction.[5] An AHD of less than 7 mm may result in impingement of the tissues that occupy the subacromial space, namely the supraspinatus tendon and subacromial bursa.[3,15] As such, narrowing of the AHD during upper extremity elevation is thought to be a risk factor for subacromial impingement syndrome (SIS).[3,12] Indeed, individuals with SIS have been reported to have reduced AHD from 30° to 90° of active upper extremity elevation.[6]

Maintaining the AHD is an important goal of shoulder rehabilitation in patients with SIS.[3,15,16] Scapular-motion impairments thought to contribute to reduced AHD include decreased upward rotation and posterior tilting.[3,5] Several interventions directed at correcting altered scapular position, including manual (passive) techniques,[17] elastic taping or rigid taping of the scapula,[18,19] neuromuscular electrical stimulation of the scapular muscles,[20] and posterior-capsule stretching exercises, have been shown to increase AHD.[14]

Scapular retraction has also been proposed as a means of improving the AHD during shoulder elevation. It is thought to minimize the anterior tilt and internal rotation of the scapula, maintaining the AHD during shoulder elevation.[14,17–20] To date, only Solem-Bertoft et al[21] have evaluated the influence of scapular retraction on AHD. They[21] reported that scapular retraction increased the AHD when compared with scapular protraction. Whereas their results provide evidence for using scapular retraction to increase AHD, the study[21] was limited to a small group of healthy individuals (N = 4); magnetic resonance imaging measures of the AHD were obtained with the participants supine, and a sandbag was used to position the scapula passively in the retracted and protracted positions.

To date, it is unclear whether active scapular retraction influences AHD similarly to what has been reported under passive conditions. Given that active scapular retraction during shoulder elevation has been advocated to increase AHD, objective data are necessary to support this premise. Therefore, the purpose of our study was to evaluate the influence of active scapular retraction on AHD at 4 shoulder-abduction angles (0°, 45°, 60°, and 90°) using real-time ultrasound. We hypothesized that active scapular retraction would result in greater AHD across all angles of shoulder abduction.

METHODS

Participants

Twenty asymptomatic individuals (10 men, 10 women; age = 22.9 ± 2.8 years, height = 169.3 ± 9.5 cm, mass = 65.5 ± 12.9 kg) participated. Inclusion criteria were no history of participating in overhead activity and age between 18 and 30 years. Individuals who reported shoulder pain or instability (or both), had a history of shoulder surgery, or reported a history of participating in overhead sports at a competitive level were excluded. All recruits provided written informed consent, and the study was approved by the Hacettepe University Institutional Review Board.

Procedures

Real-time ultrasonography (US) images of the subacromial space were obtained using an Applio 500 system (Toshiba, Otawara, Japan) with an 8- to 12-MHz linear transducer. All US images were obtained by a single investigator (U.T.) with 10 years of experience in US imaging of the shoulder. The US images of the subacromial space were obtained from the *dominant limb*, which was defined as the limb used to throw a ball. We placed the US transducer on the lateral and most anterior aspects of the acromion in line with the longitudinal axis of the humerus to visualize the anterior aspect of the subacromial space.[22] Using the US system's on-screen calipers, we measured the AHD as the linear distance between the superior aspect of the humeral head and the inferior aspect of the acromion (in millimeters; Figure 1).

The US images of the AHD were first obtained during the nonretracted scapular condition. For measurements at 0° of abduction, participants stood upright with their feet positioned shoulder-width apart, upper extremities at their sides, and elbows flexed to 90°. Next, we instructed participants to actively elevate their extremities to the desired degree of shoulder abduction (45°, 60°, and 90°), as determined with a goniometer (model 12-1000; Baseline, White Plains, NY), and hold the position while the US images were acquired. The elbows remained flexed to 90°, and the forearms were neutral throughout testing. Three US images of the AHD were obtained at each shoulder position.

For the scapular-retracted condition, participants were instructed in the performance of resisted scapular retraction at each shoulder-abduction angle (0°, 45°, 60°, and 90°). Wooden bars were used to guide the position of the elbows so they were aligned parallel with the trunk and maintaining the designated upper extremity angle (Figure 2). Participants first performed scapular retraction without resistance to become familiar with the movement. Second, they performed scapular retraction with elastic-band resistance (Thera-Band; The Hygenic Corporation, Akron, OH). Participants were instructed to "squeeze the shoulder blades together" while moving the elbows until they were parallel to the trunk and "not shrug the shoulders" to avoid activating the upper trapezius. To standardize the amount of resistance across participants, we used the OMNI Resistance Exercise Scale of perceived exertion.[23] Participants were instructed to perform 3 repetitions of scapular retraction at 90° of shoulder abduction, starting with the lowest elastic-band resistance and then increasing the resistance until the level of perceived effort was rated as 5 (*somewhat hard*) on an 11-point scale (0 = *extremely easy*, 10 = *extremely hard*). The height of the elastic-band attachment was adjusted to be parallel to the forearms (Figure 2).

After determining the band resistance, we obtained the US images of the subacromial space as participants held the retracted scapular position at 0°, 45°, 60°, and 90° of shoulder abduction. We obtained the US images at the end range of scapular retraction. As with the nonretracted condition, 3 US images of AHD were obtained at each shoulder position.

For both the nonretracted and retracted conditions, the US transducer was removed from the shoulder between trials. The average of the 3 AHD measures was used for data analysis. The order in which we obtained the AHD measures at each shoulder-abduction angle was randomized for both conditions to account for the possible effects of fatigue.

The reliability of the AHD measurements was assessed in 20 participants without shoulder pain. Testing was repeated on 2 occasions 3 days apart as described for both the nonretracted and retracted conditions. We assessed intrarater reliability using the intraclass correlation coefficient (ICC [2,1]). The error of the AHD measure was determined using the standard error of measurement (SEM) and minimal detectable change (MDC) with 90% confidence

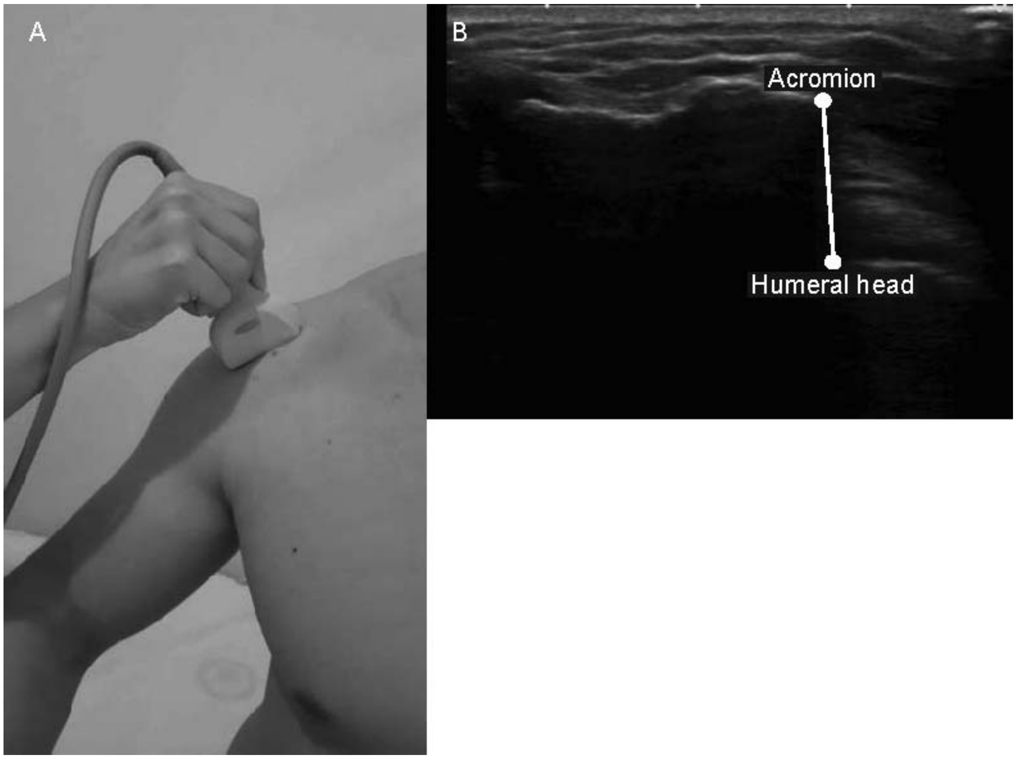

Figure 1. Measurement of the acromiohumeral distance using ultrasound. A, Positioning of the ultrasound transducer. B, Measurement of the acromiohumeral distance. The line illustrates the shortest distance between the acromion and humeral head.

intervals ($MDC_{90\%}$): $SEM = SD \times \sqrt{(1 - ICC)}$,[24] $MDC_{90\%} = 1.96 \times \sqrt{(2 \times SEM)}$.[25] Intrarater test-retest reliability of the AHD measurement revealed excellent reliability and acceptable measurement error across all shoulder-abduction angles (ICC [2,1] = 0.91–0.95, SEM = 0.3–0.5 mm, $MDC_{90\%} = 0.7$–1.1 mm; Table 1).

Statistical Analysis

We used the Kolmogorov-Smirnov test to assess the normal distribution of the data. To evaluate the influence of scapular retraction on AHD, a 2-factor analysis of variance with repeated measures was performed (retraction condition $\times$ shoulder-abduction angle). If we observed an

Figure 2. A and B, Performance of scapular retraction.

Table 1. Intrarater Test-Retest Reliability, Standard Error of Measurement, and Minimal Detectable Change With 90% Confidence Intervals of the Acromiohumeral Distance Measurement for Nonretracted and Retracted Scapular Conditions

	Nonretracted Scapula			Retracted Scapula		
Shoulder-Abduction Angle, °	Intraclass Correlation Coefficient	Standard Error of Measurement, mm	90% Minimal Detectable Change, mm	Intraclass Correlation Coefficient	Standard Error of Measurement, mm	90% Minimal Detectable Change, mm
0	0.94	0.4	0.8	0.93	0.4	0.9
45	0.94	0.4	0.9	0.92	0.4	1.0
60	0.95	0.3	0.7	0.92	0.5	1.1
90	0.94	0.36	0.8	0.91	0.5	1.1

interaction, post hoc *t* tests were used. We set the α level at .05 and used SPSS (version 21.0; IBM Corp, Armonk, NY) for all statistical analyses.

RESULTS

Descriptive statistics for the AHD in the nonretracted and retracted scapular conditions at each shoulder-abduction angle are presented in Table 2. We observed a retraction condition by shoulder-abduction–angle interaction for AHD ($F_{3,57} = 4.56$, $P = .006$). Post hoc testing revealed that AHD was smaller at 0° (10.5 versus 11.2 mm, respectively; $t_{19} = 2.22$, $P = .04$) but larger at 90° (9.4 versus 8.7 mm, respectively; $t_{19} = -2.30$, $P = .04$) of shoulder abduction during the retracted than the nonretracted scapular condition (Figure 3). No differences in AHD were observed between the retracted and nonretracted conditions at 45° ($t_{19} = 1.45$, $P = .16$) or 60° ($t_{19} = 1.17$, $P = .86$) of shoulder abduction.

DISCUSSION

We evaluated the influence of scapular retraction on AHD in participants with asymptomatic shoulders. When compared with the nonretracted condition, the retracted condition resulted in a small reduction in the AHD (0.7 mm) at 0° of abduction. Conversely, scapular retraction resulted in a small increase in AHD (0.7 mm) at 90° of shoulder abduction. However, in neither instance did the observed difference exceed the established error of the $MDC_{90\%}$ for either angle (Table 1). As such, the observed differences cannot be viewed as exceeding measurement error.

Our results are in contrast to those reported by Solem-Bertoft et al.[21] At 0° of shoulder abduction, they observed a 3-mm increase in AHD with scapular retraction compared with the protracted position. Direct comparisons between their study and ours are difficult. First, Solem-Bertoft et al[21] evaluated the influence of passive scapular positioning on AHD. In contrast, we evaluated the influence of active scapular retraction on AHD. Second, they[21] investigated the influence of retraction from a protracted scapular position with participants in a supine position, whereas we evaluated retraction from a neutral scapular position with participants in a standing position. As such, the 3-mm change reported by Solem-Bertoft et al[21] reflected the change in AHD between 2 end-range positions. It is conceivable that the actively held scapular positions we tested did not produce an end-range scapular-retraction position. This premise is supported by studies in which differences in AHD occurred when the scapula was passively positioned into retraction. Specifically, the AHD has been shown to increase at 60° of shoulder abduction (change in AHD range = 0.6–1.2 mm) when the scapula was retracted passively by taping[18,19,26] and manual positioning.[17]

Another potential explanation for the lack of a meaningful change in AHD with shoulder retraction in our study may be related to muscle recruitment. Bdaiwi et al[20] evaluated the effect of scapular-muscle activation on the AHD and reported that stimulation of both the serratus anterior (for scapular upward rotation) and lower trapezius (for scapular posterior tilt) resulted in increased AHD at 60° of shoulder abduction (mean change = 0.9 mm). However, they noted that stimulating the lower trapezius or serratus anterior in isolation did not increase the AHD. Their findings[20] suggest that, to influence the AHD, simultaneous activation of the lower trapezius and serratus anterior would be required. It is possible that our participants may not have recruited the serratus anterior and lower trapezius muscles sufficiently during the scapular-retraction condition to achieve the desired change in AHD.

As noted, the multiplanar movement of scapular retraction primarily consists of scapular posterior tilt and external rotation.[27] Therefore, an increase in AHD would be expected to occur with scapular retraction.[17] It is possible that higher degrees of shoulder abduction than those evaluated in our study may have been required for scapular retraction to affect AHD. Researchers[9,28] evaluating 3-dimensional scapular kinematics have reported that the motions of posterior tilt and upward rotation of the scapula are greatest beyond 90° of arm elevation. However, US imaging of the AHD beyond 90° of shoulder abduction was not practical in our study owing to the acoustic shadows present at the higher ranges of upper extremity elevation.[14]

Despite our negative findings, training of the scapular muscles has been reported[22,29,30] to improve pain and function in patients with shoulder symptoms. McClure et al[29] implemented a 6-week rehabilitation program in patients with SIS and observed improvements in shoulder

Table 2. Acromiohumeral Distances During Nonretracted and Retracted Scapular Conditions and 90% Confidence Intervals for Mean Differences

Shoulder-Abduction Angle, °	Scapula, mm (Mean ± SD)		90% Confidence Interval
	Nonretracted	Retracted	
0	11.2 ± 1.3	10.5 ± 1.5[a]	0.15, 1.26
45	10.0 ± 1.5	9.7 ± 1.7	−0.06, 0.70
60	9.4 ± 1.5	9.4 ± 1.5	−0.44, 0.54
90	8.7 ± 1.5	9.4 ± 1.7[a]	−1.14, −0.16

[a] Difference between conditions ($P < .05$).

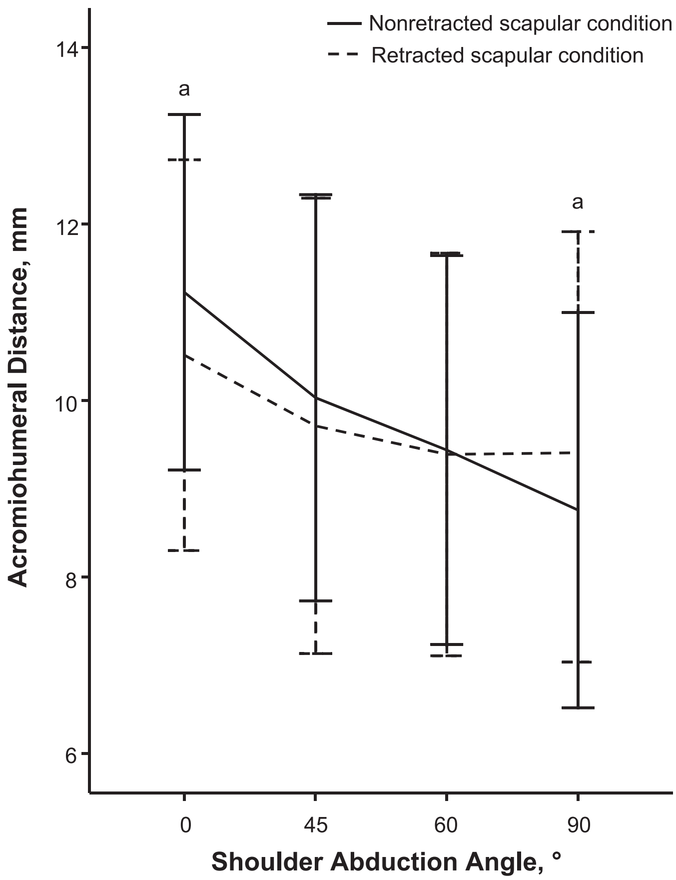

Figure 3. Acromiohumeral distances between nonretracted and retracted scapular conditions and the shoulder-abduction angle (mean ± standard deviation). [a] **Difference ($P < .05$).**

function and pain despite no change in scapular kinematics after the intervention. In addition, De Mey et al[30] reported decreased upper trapezius muscle-activation levels and upper trapezius-to-serratus anterior ratios after 6 weeks of scapular-based exercises in patients with SIS. Whereas they[30] did not quantify scapular kinematics, they postulated that improvements in shoulder function and pain occurred due to a change in scapular-muscle activation. Based on the findings of previous researchers and our study, the mechanism underlying improvements in shoulder symptoms from scapular exercises may not be related solely to improvements in AHD.

Our study had several limitations that should be considered when interpreting the results. First, we investigated only the immediate effects of scapular retraction on AHD. Researchers need to evaluate the long-term effects of scapular-retraction exercise on AHD and the relationship between muscle-strengthening patterns or muscle-recruitment patterns (or both) on AHD. Second, all participants were young, healthy adults with no shoulder symptoms. It is well known from previous studies[7,8,31,32] that patients with various shoulder conditions exhibit altered scapular control or muscle imbalance (or both). As such, it is possible that the influence of scapular retraction on AHD may differ in persons with preexisting shoulder injuries and scapular dysfunction. Third, AHD is most reduced between 60° and 120° of shoulder abduction,[5] and we could not document AHD beyond 90° of shoulder abduction because of acoustic shadows. However, the authors of 2 previous studies[33,34] indicated the supraspinatus tendon is likely not available for compression under the acromion when the humerus is above 90°. Fourth, we did not measure scapular kinematics, so we could not objectively document scapular positions during the scapular-retraction conditions. Researchers should consider using 3-dimensional scapular kinematics to gain insight into the specific scapular motions that influence AHD during specific exercises.

CONCLUSIONS

Whereas we observed changes in the AHD with active scapular retraction at 0° and 90° of shoulder abduction, the observed differences were small and did not exceed the MDC ($MDC_{90\%}$). Our results suggested that active scapular retraction during shoulder abduction had minimal to no influence on AHD in young, healthy individuals. Therefore, the MDC may be greater than the clinically meaningful difference. Investigating changes in AHD with scapular-retraction exercises in patients with impingement will aid in interpreting clinically important differences. Future studies are needed to determine whether scapular-retraction exercises influence AHD in people with SIS.

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