Clinical Factors Related to Improved Scapular Control After a Scapular Conscious Control Program in Symptomatic Overhead Athletes

Secondary Analysis of a Randomized Controlled Trial

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Background: Predictive variables associated with the effects of a scapular conscious control program should be identified and used to guide rehabilitation programs.

Purpose: To determine whether potential factors are associated with the success of scapular muscle balance with an early control program in patients with subacromial pain and scapular dyskinesis.

Study Design: Case-control study; Level of evidence, 3.

Methods: A total of 38 amateur overhead athletes with subacromial pain and medial border prominence were recruited. They performed progressive conscious control of scapular orientation during 45° and 90° of arm elevation. Stepwise logistic regression and receiver operating characteristic curve were used to determine the optimal cutoff point of related factors for success or failure of the program. Potential factors including pain level during activity, pain duration, anterior/posterior shoulder flexibility, forward shoulder posture, posterior displacement of root of spine and inferior angle, scapular kinematics, and muscle activation before conscious control program were recorded as independent variables. Successful control defined as decreases of the upper trapezius/serratus anterior ratio in 2 consecutive trials of the 90° program or failure in the program was used as a dependent variable.

Results: Having a posterior displacement of the inferior angle of the scapula of $\leq$16.4 mm and scapular posterior tipping during arm elevation of $\leq$3.3° (collected before the control program) were associated with the success of the program ($R^2 = 0.286$; $P < .05$). Additionally, participants with each or both variables present at baseline had probabilities of success of 78% and 95%, respectively.

Conclusion: The value of scapular posterior displacement and posterior tilt should be considered before early scapular control program. Other factors related to the success of the program should be found due to the limited variance explained in the regression model.

Keywords: kinematics; muscle activation; scapular dyskinesis; subacromial pain

Scapular dyskinesis is defined as altered scapular position and movement.[17] It may change the biomechanics of the shoulder complex and lead to shoulder symptoms and dysfunction. The prevalence of scapular dyskinesis is in the range of 66% to 100% in various shoulder disorders.[8,25,27,34] A recent meta-analysis showed that asymptomatic athletes with scapular dyskinesis have a 43% greater risk of developing further shoulder pain than those without scapular dyskinesis.[12] Additionally, asymptomatic competitive baseball players with scapular dyskinesis during the preseason had lower scores on sports-related shoulder functional questionnaire at postseason compared with those without scapular dyskinesis.[32] High-energy demands are placed on the shoulder complex during overhead sports, which may explain the high prevalence of shoulder injuries in this population.[1,4,23,28,33] As a result, scapular dyskinesis is highly associated with shoulder injuries and shoulder dysfunction, especially in overhead athletes.

Conscious control of scapular orientation during arm movements may be helpful in the treatment of altered muscle performance in individuals with scapular dyskinesis.[7,14,24] Altered scapular muscle performance has been

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found in individuals with scapular dyskinesis.[16] Hyperactivation of the upper trapezius (UT) with inhibited middle trapezius (MT), lower trapezius (LT), and serratus anterior (SA) activations has been related to altered scapular movement and shoulder injuries.[5,16,19] Selective activation of inhibited or weaker muscles with minimal activation of hyperactive muscles is an essential component for the restoration of muscle balance.[5] Some studies have reported the influence of conscious control of scapular orientation on scapular muscle activation during common shoulder training movements.[7,14,24] UT/MT and UT/LT activation ratios were significantly reduced with conscious control during arm elevation in the scapular plane.[24] Furthermore, a positive effect of conscious control of scapular orientation with or without video feedback was also reported to both reduce the UT/LT ratio and improve scapular internal rotation during arm elevation.[14] Therefore, conscious control of scapular orientation during arm movements can be used to control scapular movement and restore scapular muscle balance in patients with scapular dyskinesis.

In addition to the UT/LT ratio, the UT/SA ratio is a crucial factor to consider during a conscious control program.[6,14] Muscle imbalances among UT, LT, and SA muscles with altered scapular movements are highly related to shoulder injuries.[3,5,19] Patients with a prominent inferior angle or medial border of the scapula attempt to control the scapular position to decrease the posterior displacement of the scapular border. Although LT and SA muscle activations are supposed to increase during a scapular control program, excessive scapular retraction, a common incorrect way to control scapular movement, results in increased LT muscle activations, but inhibited SA muscle activation, during a scapular control program.[22,24] As a result, monitoring of the UT/SA ratio is more important than the UT/LT ratio to avoid inappropriate compensation of scapular movement during a scapular control program when correcting the prominence of the inferior angle or medial border of the scapula.

Predictive variables associated with the effects of a scapular-focused conscious control intervention program should be identified and used to guide rehabilitation programs. Furthermore, it would be useful for clinicians to have guidance in determining which patients with scapular dyskinesis may experience improvements after early conscious control training. The purpose of this study was to identify the potential factors associated with improving scapular muscle coordination during an early conscious control program for overhead athletes with subacromial pain syndrome and a prominent medial border of the scapula. Additionally, we identified the cutoff values of significantly related factors for differentiating improvement versus nonimprovement in scapular muscle balance during an early scapular control program. Our main hypothesis was that the inferior angle and medial border of the scapula posterior displacements would be directly related to an improvement in the UT/SA ratio during a scapular control program.

METHODS

Study Design

A secondary analysis of our previously published single-blind randomized controlled trial[14] was conducted. In the original trial, we recruited participants and performed experiments in the laboratory from July 2016 to January 2017. In total, 38 participants were allocated to groups with block randomization (4 participants per block) by a person not involved in the recruitment of participants. The assessor who performed the clinical measurements (W.-Y.D.) was blinded to the group assignment. After completing the preintervention measurements, the assessor opened the sealed, opaque envelope and assigned each individual to either the video feedback or no video feedback group. A sample size of 19 participants per group provided 80% power to detect differences in scapular displacement (0.6 cm) and UT/SA ratio (1.05) between the pre- and postintervention, as well as between the 2 groups of interest at an alpha level of .05 with a 2-tailed test.[24,35]

In the current secondary analysis, we investigated the potential factors associated with the effectiveness of the scapular control program. Ethical approval was received for this study and all study participants provided written informed consent.

Participants

Participants for the secondary analysis were recruited from an outpatient clinic at a university hospital and through general announcements in local internet media. We recruited 38 amateur overhead athletes (27 male; age, 26.3 ± 5.1 years; height, 170.8 ± 7.4 cm; weight, 65.4 ± 11.0 kg) with subacromial pain syndrome and scapular dyskinesis. The inclusion criteria were as follows: (1) age 18 to 60 years; (2) subacromial pain syndrome confirmed by clinical examination; and (3) obvious prominence of the medial border of the scapula visible at less than 90° of arm elevation/lowering.[15] Subacromial pain syndrome was confirmed with positive results on at least 2 of the following criteria

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Ethical approval for this study was obtained from National Taiwan University Hospital.

based on previous studies: Neer test; Hawkins-Kennedy test, empty can test, pain or weakness with resisted external rotation test, and tenderness on rotator cuff tendons.[13,21]

Patients who had a history of shoulder dislocation, fracture, or shoulder surgery, and/or a history of direct contact injury to the neck or upper extremities, or cervical-related neurological signs were excluded. Patients were also excluded if they could not complete the overall procedures.

Instrumentation

Surface electromyography (sEMG) assemblies included pairs of silver chloride circular (recording diameter of 10 mm) surface electrodes (The Ludlow Company LP) with an interelectrode (center-to-center) distance of 20 mm, and a Grass AC/DC amplifier (Model 15A12; Astro-Med, Inc) with a gain of 1000, a common mode rejection ratio of 86 dB at 60 Hz, and a bandwidth (–3 dB) of 10 to 500 Hz. A 16-bit analog to digital converter (Model MP 150; Biopac Systems Inc) was used to collect data at 1000 Hz/channel. The impedance between the electrodes was measured by an impedance meter (Model F-EZM5; Astro-Med Inc) to control the impedance over the muscle at less than 10 kΩ. The electrodes were placed on the UT, LT, and SA muscles following the methods outlined in our previous study.[14]

The Polhemus 3Space FASTRAK system (Polhemus Inc) was used to collect 3-dimensional scapular kinematics data with an accuracy of 0.8 mm and 0.15° claimed by the manufacturer. Three sensors for the system were attached to the sternum and the flat bony surface of the acromion with adhesive tape, and to the distal humerus with Velcro straps (Velcro BVBA), respectively.[16] The transmitter served as a global reference frame and was fixed to a rigid plastic base. A local coordinate system for each segment was created using digitized landmarks, including the sternal notch, xiphoid process, seventh cervical vertebra, eighth thoracic vertebra, acromioclavicular joint, root of the spine of the scapula, inferior angle of the scapula, lateral epicondyle, and medial epicondyle. The center of the humeral head was determined using the least-squares method.

Procedures

After the demographic data were collected, scapular dyskinesis was evaluated by a single physical therapist with 7 years of experience assessing scapular dyskinesis patterns (T.-S.H.). Clinical data, including forward shoulder posture (FSP), anterior/posterior shoulder flexibility (ASF/PSF), posterior displacement of root of spine (ROS) and inferior angle (IFA), were collected before the conscious control program to represent the potential factors associated with the effect of intervention (Figure 1). The level of FSP was determined by measuring the distance from the wall to the anterior portion of the acromion with a Digital Laser Distance Measurer (GLM 80; Robert Bosch GmbH). A longer distance indicated a more forward posture of the shoulder. The intraclass correlation coefficient ([ICC], 3.3) for intrarater reliability in measuring forward shoulder posture was 0.997 (SEM, 0.1 cm; minimal detectable change with 95% confidence [MDC_{95}], 0.3 cm). The degree of shoulder horizontal abduction/adduction was recorded with an inclinometer to represent the level of ASF/PSF (ICC, 0.974-0.989; SEM, 1.0°-1.1°; MDC_{95}, 2.6°-2.9°). A greater range of motion indicated more flexibility of the anterior/posterior shoulder soft tissues.[18] The distance of posterior displacement of the ROS and IFA of the scapula from the thoracic wall was measured with a scapulometer to represent the degree of scapular dyskinesis.[9] The ICC values for intrarater reliability were in the range of 0.996 to 0.998 (SEM, 0.2-0.3 mm; MDC_{95}, 0.6-0.7 mm) in this study, and those for interrater reliability were 0.95 to 0.99 (SEM, 0.7-0.8 mm) in previous research.[9]

Detailed information of the conscious control program has been presented previously.[14] In general, the participants practiced the program for 0° to 45° of arm elevation/lowering first, before progressing to 0° to 90° of arm range in the second stage. We placed a white column target near the participant for the guiding arm elevation and lowering in the scapular plane. To record the scapular kinematics and muscle activations before the conscious control program, the participant performed 3 trials of full range (at least 170°) of arm elevation in the scapular plane. After all preprogram data were collected, the conscious control program was started. One physical therapist explained how to flatten the scapula on the thorax to avoid posterior protrusion of the scapula. After several practice rounds for familiarization, the participant performed the program by controlling the scapula in the neutral or relatively neutral orientation described above. The participants performed 3 trials of formal practice while the assessor recorded the UT/SA ratio, which was calculated in the data acquisition software (AcqKnowledge; Biopac Systems Inc) and simultaneously demonstrated on the screen. The UT/SA ratio was calculated by dividing the UT root mean square (RMS) value by the SA RMS value.

The average of the first 3 trials was used as the baseline standard. Successful learning of scapular control was defined as decreases in the UT/SA ratio in 2 consecutive trials compared with the baseline; in these cases, the average of the postbaseline UT/SA ratios in the last 2 consecutive trials in the 90° program was recorded. If the participants could not reduce the UT/SA ratio in 2 consecutive trials, they continued to practice the program until the 10th trial. The value of the UT/SA ratio in the group with no reduction in the UT/SA ratio was the average of the postbaseline UT/SA ratios for all 10 postbaseline trials in the 90° program.

The success or failure in decreasing the UT/SA ratio in 2 consecutive trials compared with the baseline standard at 90° was recorded as improvement or nonimprovement of the conscious control program. We chose decreased UT/SA ratio as the criterion of success because the goal of early scapular conscious control was to learn how to control scapular orientation with scapular muscle balance. Patients with scapular dyskinesis and shoulder injuries are prone to using an incorrect strategy with excessive scapular retraction and elevation, which causes an excessive UT/SA ratio during scapular control. As a result, choosing the UT/SA ratio as the criterion of improvement of scapular

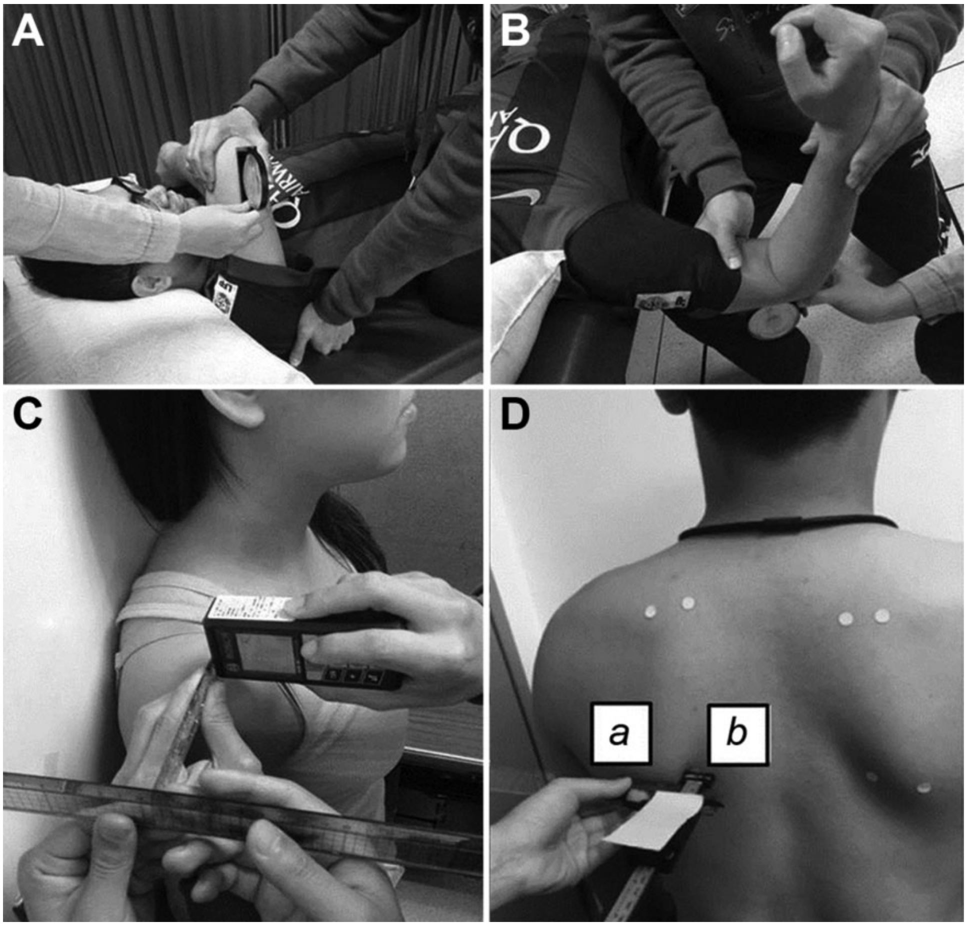


Figure 1. Clinical measurements: the tester used an inclinometer to measure (A) shoulder horizontal adduction and (B) horizontal abduction of the glenohumeral joint to represent the level of anterior/posterior shoulder flexibility, respectively; (C) the level of forward shoulder posture was determined by measuring the distance from the wall to the anterior portion of the acromion with a digital laser distance measurer. A solid ruler was held in contact with the front to anterior portion of the acromion and parallel to the wall, which was confirmed by another ruler held perpendicular to the former ruler and to the wall by a second examiner. The laser distance measurer was in contact with the front of the former ruler and emitted the laser to the wall; (D) the posterior displacement of the root of spine (ROS) and inferior angle (IFA) of the scapula from the thoracic wall was measured with a scapulometer to represent the degree of scapular dyskinesis. The ruler end of the scapulometer (*a*) was placed on the IFA or ROS of the scapula, and the caliper end (*b*) was placed on the landmark located 1 cm medially to the IFA or ROS of the scapula.

control is more appropriate than using kinematics outcomes and the UT/LT ratio as the criteria of success. This was supported by the data, which showed that in most participants, the UT/LT ratio decreased, while in some participants, the UT/SA ratio decreased during the scapular control program.

The average muscle activations of the UT, LT, and SA muscles before the program were analyzed as independent variables related to the effect of the scapular control program. The EMG data for each muscle were averaged for 3 trials of arm elevation/lowering. Full bandwidth sEMG data captured by data acquisition software were reduced using a RMS algorithm to produce EMG envelopes with an effective sampling rate of 50 samples. Results were normalized to the maximal voluntary isometric contraction with a procedure reported in previous methods.[16]

Motion Monitor Software (Innovative Sports Training Inc) was used to calculate the humerus elevation, scapular upward/downward rotation, anterior/posterior tilt, and internal/external rotation. The scapular kinematics data of arm elevation/lowering before the program were averaged for 3 trials as independent variables related to the effect of the scapular control program. The International Society of Biomechanics guidelines were followed for constructing a shoulder joint coordinate system.[36] Raw kinematics data were low-pass filtered at a cutoff frequency of 6 Hz and converted into anatomically defined rotations. The Euler angle sequence of rotation was used to describe scapular orientation relative to the trunk as rotation about Z_s (protraction/retraction), rotation about Y'_s (downward/upward rotation), and rotation about X''_s (posterior/anterior tipping). Humeral orientation relative to the scapula was described such that the first rotation represented the plane of elevation, the second rotation defined the amount of elevation, and the third rotation described the amount of axial rotation.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) 17.0 and MedCalc 18.11 were used for data analysis. The Shapiro-Wilk test was performed to confirm normal distribution of the outcomes. If the data were nonnormally distributed, we used nonparametric testing to analyze the data. Improvement and nonimprovement of the UT/SA ratios during the conscious control program were used as the dependent variable. First, we used the independent *t* test or Mann-Whitney *U* test to evaluate the difference in the change in UT/SA ratio between the improvement and nonimprovement groups. Moreover, the paired *t* test or Wilcoxon signed-rank test was used to compare the differences between the baseline and postbaseline trials during the 90° program in each group.

To address the potential variables, we used the independent *t* test or Mann-Whitney *U* test to compare scapular kinematics, muscle activation, clinical measurements including FSP, ASF/PSF, and posterior displacement of ROS and IFA, and demographic data including pain level during activity and pain duration at preprogram assessment, between the improvement and nonimprovement groups. Additionally, to ensure that there was no effect from feedback, we used the chi-square test to compare the difference of the number of participants allocated to the feedback and without feedback groups between the improvement and nonimprovement groups.

Potential variables were entered into a multivariate stepwise logistic regression equation to determine the predictors for the success or failure of the program. Pairwise associations among continuous variables were checked to determine if any factors were strongly correlated ($r > 0.8$) to avoid multicollinearity. Variables with a significance level of $P < .20$ were retained as potential variables; a more liberal significance level was chosen at this stage to avoid excluding potential variables. A significance of .05 was required to enter a variable into the model and a significance of .20 was required to remove it. Variables retained in the regression model were used to develop a multivariable model for determining outcomes in the prediction of the success of reducing the UT/SA ratio in 2 consecutive trials during the 90° program.

Finally, the receiver operating characteristic (ROC) curve was analyzed to determine the optimal cutoff points of the final variables with the best diagnostic accuracy to discriminate the success and failure groups. Area under the curve (AUC) values derived from the ROC curve analyses were used to determine the probability that the patient could be correctly identified by significant variables. AUC values are in the range of 0.5 to 1.0, with 0.5 indicating no discriminative ability beyond chance and 1.0 suggesting perfect discriminatory ability.[11] An AUC ≥ 0.7 is considered to be satisfactory.[20] Sensitivity, specificity, and positive likelihood ratios (PLRs) were calculated for those variables. The PLR was calculated as *sensitivity*/(1 − *specificity*). Additionally, the probability of success in the scapular control program was calculated as the number of true successes with predictors estimated/number of people estimated as success by predictors (Figure 2).

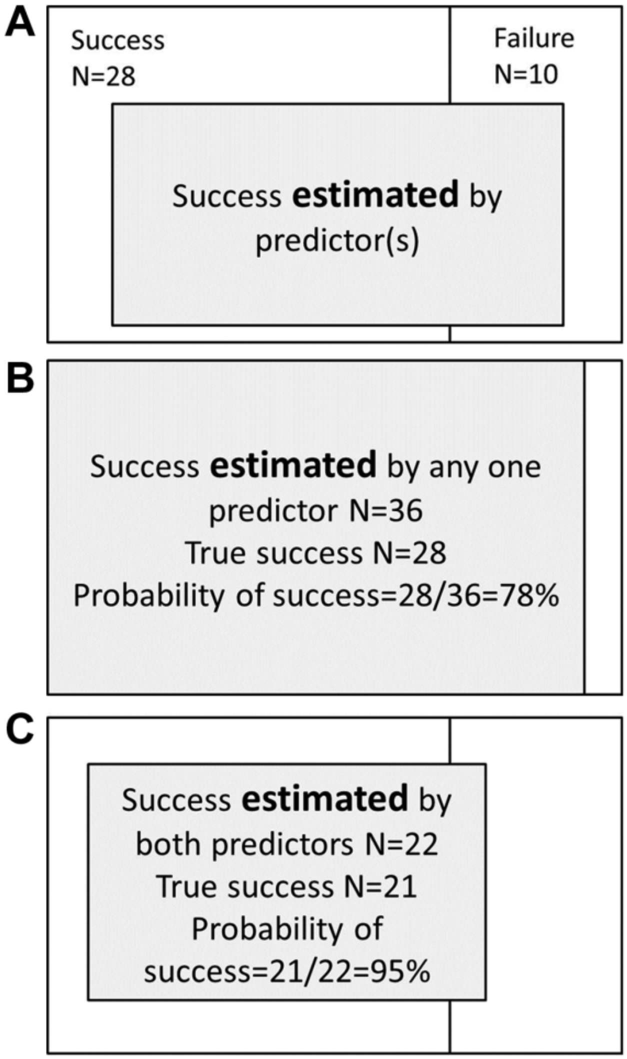


Figure 2. (A) Demonstration of calculating the probability of success: number of true successes with predictors estimated/number of people estimated as success by predictors. (B) Probability of success estimated by any 1 positive variable (28/36; 78%) and (C) both positive variables (21/22; 95%).

RESULTS

All participants finished the conscious control program. After the 90° program, 28 participants (74%) were classified as having an improved UT/SA ratio (improvement group); the remaining 10 participants (26%) comprised the nonimprovement group. The demographic, clinical measurement, and scapular kinematics data were normally distributed, but the muscle activation data were nonnormally distributed. There were no significant demographic

TABLE 1
Demographic Data, Clinical Measurements, Scapular Kinematics, and Muscle Activation Collected Before the Conscious Control Program in the Improvement and Nonimprovement Groups[a]

	Improvement Group (n = 28)	Nonimprovement Group (n = 10)	*P* Value
Demographic data			
Age, y	27.1 ± 4.8	24.2 ± 5.6	.127
Height, cm	169.7 ± 7.3	174.1 ± 7.1	.105
Weight, kg	64.8 ± 10.8	67.3 ± 12.0	.537
VAS for pain	4.3 ± 1.6	4.5 ± 1.0	.747
Pain duration, mo	42.8 ± 50.2	32.9 ± 33.6	.569
FLEX-SF (0-50)	43.3 ± 6.0	44.0 ± 4.9	.751
Feedback	F:14 WF:14	F:5 WF:5	.999
Clinical measurement (collected before the program)			
FSP, cm	11.8 ± 2.0	12.7 ± 1.6	.183[b]
Posterior displacement of IFA, mm	11.6 ± 4.5	15.2 ± 5.4	.045[b]
Posterior displacement of ROS, mm	11.9 ± 3.8	12.7 ± 4.3	.606
ASF, deg	26.6 ± 9.4	21.2 ± 6.8	.102[b]
PSF, deg	37.0 ± 6.4	36.7 ± 7.5	.892
Kinematics and muscle activation (collected before the program)[c]			
Posterior tipping, deg	–0.01 ± 8.1	5.3 ± 9.8	.099[b]
Upward rotation, deg	37.6 ± 7.3	40.9 ± 11.7	.297
Internal rotation, deg	–1.7 ± 5.2	-2.6 ± 10.7	.798
UT activation, %MVIC	24.9 (13.3-8.54)	23.2 (11.3-60.8)	.426
LT activation, %MVIC	14.9 (3.4-49.2)	10.2 (5.6-29.4)	.407
SA activation, %MVIC	29.6 (18.5-58.4)	35.8 ± 14.5	.881

[a] Data are reported as mean ± SD, absolute value, or median (range). ASF, anterior shoulder flexibility; F, feedback; FLEX-SF, Flexilevel Scale of Shoulder Function; FSP, forward shoulder posture; IFA, inferior angle; LT, lower trapezius; MVIC, maximal voluntary isometric contraction; PSF, posterior shoulder flexibility; ROS, root of spine; SA, serratus anterior; UT, upper trapezius; VAS, visual analog scale; WF, without feedback.

[b] Variables with a significance level of $P < .20$ based on independent sample *t* tests.

[c] Mean kinematics and muscle activation values during arm elevation/lowering in the scapular plane are reported.

differences between the improvement and nonimprovement groups (Table 1). Furthermore, the number of participants in the feedback and no-feedback training groups in the original article (n = 19 each, for a total of 38 participants)[14] was the same as in the improvement and nonimprovement groups of the current secondary analysis. Because video feedback did not influence the improvement of the UT/SA ratio during the 90° program,[14] this finding supported the combining of all participants.

TABLE 2
Changes in the UT/SA Ratio Before and After the 90° Conscious Control Program in the Improvement and Nonimprovement Groups[a]

UT/SA Ratio	Improvement Group (n = 28)	Nonimprovement Group (n = 10)
Baseline	1.52 (0.53 to 7.43)[b]	1.31 (0.46 to 4.38)[c]
Postbaseline	1.31 (0.51 to 6.55)[b]	1.37 (0.49 to 5.26)[c]
Change from baseline	–0.20 (–0.02 to –1.10)[d]	0.15 (0.03 to 0.88)[d]

[a] Data are reported as median (range). SA, serratus anterior; UT, upper trapezius.

[b] Significant difference between baseline and postbaseline measurements during the 90° program in the improvement group.

[c] Significant difference between baseline and postbaseline measurements during the 90° program in the nonimprovement group.

[d] Significant difference between the 2 groups ($P < .0005$).

Table 2 reports the changes in the UT/SA ratio between baseline and postbaseline data during the 90° program in the 2 groups, and there was a significant difference in the change in the UT/SA ratio between the 2 groups (–0.20 vs 0.15; $P < .0005$). Meanwhile, in most of the participants in both groups, the UT/LT ratio improved during the scapular control program. Table 2 also shows all the variables recorded before the conscious control program between the 2 groups. The potential variables were FSP, posterior displacement of IFA, ASF, and scapular posterior tipping.

These potential variables were entered into the logistic regression analysis. The 2 retained in the final model were posterior displacement of IFA and scapular posterior tipping (model chi-square, 8.289; df, 2; $P = .016$; Nagelkerke $R^2 = 0.286$). The cutoff values and diagnostic statistics of these variables from ROC curve analyses were posterior displacement of IFA of 16.4 mm and scapular posterior tipping of 3.3° (Table 3). The AUC values were 0.689 and 0.711 for posterior displacement of IFA and scapular posterior tipping, respectively (Figure 3). The findings indicated that posterior displacement of more than 16.4 mm and scapular posterior tipping of more than 3.3° could predict the failure of the conscious control program. A total of 36 and 22 participants were predicted as successful controls by any 1 positive variable and both positive variables, respectively (Figure 3). Of the 36 participants, 28 (78%) were truly in the success group with 1 positive variable. Of the 22 participants with positive results for both variables, 21 (95%) were truly in the success group. Accuracy statistics were calculated for each level of the prediction method (Table 3). Based on the probability of success found in this study, a participant with 2 variables present at baseline has a probability of improvement in the range of 78% to 95%.

DISCUSSION

Subacromial pain syndrome is associated with scapular dyskinesis and altered muscle activation patterns.[5,19] Reestablishing appropriate scapular movement and coordination among scapular stabilizers is crucial to shoulder rehabilitation and prevention programs in overhead athletes with subacromial pain.[10] Conscious correction of scapular orientation has been shown to improve scapular kinematics and muscle activation in patients with scapular dyskinesis.[14,24,35] In the current study, we found that posterior displacement of the inferior angle of the scapula and scapular posterior tilting during arm movement were associated with the success of early conscious control on scapular muscle coordination. Identifying these factors could help practitioners find the candidate for performing the scapular conscious control program in overhead athletes with subacromial pain syndrome and scapular dyskinesis and improve clinical decision making.

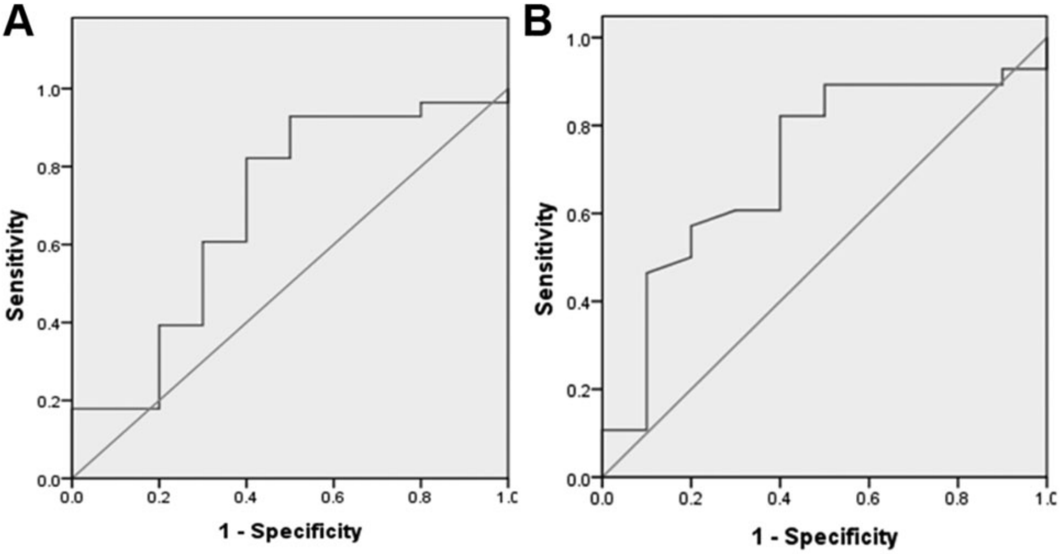
With regard to the posterior displacement of IFA, more IFA posterior displacement indicates increasing anterior tipping with the arm by the side. Many patients with prominence of the medial border combined with IFA protrusion may be influenced by insufficient muscle flexibility, and most often limited pectoralis minor length, which was associated with subacromial pain syndrome.[2] Without restoring pectoralis minor muscle flexibility related to scapular posterior tipping, patients may find it difficult to control their scapular orientation and tend to use improper compensation methods, such as overactivating the UT muscle and impairing the balance of scapular muscle recruitment. Owing to its limited AUC value, this variable should be used as a rule-out method only, based on its high sensitivity value. We suggest that the posterior displacement of the IFA measured by the scapulometer should be less than or equal to 16.4 mm for improvement of scapular muscle balance in the early conscious control program. If the posterior displacement of the IFA is beyond 16.4 mm, restoring limited muscle flexibility should be considered prior to beginning the scapular control program to improve the effectiveness of the program.

TABLE 3
Sensitivity and Specificity Statistics of Predicting Variables[a]

Predicting Variable	Sensitivity	Specificity	PLR
Posterior displacement of IFA, ≤16.4 mm	92.9 (76.5-99.1)	50.0 (18.7-81.3)	1.86
Posterior tipping, ≤3.3°	82.1 (63.1-93.9)	60.0 (26.2-87.8)	2.05
No. of predictor variables present			
1+	100 (15.8-100)	88.9 (73.9-96.9)	9.0
2+	43.7 (19.8-70.1)	100 (84.6-100)	

[a] Values in parentheses represent 95% CIs. IFA, inferior angle of the scapula; PLR, positive likelihood ratio.

We found that less scapular posterior tipping during arm elevation before the program was also associated with an improvement of the UT/SA ratio at 90° in the conscious control program. Theoretically, people without prominence of the IFA of the scapula require less scapular posterior tipping during arm elevation. Our findings showed that 95% of participants who had less IFA distance combined with less scapular posterior tipping during arm elevation had successful learning of the scapular control program, supporting the above statement. Interestingly, decreased scapular posterior tipping during arm elevation has been reported in patients with subacromial pain in previous studies.[19,31] The possible reason is that insufficient scapular posterior tipping may partially result from excessive



Posterior displacement of IFA

Average posterior tipping during arm elevation

Figure 3. The receiver operator characteristic curve analysis of (A) posterior displacement of inferior angle (IFA) and (B) average posterior tipping during arm elevation.

IFA distance (inferior angle prominence) with anterior soft tissue tightness, such as the pectoralis minor, which limits scapular movement. Our findings emphasize the importance of scapular position during shoulder evaluation. On the other hand, the optimal cutoff value of 3.3° of scapular posterior tipping may not be easily measured in a clinical setting or courtside. The use of a scapular assistance test to assist scapular posterior tipping during arm elevation may alleviate shoulder symptoms in a population with insufficient posterior tilt. It can be used as a clinical method to confirm posterior tipping movement.[30] A device that can measure posterior tilt in a clinical setting or courtside should be developed in the future.

The likelihood ratio statistics were used to express the importance of this model. When the participants meet the prediction rule criteria, a PLR expresses the change in odds favoring success.[29] In the current study, the probability of success was 95% if both variables were present, compared with only 78% for 1 variable. Therefore, almost all individuals with an IFA larger than 16.4 mm and scapular posterior tilt less than 3.3° will respond to the early conscious control program. For clinical implications, posterior displacement of the IFA measured by scapulometer and insufficient posterior tipping of the scapula confirmed by scapular assistance test should be considered as clinical factors before choosing conscious control of scapular orientation as an intervention program. However, the application of these results should be cautious due to limited variance explained by this model. Other potential factors should be found and investigated in a future study.

The limitations of the study should be mentioned. First, an immediate program of scapular conscious control may have limited effects on scapular kinematics, muscle activation, shoulder pain, and dysfunction. Many participants had shoulder symptoms only when they performed sports-specific movements, so we were unable to identify the effects of the control program on reducing pain and improving function immediately after the program. We used a 1-trial intervention first to confirm the appropriate direction of the intervention for improving muscle balance. The effect of a progressive conscious control program and the potential factors of improvement of scapular kinematics, muscle balance, shoulder pain, and dysfunction should be investigated in a long-term intervention and follow-up. Second, the regression model may have been influenced by the limited sample size. For this reason, we chose an appropriate number of variables for the model to avoid the effect.[26] Third, the scapular control program progressed only to 90° of arm elevation rather than to the functional range above 90°. The choice of 90° was due to the appropriate dosage for early intervention. Fourth, conscious control with and without video feedback may be a confounding factor. However, we found that the number of successes and failures were similar between participants with and without video feedback. Using this factor as a predictor, it was not a significant factor in the regression model. Finally, the participants were mostly young and participated in overhead sports, and they had sufficient cognition to comprehend how to control the scapula. The generalization of the findings of this study to elderly individuals is uncertain.

CONCLUSION

According to the final model, overhead athletes with subacromial pain and scapular medial border prominence who met 2 criteria (posterior displacement of IFA $\leq$16.4 mm, scapular posterior tipping during arm elevation $\leq$3.3°) at baseline demonstrated a 95% probability of success to improve the UT/SA ratio at 90° of the conscious control program of scapular orientation in our sample. Excessive posterior displacement of the IFA measured by scapulometer and insufficient posterior tipping of the scapula confirmed by scapular assistance test should be considered potential clinical factors before choosing conscious control of scapular orientation as an intervention program. The applications of our results should be cautious due to the limited variance of our model. Objective clinical tests to identify scapular posterior tipping should be further investigated.

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