



Adaptation of muscle activity in scapular dyskinesis test for collegiate baseball players

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Background: The characteristics of scapular muscle activities in elevation and descent exercises have yet to be elucidated to assess scapular dyskinesis. The purpose of this study was to identify the adaptation of electromyograph (EMG) activities of the upper trapezius (UT), lower trapezius (LT), serratus anterior (SA), and anterior deltoid (AD) muscles with different weight loads in flexion (FLX) and abduction (ABD) in collegiate baseball players.

Materials and methods: Twenty eight individuals, including 13 pitchers, were tested. Normalized EMG signals for the UT, LT, SA, AD muscle of the both the dominant (DOM) and nondominant (NON) side were blocked at every 1 second during each of the exercises. A 3-way repeated analysis of variance design was used to identify differences in the mean values between DOM and NON and between FLX and ABD for DOM.

Results: The mean EMG value of the UT in the DOM was significantly less than that of the NON for all joint angles ($P < .01$), whereas the mean EMG value of the LT in the DOM was significantly greater than that of the NON ($P < .01$). In contrast, no difference in the SA EMG activity was determined between DOM and NON. However, the mean EMG value of SA in FLX was significantly greater than in ABD ($P < .01$).

Conclusion: This study identified an apparent adaptation of scapular muscle activities in the currently advocated scapular dyskinesis test for healthy active overhead athletes who are vulnerable to shoulder pathologies.

Level of evidence: Basic Science Study; Kinesiology

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Keywords: Scapular dyskinesis test; EMG; Baseball players; Muscular adaptation; Bilateral comparison; Lower trapezius; Upper trapezius

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A dynamic test of scapular dyskinesis has been of interest to clinicians and researchers for the purposes of diagnosis and rehabilitation in the symptomatic shoulder.^{2,4,5,7,8,10,12,15-18,20,23,25,28,30} Scapular dyskinesis is defined as altered scapular position in dynamic motion such as excessive internal rotation and anterior tilt of the scapula in the scapulohumeral rhythm (SHR).^{7,9,12}

Scapular dyskinesis has been reported to be associated with overhead throwing injuries, including labral tears, internal impingement, and elbow injuries.^{7,23} One possible mechanism for this is that scapular dyskinesis is related to a decrease in subacromial space width, scapular muscle activation, and glenohumeral (GH) joint congruency problems.^{7,15}

The scapular dyskinesis test^{12,16,18,25} and scapulohumeral rhythm have been examined by 3-dimensional motion analysis using digitized bony landmarks in shoulder flexion and abduction.^{15,17,30} Scapular upward rotation constantly occurs while the arm is elevated, whereas most posterior tilting occurs beyond 90° of arm elevation.¹⁷ Most external rotation of the scapula also occurs beyond 90° of arm elevation, with very little taking place in the internal rotation position.¹⁷

SHR was evaluated as visual dynamic assessment for 57 active uninjured pitchers and 14 catchers from a professional baseball club using a 0.9-kg dumbbell held in each hand before an upcoming season of professional baseball. All participants were instructed to elevate their arms for a 4-second count to complete maximal scapular plane elevation, followed by eccentrically lowering the arms for another 4-second count. Unlike other previous studies,^{16,25,30} low inter-rater reliability was found in classifying each scapula into the currently established 4 types of scapular dyskinesis⁵: prominence of the inferior angle (type I), prominence of the medial border (type II), prominence of the superior border (type III), and symmetrical scapulohumeral rhythm (type IV).¹²

With regard to scapular muscle activities in SHR, non-athletic patients with shoulder impingement significantly increase both the upper trapezius (UT) and lower trapezius (LT) muscle activation at joint angles from 61° to 120° when elevating the arm in the scapular plane with a handheld load of 4.6 kg compared with matched control participants without symptoms.¹⁵ However, we observed that a symptomatic collegiate baseball pitcher with type II scapular dyskinesis showed inhibition of the LT muscle along with hyperactivity of the UT during the descent phase of shoulder flexion with a wrist cuff weight of 3.2 kg.²⁸

In overhead athletes, the posterior tilt of the scapula controlled by the LT is important to be synchronized with GH external rotation during the cocking phase of the tennis serve.^{11,13} Consequently, previous literature has emphasized optimization of the ratio of UT to LT muscle activity in rehabilitation exercises for symptomatic shoulders.^{3,4,10} Nevertheless, the characteristics of scapular muscular activity during the elevation and descent phases from a standing position have yet to be elucidated. Therefore, the purpose of this study was to identify any difference in the muscle activity of the UT, LT, SA and anterior deltoid (AD) at different joint angles of SHR between the dominant (DOM) and nondominant (NON) side using the currently advocated scapular dyskinesis test with different weight loads. The purpose of this study was also to compare these muscular activities between shoulder flexion (FLX) and abduction (ABD) movements for the DOM side of asymptomatic collegiate baseball players.

Materials and methods

Participants

The study included 28 active college baseball players (height, 182.3 ± 5.6 cm; weight, 82.8 ± 6.0 kg, age, 19.2 ± 1.4 years), including 13 pitchers, who volunteered to be tested. All subjects belonged to the National Collegiate Athletic Association Division I conference in the United States and gave informed consent to the procedures.

The subjects indicated neither history of neurologic and physiologic deficits in the upper body nor thoracic kyphosis on a preliminary screening questionnaire. All subjects demonstrated symmetrical scapular motions during shoulder ABD and FLX, regardless of weight loads (no apparent scapular dyskinesis), while UT, LT, SA, and AD muscle activities were examined. Each subject was tested for approximately 45 minutes on 1 day at a randomly assigned test time, and all tests were conducted in a quiet room. The examination was conducted before an upcoming season of collegiate baseball.

Clinical measures

This study measured 4 different muscle activities of both the DOM and NON extremity during shoulder FLX and ABD movements, and compared among 3 different weight loads. The use of different weight loads allowed the study to identify the modulation of muscular activity due to compensation from other muscles during similar movements with different weight loads.²⁹

Electrode placement

Raw electromyograph (EMG) amplitudes of the UT, LT, SA, and AD muscle were collected in accordance with our previous study.^{28,29} To measure EMG amplitudes, bipolar surface EMG electrodes (Ag) with a bar length of 10 mm, a width of 1 mm, and a distance of 1 cm between active recording sites (Bagnoli-8; Delsys, Natick, MA, USA) were used.

Electrode placements for the UT, LT, SA, and AD muscles were determined according to previous reports.^{11,28,29} The electrodes were placed centrally over the muscle bellies as follows: the UT, halfway between the occipital bone and the lateral border of the clavicle at the level of the C7 spinous process; LT, an oblique angle 5 cm down from the scapular spine and just outside the medial border of the scapula; the SA, below the axilla at the level of the inferior angle of the scapula; the AD, 2 cm inferior to the lateral border of the clavicle and angled parallel to the muscle fibers.

The EMG electrodes were preamplified (10×) and routed through the EMG mainframe, which further amplified (100×), a total gain of 1000× and band-pass filtered (20–450 Hz) signals. A metal reference electrode was placed between the superior angles of the scapulae. To ensure that EMG activities were analyzed similarly between subjects, the timing of shoulder movements from the initiation to completion was controlled by a metronome.

Procedures

For the isotonic contraction measurement of FLX of the GH joint, the subject performed bilateral shoulder FLX from the lateral side

of the hip to full FLX in the standing position. The subject was requested to avoid using the torso to lean backward or hip extension. The subject was also requested to extend the elbow with the arm in a position such that both thumbs were pointing upward toward the ceiling up to 90°, followed by pointing backward.

For the isotonic contraction measurement of ABD of the GH joint, the subject performed bilateral shoulder ABD from the lateral side of the hip to full ABD in the coronal plane while standing upright. The subject was requested to avoid flexing the hip joint during the movement and to use the coronal plane (not the scapular plane as a compensation strategy.) None of the subjects performed ABD in a slouched position. The subject was also requested to extend the elbow with the arm in the neutral position, such that both thumbs were pointing upward toward the ceiling up to 90° of ABD, followed by the thumbs medially pointing at each other after 90°. The subject performed the FLX and ABD movements without weight (0 kg) as well as with an adjustable wrist cuff weight of between 1.8 kg and 3.2 kg.

Each subject performed the isotonic contraction of FLX/extension and ABD/adduction movements for 3 consecutive repetitions and followed auditory cues for each repetition. The subject completed each of the exercises for 5 seconds, with an interval of 10 seconds between each of the repetitions. A metronome with a frequency of 1 Hz or 1 beat per second was used to standardize the speed of movements and controlled the intervals between repetitions. During the pause between the completion of arm elevation and the initiation of the descent, the subject was quiet with the arms placed in the complete elevation position without losing extension of the elbow joint for 5 seconds, and waiting for the initial auditory cue to lower the arm. The subject performed several practice repetitions to ensure the movement tempo of the upcoming test condition before formal data generation took place.

Data management and analyses

Input signals of EMG activities were recorded using a data collection system (MP 150 Data Acquisition System; BIOPAC System Inc, Goleta, CA, USA) with a sampling rate of 1000 Hz, and all data were stored in a computer for off-line analyses. The root-mean-square values of the EMG signals for the UT, SA, and AD were normalized to the maximum voluntary isometric contraction (MVIC) of the corresponding muscles in scapular plane elevation at 90° of GH flexion (%), whereas the root-mean-square of the EMG signal for the LT was normalized to the MVIC of the corresponding muscle at 180° of GH flexion or with as much flexion as possible in a quadruped position in which the hips and knees were flexed at 90°. The mean value of normalized EMG activity out of 3 trials for each of the movements (FLX/extension and ABD/adduction) was used for individual data collection.

Data reduction of this study was the same as in our preliminary study in terms of determination of joint angles based on the number of the EMG samples while all subjects followed the same tempo by the metronome with 1 Hz in each of the exercises.²⁸ Each of the data sets consisted of 5000 samples of EMG activity as a dependent variable measured for 5 seconds from the initial activity of the DOM UT muscle to the completion each of the exercises (1000 Hz × 5 seconds). This study analyzed the dependent variable, which was blocked at every 1000 samples of the EMG activity or every 1 second during each of the exercises. Consequently, 5000 samples of EMG activity for each exercise were divided into 5

blocks of dependent variables from the initial EMG activity to the end of the exercise for upward movement and descent, for a total of 10 blocks.

For data analyses of the EMG activity of the muscles across the movement conditions, a $2 \times 3 \times 10$ (DOM/NON × weight load × block) repeated-measures analysis of variance (ANOVA) design within subjects crossed with weight load and angle was used to test for differences in each mean value of the EMG activities between the DOM and NON extremity for both FLX and ABD. This study also analyzed whether there was any difference in the mean values of EMG activity between FLX and ABD for the DOM side using a $2 \times 3 \times 10$ (exercise × weight load × block) repeated ANOVA. Because identifying any difference in the mean values of EMG activity between the DOM and NON, and between FLX and ABD for DOM side, was of particular interest in this study, the simple-simple main effect was used after the omnibus 3-way repeated ANOVA. To minimize the type I error of rejecting the null hypothesis, all statistical tests were performed at 0.01 level of probability ($P < .01$).

Results

Upper trapezius

Analysis of the results indicated a significant 2-way interaction in the mean value of UT EMG activity between the DOM and NON extremity across joint angles for FLX ($F_{9,243} = 4.38$, $P < .001$) and ABD ($F_{9,243} = 6.53$, $P < .001$). Specifically, analysis of the results indicated that all of the mean values in the DOM extremity were significantly less than those of the NON extremity at each of the joint angles in both upward and descent phases for both FLX and ABD, regardless of the amount of weight load ($P < .01$; Table I).

A comparison of the UT EMG activity between ABD and FLX for the DOM extremity showed the mean value of the EMG activity in ABD was significantly greater than that of FLX for joint angles ranging between 3 seconds and 5 seconds after the initial upward movement with the weight load of 0 kg ($P < .01$). For the weight load of 1.8 kg, the mean value of EMG activity in ABD was significantly greater than that of FLX for the joint angles ranging between 2 seconds and 4 seconds after the initial upward movement ($P < .01$), whereas for the weight load of 3.2 kg, the mean value in ABD was significantly greater than that of FLX for the joint angles ranging between 0 seconds and 4 seconds after the initial upward movement as well as between 6 seconds and 7 seconds in descent ($P < .01$; Fig. 1).

Lower trapezius

Analysis of the results indicated that the mean values of LT EMG activity in the DOM extremity were significantly greater than that of the NON in FLX ($F_{1,27} = 8.37$, $P = .007$) as well as in ABD ($F_{1,27} = 9.54$, $P = .005$). Furthermore, analysis of the results indicated that all of the mean values at each of the joint angles in both upward movement and descent in the

Table 1 Electromyography activities (mean \pm standard deviation) of the upper trapezius normalized by the maximum isometric voluntary contraction in each of flexion and abduction exercise with different weight loads

Movement (N = 28)	FLX-dominant EMG (%MVIC)			FLX-nondominant EMG (%MVIC)			ABD-dominant EMG (%MVIC)			ABD-nondominant EMG (%MVIC)		
	0 kg	1.8 kg	3.2 kg	0 kg	1.8 kg	3.2 kg	0 kg	1.8 kg	3.2 kg	0 kg	1.8 kg	3.2 kg
Upward												
1 sec	30 \pm 20*	34 \pm 22 [†]	33 \pm 16 [†]	47 \pm 22*	47 \pm 20 [†]	48 \pm 18 [†]	32 \pm 20*	35 \pm 18 [†]	36 \pm 16 [†]	48 \pm 22*	50 \pm 20 [†]	51 \pm 17 [†]
2 sec	34 \pm 19*	40 \pm 21 [†]	42 \pm 15 [†]	49 \pm 21*	51 \pm 18 [†]	56 \pm 15 [†]	36 \pm 18*	44 \pm 17 [†]	49 \pm 15 [†]	51 \pm 20*	56 \pm 18 [†]	61 \pm 15 [†]
3 sec	39 \pm 19*	46 \pm 21 [†]	52 \pm 15 [†]	52 \pm 21*	55 \pm 18 [†]	61 \pm 16 [†]	42 \pm 18*	52 \pm 17 [†]	57 \pm 16 [†]	55 \pm 20*	62 \pm 17 [†]	66 \pm 16 [†]
4 sec	42 \pm 21*	52 \pm 22 [†]	55 \pm 18 [†]	53 \pm 21*	57 \pm 19 [†]	62 \pm 20 [†]	46 \pm 19*	55 \pm 19 [†]	58 \pm 18 [†]	57 \pm 20*	61 \pm 19 [†]	64 \pm 17 [†]
5 sec	41 \pm 20*	48 \pm 19 [†]	51 \pm 18 [†]	52 \pm 21*	55 \pm 20 [†]	57 \pm 19 [†]	47 \pm 20*	50 \pm 18 [†]	52 \pm 18 [†]	56 \pm 21*	58 \pm 20 [†]	60 \pm 19 [†]
Descent												
6 sec	36 \pm 19*	39 \pm 18 [†]	42 \pm 18 [†]	48 \pm 19*	49 \pm 18 [†]	51 \pm 18 [†]	39 \pm 18*	40 \pm 18 [†]	44 \pm 18 [†]	50 \pm 19*	50 \pm 19 [†]	53 \pm 18 [†]
7 sec	33 \pm 18*	36 \pm 16 [†]	38 \pm 15 [†]	47 \pm 19*	48 \pm 18 [†]	49 \pm 17 [†]	36 \pm 18*	39 \pm 17 [†]	43 \pm 17 [†]	49 \pm 19*	50 \pm 18 [†]	53 \pm 18 [†]
8 sec	31 \pm 18*	35 \pm 16 [†]	37 \pm 15 [†]	46 \pm 19*	48 \pm 18 [†]	48 \pm 16 [†]	34 \pm 18*	37 \pm 18 [†]	40 \pm 18 [†]	48 \pm 19*	49 \pm 18 [†]	52 \pm 17 [†]
9 sec	30 \pm 19*	33 \pm 17 [†]	34 \pm 16 [†]	45 \pm 19*	46 \pm 18 [†]	46 \pm 17 [†]	32 \pm 19*	34 \pm 18 [†]	36 \pm 18 [†]	47 \pm 19*	48 \pm 18 [†]	49 \pm 18 [†]
10 sec	28 \pm 20*	30 \pm 18 [†]	30 \pm 17 [†]	44 \pm 20*	45 \pm 19 [†]	43 \pm 19 [†]	29 \pm 20*	30 \pm 18 [†]	30 \pm 18 [†]	45 \pm 19*	45 \pm 18 [†]	45 \pm 18 [†]

ABD, abduction; EMG, electromyograph; FLX, flexion; MVIC, maximum isometric voluntary contraction.

* $P < .01$ for weight load of 0 kg, $^{\dagger}P < .01$ for weight load of 1.8 kg, and $^{\ddagger}P < .01$ for weight load 3.2 kg, indicating a significant difference between the dominant and nondominant side in FLX and ABD. All of the mean values in the dominant side were significantly less than those of the nondominant side at each of the joint angles in both upward movement and descent for both FLX and ABD, regardless of the amount of weight load ($P < .01$).

DOM arm were significantly greater than those of the NON in both FLX and ABD, regardless of the amount of weight load ($P < .01$; Supplementary Table I).

A comparison of the LT EMG activity between ABD and FLX for the DOM extremity showed the mean value of the EMG activity in ABD was significantly greater than that of FLX for the joint angles ranging between 6 seconds and 8 seconds in descent with the weight load of 0 kg ($P < .01$). However, the mean value of the EMG activity in ABD for weight loads of 1.8 kg and 3.2 kg was significantly greater than that of FLX for the joint angles ranging between 3 seconds and 4 seconds after the initial upward movement and between 6 seconds and 9 seconds in descent ($P < .01$; Fig. 2).

Serratus anterior

Analysis of the results indicated a significant 3-way interaction in the mean values of SA EMG activity between DOM/NON and weight loads across joint angles for FLX ($F_{18,486} = 2.62$, $P < .001$), whereas no 3-way interaction was found for ABD. However, a significant 2-way interaction was found between DOM and NON across joint angles for ABD ($F_{9,243} = 3.40$, $P = .001$). Specifically, for FLX, no difference was found in the mean value of the EMG activity between DOM and NON with the weight load of 0 kg, whereas the mean value in the DOM extremity was significantly greater than that of the NON for the joint angles ranging between 4 seconds and 5 seconds after the initial upward movement with the weight load of 1.8 kg ($P < .01$). The mean values in the DOM extremity were also significantly greater than those of NON for the joint angles ranging between 4 seconds and 5 seconds after the initial upward movement and between 6 seconds and 7 seconds in descent with the weight load of 3.2 kg for FLX ($P < .01$). Likewise, for ABD no difference was found in the mean value of SA EMG activity between DOM and NON with the weight load of 0 kg, whereas the mean values in the DOM extremity were significantly greater than those of the NON for the joint angles ranging between 4 seconds and 5 seconds after the initial upward movement and between 6 seconds and 7 seconds in descent with weight loads of 1.8 kg and 3.2 kg ($P < .01$) (Supplementary Table II).

With regard to a comparison of the SA EMG activity between ABD and FLX for the DOM extremity, the mean value of the EMG activity in FLX was significantly greater than that of ABD for the joint angles ranging between 3 seconds and 4 seconds after the initial upward movement with the weight load of 0 kg ($P < .01$), whereas no difference was found between ABD and FLX with the weight load of 1.8 kg. In contrast, the mean values of the EMG activity in FLX for the weight load of 3.2 kg were significantly greater than those of ABD for the joint angles ranging between 0 seconds and 4 seconds after the initial upward movement ($P < .01$; Fig. 3).

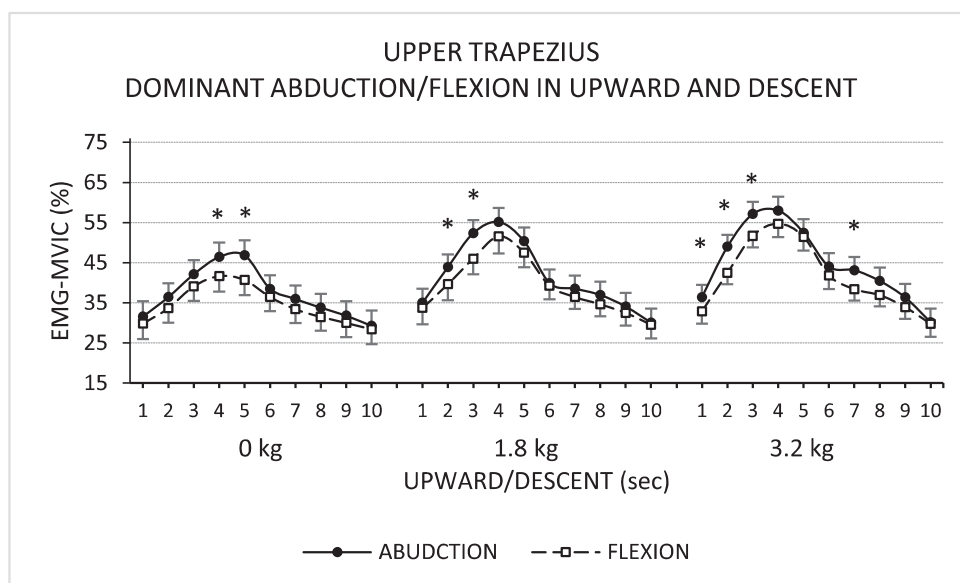


Figure 1 Upper trapezius: a comparison of mean values of electromyography (EMG) activities normalized by the maximum isometric voluntary contraction (MVIC) between flexion and abduction across different joint angles with different weight loads for the dominant arm. The *solid lines* indicate the mean values of upper trapezius EMG activity in the dominant side for abduction with weight loads of 0 kg, 1.8 kg, and 3.2 kg, from left to right, respectively, and the *dashed lines* indicate the mean values of the upper trapezius EMG activity for flexion. Note that the mean values in abduction were significantly greater than those of flexion for joint angles ranging between 0 seconds and 4 seconds after the initial upward movement, and between 6 seconds and 7 seconds in descent with the weight load of 3.2 kg. The *error bars* denote the standard error of the mean. * $P < .01$.

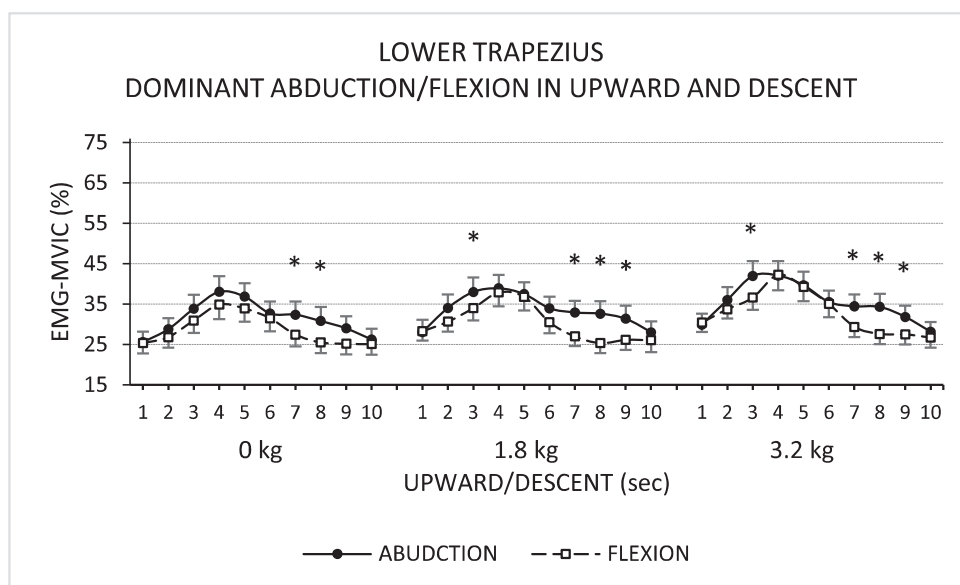


Figure 2 Lower trapezius: a comparison of mean values of electromyography (EMG) activities normalized by the maximum isometric voluntary contraction (MVIC) between flexion and abduction across different joint angles with different weight loads for the dominant arm. The *solid lines* indicate the mean values of lower trapezius EMG activity in the dominant side for abduction with weight loads of 0 kg, 1.8 kg, and 3.2 kg, from left to right, respectively, and the *dashed lines* indicate the mean values of the lower trapezius EMG activity for flexion. Note that the mean values in abduction were significantly greater than those of flexion for the joint angles ranging between 3 seconds and 4 seconds after the initial upward movement and between 6 seconds and 8 seconds in descent with weight loads of 1.8 kg and 3.2 kg. The *error bars* denote the standard error of the mean. * $P < .01$.

Anterior deltoid

Analysis of the results indicated that neither 3-way interaction nor 2-way interactions were found in the mean values of AD EMG activity for FLX and ABD. However, analysis of the results found that the mean values in the DOM extremity were significantly greater than those of the NON for the joint angles ranging between 3 seconds and 5 seconds after the initial upward movement with the weight load of 1.8 kg for FLX ($P < .01$). Also, the mean values in the DOM extremity were significantly greater than those of the NON for the joint angles ranging between 1 second and 5 seconds after the initial upward movement with the weight load of 3.2 kg for FLX ($P < .01$). Likewise, for ABD the mean value in the DOM extremity was significantly greater than that of the NON for the joint angles ranging between 4 seconds and 5 seconds after the initial upward movement. Also, the mean values in the DOM extremity were significantly greater than those of the NON for the joint angles ranging between 3 seconds and 5 seconds after the initial upward movement with the weight load of 3.2 kg for FLX ($P < .01$). No difference was found in the mean value of the EMG activity between DOM and NON with the weight load of 0 kg for FLX or ABD (Supplementary Table III).

A comparison of the AD EMG activity between ABD and FLX for the DOM extremity showed the mean values of the EMG activity in FLX were significantly greater than those of ABD for the joint angles ranging between 1 second and 3 seconds after the initial upward movement with the weight load of 0 kg ($P < .01$), whereas the mean values in FLX were

significantly greater than those of ABD for the joint angles ranging between 0 seconds and 2 seconds after the initial upward movement with both weight loads of 1.8 kg and 3.2 kg ($P < .01$; Fig. 4).

Discussion

This study identified the patterns of EMG activities of the UT, LT, SA, and AD muscles in healthy collegiate baseball players who abducted and flexed the GH joint with 3 different weight loads in the currently advocated scapular dyskinesis test.^{16,25,28} Although none of the subjects in this study presented with any shoulder pathology or apparent scapular dyskinesis, the subjects elevated and lowered the arms with a steady and consistent tempo for 5 seconds, which was similar to the previous study.⁵ All subjects followed a metronome with a frequency of 1 Hz whereby raw EMG activity with 5000 samples for each of the exercises were obtained and divided into 5 blocks as 5 different ranges of GH joint angles in upward movement and descent.

The amount of muscle activity varied depending on extremity dominance with respect to the UT and LT muscle for these overhead athletes. It is interesting to note that the subjects maximized the LT muscle activity in their DOM side compared with their NON side, regardless of the weight load. Furthermore, the LT muscle activity in ABD was significantly greater than that of FLX at the movement ranging between 1 second and 3 seconds after the initial upward movement and between 6 seconds and 9 seconds in the descent with weight

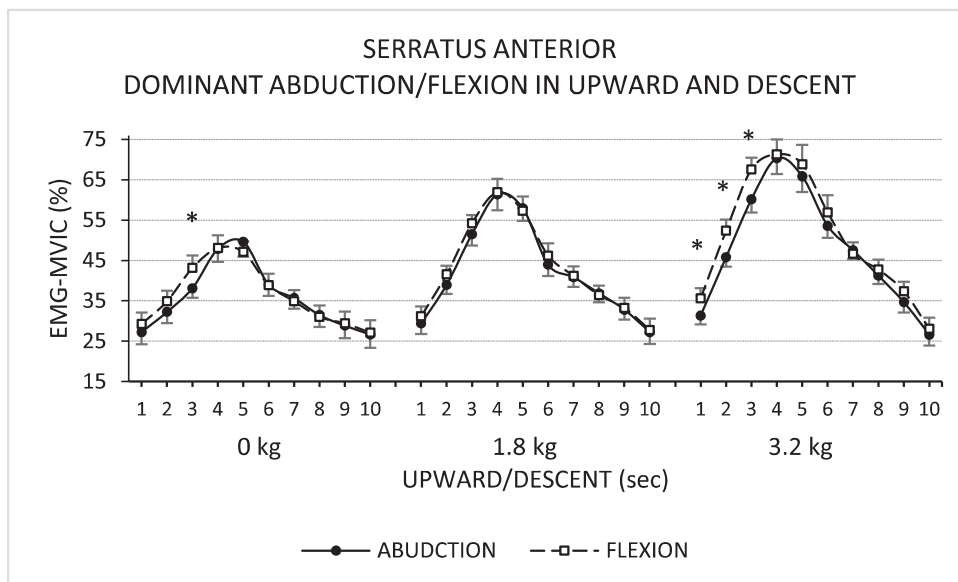


Figure 3 Serratus anterior: a comparison of mean values of electromyography (EMG) activities normalized by the maximum isometric voluntary contraction (MVIC) between flexion and abduction across different joint angles with different weight loads for the dominant arm. The solid lines indicate the mean values of serratus anterior EMG activity in the dominant side for abduction with weight loads of 0 kg, 1.8 kg, and 3.2 kg, from left to right, respectively, and the dashed lines indicate the mean values of the serratus anterior activity for flexion. Note that the mean values in flexion were significantly greater than those of abduction for the joint angles ranging between 0 seconds and 4 seconds after the initial upward movement with the weight load of 3.2 kg. The error bars denote the standard error of the mean. * $P < .01$.

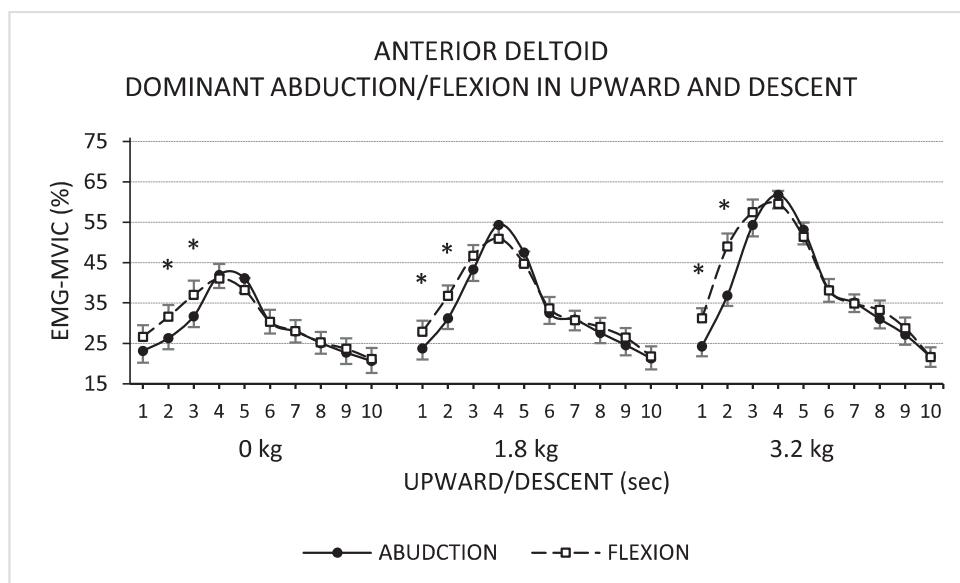


Figure 4 Anterior deltoid: a comparison of mean values of electromyography (EMG) activities normalized by the maximum isometric voluntary contraction (MIVC) between flexion and abduction across different joint angles with different weight loads for the dominant arm. The *solid lines* indicate the mean values of anterior deltoid EMG activity in the dominant side for abduction with weight loads of 0 kg, 1.8 kg, and 3.2 kg, from left to right, respectively, and the *dashed lines* indicate the mean values of the anterior deltoid EMG activity for flexion. Note that the mean values in flexion were significantly greater than those of abduction for the joint angles ranging between 0 seconds and 2 seconds after the initial upward movement with weight loads of 1.8 kg and 3.2 kg. The *error bars* denote the standard error of the mean. * $P < .01$.

loads of 1.8 kg and 3.2 kg. This indicates that healthy baseball players effectively maintain the posterior tilt and acromial elevation, which has been suggested to be controlled by the LT muscle during active ABD movement. This is critical in the late cocking phase of the throwing or serving cycle.^{7,13,15}

One possible mechanism that could account for the differences in the LT muscle activity observed between FLX and ABD could be the amount of internal rotation of the scapula inherent in shoulder elevation. External rotation will not occur until 90° of the shoulder flexion, which could lead to minimizing the activity of the LT muscle during the flexion movement.¹⁷ Also, EMG activity in the UT muscle of the DOM arm was effectively minimized across the entire joint range of motion compared with the NON arm regardless of the weight load used in the scapular dyskinesis test. Hyperactivity of the UT has been proposed as a mechanism producing abnormal scapular motion.^{3,4} In addition, because ABD elicits this excessive activity of the UT muscle compared with FLX, it is plausible to suggest that type III scapular dyskinesis (prominence of superior angle of the scapula) can be more readily detected in ABD.

No adaptation was seen in the SA muscle with respect to the comparison of the DOM to the NON extremity for these baseball players, except for joint angles in terminal FLX or ABD. The SA muscle is primarily responsible for producing the characteristic upward rotation component of SHR.^{8,15} The degree of scapular upward rotation has been shown to

be decreased at ABD angles greater than 60° in the DOM side of overhead athletes from the preseason to the postseason in collegiate baseball players.²⁶ This study was also conducted during the preseason; conversely, the adaptation of the SA muscle might be seen more conclusively during the course of competitive season. In addition, because the movement pattern of FLX elicits the greater activity of the SA muscle during the upward phase compared with ABD, type II scapular dyskinesis (prominence of scapular medial border) could be detected more readily in the upward phase of FLX. Unlike the LT muscle activity, which was relatively consistent in the descent phase, the SA muscle progressively decreased its activity as the extremity was lowered during the descent phase.

Lastly, the AD muscle of the DOM extremity was facilitated with the weight load of 3.2 kg in the upward phase of FLX compared with the NON extremity for the baseball players in this study. The increased activity of the AD has been suggested to reduce the amount of subacromial space as a result of the translation of the humeral head during a superiorly directed shear force in the glenoid fossa.^{6,21} Therefore, based on this finding from this study, the patient with a symptomatic shoulder, such as impingement syndrome, should be given the scapular dyskinesis test in FLX with some caution or understanding that exacerbation of the impingement mechanism may ensue due to the inherent increase in deltoid activity.

Conclusion

Evaluation of the DOM shoulder in overhead athletes like baseball players often identified characteristic adaptations such as glenohumeral internal rotation range of motion deficits or glenohumeral internal rotation deficit,^{1,22,23} which has also been associated with a decrease in glenohumeral horizontal adduction range of motion.¹⁴ Likewise, alterations of scapular orientation in overhead athletes, such as DOM arm scapular internal rotation and anterior tilting, has been measured in with scapular testing^{19,22,24,31} and compared with the NON side across the different competitive levels, such as college and high school baseball players.²⁷ This study reported apparent adaptation and differences of scapular muscle activation during both upward movement and descent phases of GH elevation using bilateral DOM/NON comparison.

The healthy active overhead athletes in this study appeared to develop a positive adaptation of both the UT and LT muscle activity during the scapular dyskinesis test. The muscular activity of the LT varied based on extremity dominance with no apparent effect of extremity dominance noted in the SA. Further studies are warranted to clarify scapular muscle activities relative to the scapular dyskinesis test in a variety of subject populations, with or without shoulder symptoms, and to identify if there are any relationships between scapular muscle adaptations and scapular dyskinesis in overhead athletes.

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Disclaimer

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Supplementary data

Supplementary data related to this article can be found online at [doi:10.1016/j.jse.2016.03.004](https://doi.org/10.1016/j.jse.2016.03.004).

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