The Effect of ASSET Rehabilitation Protocol on the Shoulder Kinematics after Rotator Cuff Tendons Repair

Nazanin Fatemeh Afshari [a], Farid Bahrpeyma [a], Mohammad Najafi Ashtiani [a]

[a] Department of Physiotherapy, TarbiatModares University, Tehran, Iran.

* ***Corresponding author***: Farid Bahrpeyma, Department of Physiotherapy, Tarbiat Modares University, Tehran Province, Tehran, Jalal Al Ahmad, Tehran, 111-14115, Iran. ***E-mail***: bahrpeyf@modares.ac.ir

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Abstract

Introduction: To examine how rehabilitation exercises following rotator cuff surgery using the ASSET protocol affect shoulder kinematics. **Material and Methods:** This pre-post quasi-experimental study involved 15 individuals aged 40 to 65 who had a degenerative rupture of the supraspinatus tendon. Each participant underwent tendon repair surgery and two stages of rehabilitation. The first stage consisted of passive treatment for six weeks of ASSET protocol, totaling 18 sessions. The second stage included active-assisted and active motions over four weeks, with 12 sessions. Shoulder kinematics, such as scapular upward rotation and glenohumeral elevation, were assessed using a motion analysis system, measuring parameters like range of motion (ROM), peak time, and raising velocity. Kinematic data were collected before and after the ASSET protocol at the sixth and tenth weeks post-surgery. A paired t-test or Wilcoxon signed-rank test was used to compare the kinematic indices before and after the intervention. **Results:** The results on glenohumeral elevation and shoulder elevation indicated employing ASSET rehabilitation protocol between the sixth and tenth week following rotator cuff tendon repair lead to a significant increase in the ROM in sagittal and scapular planes ($P<0.05$), but not for ROM on scapula upward rotation ($P=0.691$). The peak time of scapula upward rotation significantly decreased in both sagittal and scapular planes ($P=0.001$), while the raising velocity significantly increased in the scapular plane ($P=0.009$), but not in sagittal plane ($P=0.691$). There was a significant decrease in peak time and a significant increase in raising velocity in both planes on glenohumeral elevation and shoulder elevation ($P<0.05$). For the scapulo-humeral rhythm in scapula upward rotation movement, the results showed no significant change in sagittal and scapular planes ($P=0.061$). **Conclusion:** The study's results demonstrate that ASSET protocol can enhance shoulder function following rotator cuff repair surgery by striking a balance between increasing ROM and preserving muscle control.

Keywords: Rotator cuff tendon surgery; Shoulder kinematics; ASSET; Shoulder rehabilitation

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Introduction

Rupture of the rotator cuff tendons is a common cause of various shoulder joint movement disorders, significantly reducing people's performance in daily and work activities, as well as impacting recreational and professional sports activities. The prevalence of rotator cuff tears is reported to be 20.7% in people with an average age of 58 years (2 ,1). As age increases, this rate also rises; by the eighth decade of life, 51% of people will have an asymptomatic tear in the rotator cuff, and more than half of these tears will progress in size and become symptomatic within 3 years (3).

There are various methods for treating rotator cuff tendon tears, including non-surgical treatments, rehabilitation, and, if needed, tendon repair surgery. Proponents of surgical treatment believe that repairing the rotator cuff tendon, especially in the early stages of the disease, can eliminate the underlying issues and prevent tearing, tissue degeneration, biceps involvement, and glenohumeral joint degeneration (4)

After undergoing rotator cuff tendon surgery, rehabilitation is crucial for promoting recovery and preventing excessive loading, particularly in the initial stages post-surgery. The primary objective of shoulder surgery rehabilitation is to restore full and symmetrical passive and active range of motion (ROM) of the shoulder, establish equilibrium in the glenohumeral and scapulothoracic force couples, and attain pain-free shoulder function. Therapeutic exercise is recognized as the cornerstone of this treatment. It is important to note that rotator cuff injuries can disrupt the normal shoulder and scapulothoracic joint kinematics, as well as the function of the surrounding muscles (7-5). Therefore, the exercise program for these patients should aim to restore normal kinematics, enhance scapular stability, promote proper neuromuscular control of the shoulder girdle, and align thoracic posture correctly (6).Studies have indicated that assessing the effect of rehabilitation on shoulder injuries involves considering the scapular and shoulder movement kinematics as a parameter for evaluating the quality of shoulder complex movement. In fact, some studies have used this as an indicator in predicting shoulder musculoskeletal disorders (SMDs) (8). Additionally, restoring the normal and coordinated rhythm of scapular movement and normalizing the shoulder complex kinematics have been cited as crucial outcomes of SMDs treatment (9).

The American Society of Shoulder and Elbow Therapists (ASSET) protocol is the first consensus statement published by a multidisciplinary community of experts involved in rehabilitating patients after rotator cuff repair (10). It emphasizes the application of controlled, gradual loading to accelerate tissue repair and remodeling. Another key focus is on mobilizing the shoulder joint without putting too much stress on the repaired tissues. According to this statement, ASSET members recommend performing passive-assistive and limited ROM exercises in the first 6 weeks after rotator cuff surgery. After 6 weeks, active-assistive ROM exercises can be performed in a limited and controlled manner, and after that, active movements can gradually be started. Finally, 4-5 months after surgery, if the patient is in a suitable and acceptable condition, rehabilitation with the aim of returning to work and sports can be implemented (10).

It seems very necessary to deal with effective rehabilitation methods that can help the patient and treatment team in every part of this long and difficult process. Therefore, the aim of this study was to investigate the effect of performing rehabilitation exercises with the ASSET protocol after rotator cuff surgery on shoulder kinematic parameters.

Materials and methods

Participants

This pre-post quasi-experiment study included 15 individuals with a degenerative rupture of the supraspinatus tendon who underwent tendon repair surgery performed by the same surgeon using the single-row rotator cuff repair technique. The inclusion criteria were as follows: anincomplete degenerative tear of the supraspinatus tendon (medium or tear size 1-3 cm) as per the Cofield classification (3)diagnosed by MRI and clinical tests by a shoulder specialist following the AAOS guideline criteria (11), experiencing symptomatic tear for up to one year before surgery, having a pain intensity of 2 to 5 on the visual analog scale when initiating active movement, being able to perform the movement, ages 40 to 65, body mass index below 30, no history of professional exercises, and no glenohumeral joint arthritis, frozen shoulder, history of surgery in the affected shoulder, or lower limb, hip, and spine problems that would interfere with exercises. The exclusion criteria were re-rupture, patient non-cooperation, and inability to fully adhere to the exercise protocols.

Procedure

The participants were referred to the physiotherapist by a specialist doctor immediately after surgery. The study procedures were explained to them in order to obtain their informed consent, including the number and duration of sessions, type of assessment and intervention, potential risks, and the benefits of participating in the study. After that, they filled out a demographic information questionnaire.

All participants underwent two stages of treatment. The first stage involved passive treatment for the first 6 weeks of the ASSET rehabilitation protocol, totaling 18 sessions. After the first 6 weeks, the initial evaluation session took place, which included kinematic evaluation of the shoulder joint using a motion analysis system. Following this evaluation, participants entered the second stage of treatment for 4 weeks, consisting of 12 sessions. During this phase, participants received ASSET rehabilitation treatment involving active-assisted and active motions (10). Throughout the treatment sessions, participants performed exercises under direct supervision of a physiotherapist. At the end of the 4-week period, the second kinematic evaluation session, similar to the first session, was conducted.

ACESS protocol

The ACESS treatment protocol from week 1 to week 10 is outlined in Table 1. All exercises involved a maximum of 10 repetitions, based on the ASSET protocol, which focuses on performing exercises with low repetitions. The exercises progressed from passive to active-assisted to active, and from exercises on a horizontal surface to exercises on a sloped surface with increasing gravity. Additionally, the exercises transitioned from high support to less support. The design of these exercises in the ASSET protocol was based on observing specific restrictions related to EMG muscle activity levels of the repaired rotator cuff muscles and the allowable ROM proposed in the referenced studies on this protocol (10).

Table 1. Taught ASSET exercise during the study

Exercises	Permissible range of motion	Repetition
First phase, weeks 1 and 2		
Therapist-assisted forward elevation	60 to 90 degrees	10
CPM in forward elevation	60 to 90 degrees	10 minutes
Pendulum exercise in the anterior-posterior direction	-	10
Forward bow: Bending forward and hanging the upper limb and staying in this position for 30 seconds	-	3
Self-assisted forward elevation: Elevation of the operated upper limb by the healthy one by the patient in supine position	60 to 90 degrees	10
First phase, weeks 3 and 4		
Therapist-assisted forward elevation	90to 105 degrees	10
CPM in forward elevation	90to 105 degrees	10 minutes
Pendulum exercise in the anterior-posterior and lateral direction	-	10repetitions on each side
Forward bow	-	3
Self-assisted forward elevation	90to 105 degrees	10
Passive shoulder external/internal rotation with stick	Up to 20 degrees in both directions	10
First phase, week 5		
Therapist-assisted forward elevation	Up to 110 degrees	10
CPM in forward elevation	Up to 110 degrees	10 minutes
pendulum exercise in the anterior-posterior and lateral direction	-	10repetitions on each side
Forward bow	-	3
Self-assisted forward elevation	Up to 110 degrees	10
Passive shoulder external/internal rotation with stick	Up to 25 degrees in both directions	10
First phase, week 6		
Therapist-assisted forward elevation	120 degrees	10
CPM in forward elevation	120 degrees	10 minutes
Pendulum exercise in anterior, posterior, lateral and rotational directions	-	10repetitions on each side
Forward bow	-	3
Self-assisted forward elevation	120 degrees	10
Passive shoulder external/internal rotation with stick	Up to 30 degrees in both directions	10
Active-assistive ROM supine washcloth press-up	-	10
Second phase, week 7		
Therapist-assisted forward elevation	130 degrees	10
CPM in forward elevation	130 degrees	10 minutes
Towel slide or horizontal dusting	Up to 130 degrees of flexion	10
Active-assistive ROM supine washcloth press-up	-	10
Side lying supported active elevation	130 degrees	10
Second phase, week 8		
Therapist-assisted forward elevation	140 degrees	10
CPM in forward elevation	140 degrees	10 minutes
Incline dusting	140 degrees	10
Active ROM supine press-up	-	10
Sitting external rotation at 0°	40 degrees	10
Forward elevation with upright T-bar	140 degrees	10
Second phase, week 9		
Therapist-assisted forward elevation	155 degrees	10
CPM in forward elevation	155 degrees	10 minutes

Upright wall slide	155 degrees	10
Forward elevation with upright T-bar	155 degrees	10
Upright T-bar active-assistive ROM forward elevation, active lowering	155 degrees	10
Active ROM reclined wedge press-up	-	10
Side lying external rotation at 0°-20°	30 to 45 degrees	10
Second phase, week 10		
Therapist-assisted forward elevation	Up to the limit	10
CPM in forward elevation	Up to the limit	10 minutes
Upright T-bar active-assistive ROM forward elevation, active lowering	Up to the limit	10
Active ROM reclined wedge press-up	-	10
Side lying external rotation at 0°-20°	Up to the limit	10
Upright active forward elevation with no weight	-	10

Table 2. Demographic information of the participants

Variables		**Values**
Age (year), mean (SD)		57.9 (3.8)
Gender, n	**Male**	6
	Female	9
Height (m), mean (SD)		1.70 (0.10)
Weight (kg), mean (SD)		72.8 (11.5)
Body mass index (m/kg^2), mean (SD)		26.00 (2.6)

SD: standard deviation

Kinematic evaluation

The Vicon motion analysis system, which is made in England, recorded shoulder kinematic data using 8 cameras with a sampling frequency of 120 Hz. To determine joint centers and the amount and direction of shoulder girdle movements, retroreflective markers were used. Anatomical landmarks were marked according to the International Society of Biomechanics (ISB) method(12). However, the glenohumeral joint marker, which is not an anatomical landmark, was estimated indirectly through the regression method and used in the calculations(13). The markers were placed at specific locations including the glenohumeral joint (GH), angulus acromialis (AA), trigonum spinae (TS), angulus inferior (AI), acromioclavicular joint (AC), processus coracoideus (PC), medial and lateral epicondyles of the humerus (EM and EL), sternoclavicular joint (SC), incisura jugularis (IJ), processus xiphoideus (PX), and the spinous process of C7 and T8 vertebrae.

The analysis was based on the article by Forte *et al.* (14), and a MATLAB software package was used for the shoulder analysis. The required parameters were then extracted and recorded. The thorax segment, which includes the C7, T8, IJ, and PX markers, was used as a reference for shoulder movement. The shoulder joint's elevation movement in the sagittal (shoulder flexion) and scapular (shoulder scapular) planes was defined as the angle of the humerus segment with this segment. The humerus segment was defined by the EM, EL, and GH markers, and the scapula segment was defined by the AA, AC, AI, and TS markers.

The extracted parameters from Vicon include the following:

-Shoulder joint elevation angle in the sagittal plane (sum of glenohumeral and scapulothoracic joint movement): the angle of the humerus segment relative to the thorax segment.

-Glenohumeral elevation angle in the sagittal plane (movement of the glenohumeral joint alone): the angle of the humerus segment relative to the scapula segment in the sagittal plane.

-Shoulder joint elevation angle in the scapular plane (total movement of the glenohumeral and scapulothoracic joints): the angle of the humerus segment relative to the thoracic segment in the scapular plane.

-Glenohumeral elevation angle in the scapular plane (movement of the glenohumeral joint alone): the angle of the humerus segment relative to the scapula segment in the scapular plane.

-Upward/rotation angle of the scapula in the sagittal and scapular planes.

The variables involved in the kinematics of the shoulder joint include scapular upward rotation, glenohumeral elevation, and shoulder elevation in two planes: sagittal (in the shoulder flexion movement) and scapular (in the shoulder abduction movement). The kinematic data for these variables include maximum range of motion (primary outcome), peak time (secondary outcome), and raising velocity (secondary outcome). Additionally, the scapulohumeral rhythm of scapular upward rotation movement (secondary outcome) in both sagittal and scapular planes was derived from the kinematic data. Peak time refers to the time required to reach the maximum ROM during a movement, and raising velocity refers to the speed of raising the segments (scapula, glenohumeral, and shoulder) during a movement.

To evaluate the scapulohumeral rhythm, the elevation of the operated shoulder joint (arm elevation above the head) was considered in two planes: sagittal and scapular.

Table 3. Mean (standard deviation) along with pre-post p-value for outcome measures in movements of scapula, glenohumeral and shoulder in flexion and scapular planes

Variables		Pre-intervention		Post-intervention		Pre-post comparison (Sagittal)	Pre-post comparison (Scapular)
		Sagittal	**Scapular**	**Sagittal**	**Scapular**		
Peak time (s)	**Scapula upward rotation**	2.2 (0.2)	2.2 (0.20)	1.3 (0.4)	1.3 (0.5)	0.001*a	0.001*a
	Glenohumeral elevation	2.2 (0.2)	2.1 (0.2)	1.4 (0.6)	1.6 (0.5)	0.001*	0.006*
	Shoulder elevation	2.2 (0.2)	2.1 (0.2)	1.4 (0.6)	1.6 (0.5)	0.001*	0.005*
Maximum active ROM (degree)	**Scapula upward rotation**	12.7 (4.2)	14.1 (4.6)	14.6 (14.1)	16.8 (12.6)	0.691a	0.691a
	Glenohumeral elevation	50.0 (2.6)	42.3 (2.0)	63.5 (6.0)	59.7 (11.4)	0.001*a	0.001*a
	Shoulder elevation	74.11 (4.24)	51.0 (7.7)	78.05 (6.39)	83.0 (29.7)	0.001*a	0.001*a
Raising velocity (degree/s)	**Scapula upward rotation**	2.8 (0.6)	3.1 (0.8)	4.8 (5.0)	7.0 (.46)	0.691a	0.009*a
	Glenohumeral elevation	8.4 (1.9)	10.1 (0.8)	11.8 (2.8)	22.00 (10.6)	0.001*	0.001*a
	Shoulder elevation	18.39 (2.97)	12.1 (2.0)	19.97 (2.50)	31.5 (20.3)	0.001*	0.001*a
Scapulo-humeral rhythm	**Scapula upward rotation**	2.8 (0.3)	3.4 (0.3)	4.40 (2.70)	5.3 (2.5)	0.061a	0.061 a

**P<0.05, a: non-parametric Wilcoxon signed-rank test*

Statistical analysis

The data was analyzed using SPSS 21 software at a significance level of *P*<0.05. The Shapiro-Wilk test was used to check the normality of the data.To compare the kinematics indices before and after the intervention, then, a paired t-test was used for data with a normal distribution, and a Wilcoxon test was used for data without a normal distribution.

Results

The participants' demographic characteristics are summarized in Table 2. The results of paired t-test for the data with normal or non-normal distribution are presented in Table 3.

The results of the paired t-tests on scapula upward rotation indicated that employing the ASSET rehabilitation protocol between the sixth and tenth week following rotator cuff tendon repair did not lead to a significant improvement in the ROM in the sagittal (*P*=0.691) and scapular (*P*=0.691) planes. However, the peak time significantly decreased in both the sagittal and scapular planes (*P*=0.001). Additionally, the raising velocity significantly increased in the scapular plane (*P*<0.009), but not in the sagittal plane (*P*=0.691).

In terms of glenohumeral elevation, the ROM significantly increased after performing ASSET exercises in both the sagittal (*P*=0.001) and scapular (*P*=0.001) planes. The peak time and raising velocity variables also changed significantly in both planes (*P*<0.05).

Regarding shoulder elevation, the ROM significantly increased after performing ASSET exercises in both the sagittal and scapular planes (*P*<0.05). Furthermore, there was a significant decrease in peak time and a significant increase in raising velocity in both planes (*P*<0.05).

Finally, for the scapulo-humeral rhythm in scapula upward rotation movement, the results showed no significant change in the sagittal and scapular planes *(P*=0.061).

Discussion

Scapula upward rotation

The use of the ASSET rehabilitation protocol between the sixth and tenth week following rotator cuff tendon repair did not result in a significant improvement in the ROM of scapular upward rotation in the sagittal and scapular planes. This lack of change may be attributed to the timing of the ASSET protocol application. Since the protocol was initiated between the sixth and tenth week after the surgery, it is possible that the process of complete tissue regeneration and enhancement of neuromuscular control had not progressed enough to produce significant changes in this aspect.

After completing the ASSET protocol exercises in the present study, two secondary variables showed significant changes. The peak time in both the sagittal and scapular planes decreased, while the raising velocity in scapular plane increased. The reduction in peak time may be attributed to the improvement of the shoulder and scapula stabilizing muscles as a result of the exercises and the recovery process post-surgery, which enhances movement efficiency. Additionally, the increased raising velocity suggests that the skeletal-muscular system is working to enhance the efficiency and control of scapula movement in response to rehabilitation exercises.

Glenohumeral Elevation

After performing ASSET exercises, the ROM of glenohumeral elevation significantly increased in both sagittal and scapular planes. The increase in ROM after surgery indicates a gradual recovery of normal function of the glenohumeral joint and improvement in the coordination between the muscles around the shoulder. This improvement is likely due to increased joint capsule flexibility, decreased tissue adhesions, and improved neuromuscular control (15). A systematic review study by Melo *et al.* demonstrated that rehabilitation programs based on therapeutic exercises can lead to an increase in glenohumeral joint ROM in patients after shoulder surgeries (16).

The peak time and raising velocity variableschanged significantly in the sagittaland scapular planes after performing the ASSET exercises. The increase in glenohumeral elevation velocity suggests an improvement in shoulder motor function and neuromuscular control following surgery. It is an important finding as it indicates progress in the initial stages of rehabilitation, where the primary goal is to restore ROM and muscle control in the glenohumeral joint. On the other hand, research by Lee *et al.* suggests that increasing raising velocity in the early stages of rehabilitation might be risky and could put added stress on the healing tendons. This highlights the significance of controlled and gradual rehabilitation regimens that seek to avoid an excessive load on the healing structures(17). Therefore, it can be concluded that while increased raising velocity in glenohumeral elevation might signal improved performance, it is crucial to apply it cautiously and under the guidance of kinesiology and physiotherapy experts to prevent further injuries.Overall, the ASSET protocol seems to strike a good balance between increased velocity and motor control, which can be beneficial for patients after rotator cuff surgery.

Shoulder elevation

The results indicated that ROM for shoulder elevation significantly increased after performing ASSET exercises in both sagittal and scapular planes. An important factor in increasing shoulder ROM is the improvement in coordination between the rotator cuff muscles and the scapulothoracic muscles, which are crucial in stabilizing and moving the shoulder joint. Specifically, the rotator cuff muscles stabilize the humeral head in the glenoid cavity, while the scapulothoracic muscles, such as the trapezius and serratus anterior, are involved in the movement of the scapula. Enhancing the strength and endurance of these muscles leads to increased ROM and reduced restrictions (18). Similar studies have also reported increased shoulder ROM after using rehabilitation protocols focusing on strengthening shoulder stabilizer muscles. For instance, Zhang *et al.* demonstrated that exercises concentrating on strengthening the scapulothoracic and glenohumeral muscles significantly improved shoulder ROM (15). Conversely, some studies highlight that rapid increases in ROM may be associated with the risk of re-injury of repaired tendons. A review study by Ladermann *et al.* illustrated that rehabilitation protocols emphasizing a rapid increase in ROM can lead to increased stress on regenerated tendons. These studies underscore the importance of employing a gradual and controlled approach to increasing shoulder ROM (19). In the exercises and their progression in the ASSET protocol, this issue is particularly crucial.

After doing ASSET exercises, there was a significant decrease in the peak time variable and a significant increase in raising velocity for shoulder elevation in both the sagittal and scapular planes. These changes suggest improved coordination and muscle control between the scapula and humerus as a result of the rehabilitation exercises aiming to enhance the control of scapulothoracic and glenohumeral movements. This finding aligns with Piitulainen *et al.*'s study, which indicated that improved scapulohumeral coordination can enhance shoulder movement efficiency and velocity(20).

Scapulohumeral rhythm

The study's results indicated no significant difference in the scapulohumeral rhythm in the sagittal andscapular planes. In this regard, no similar study was found that investigated the scapulohumeral rhythm after rotator cuff tendon repair surgery.The scapulohumeral rhythm in reverse shoulder arthroplasty (1.3:1) was significantly lower than in normal shoulders (3:1), as shown in Walker *et al.* (21). In the study by Reina *et al.*, the contribution of scapular motion in reverse shoulder arthroplasty was greater than in the healthy shoulder, unlike the findings in the present study (22). These differences could be due to several potential reasons, including kinematic differences between joint replacement surgery and rotator cuff repair, conducting our study within the first 4 weeks of initiating active shoulder movements, and differences in the evaluation methods for checking the rhythm.

Limitation and suggestions

The present study had certain limitations and suggested areas for improvement:

1) The sample size was limited, consisting of individuals who had undergone rotator cuff repair surgery and followed a specific exercise protocol (ASSET). This could restrict the generalizability of the results to broader populations. In future studies, including a more diverse range of participants in terms of demographic characteristics and clinical conditions could enhance the applicability of the results.

2) Shoulder kinematics were evaluated at two time points: the sixth week and the tenth week after surgery. This duration may not have been sufficient to observe all the kinematic changes associated with the repair and rehabilitation processes. Longer follow-up periods in future studies could yield a more comprehensive understanding of changes in shoulder kinematic variables after rotator cuff surgery.
3) Shoulder EMG was not evaluated. Including EMG analysis as a complementary tool alongside kinematic analysis could provide a better understanding of muscle dynamics and biomechanical changes after surgery and during the rehabilitation period.

Conclusion

The study's findings indicate that the ASSET protocol can enhance shoulder function following rotator cuff repair surgery by striking a balance between increasing ROM and preserving muscle control. It is crucial to emphasize the need for careful monitoring and control during the rehabilitation process to minimize the risk of injuries.

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Ethical considerations
The study was approved by ethic committee of Tarbiat Modares University (IR.MODARES.REC.1402.037) and all participants signed the written consent form for the study.

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Authors' contributions
All authors contributed equally to the preparation of this manuscript.

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