Article

The Effect of Early Scapular Training on Shoulder Joint Function after Surgery for Rotator Cuff Injuries: A Retrospective Study

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AIM: This study aims to evaluate the impact of early scapular rehabilitation training in patients after rotator cuff injury. Furthermore, it sought to analyze the application of this approach in promoting surgical site healing and enhancing shoulder joint function recovery.
METHODS: This retrospective study obtained the clinical data from 74 patients who underwent rotator cuff repair between July 2022 and June 2024. Patients were divided into two experimental groups: the control group (n = 35), including those who underwent routine rehabilitation exercises after rotator cuff repair, and the exposed group (n = 39), who received scapular training exercises. The patients were followed up and examined at 8 weeks and 16 weeks after surgery. The range of motion (adduction and abduction), shoulder muscle strength (adduction and abduction), Visual Analogue Scale (VAS) scores, and the University of California-Los Angeles (UCLA) shoulder scales were compared between the two groups before rotator cuff repair.
RESULTS: We observed that after 8 weeks of treatment-post-surgery, both the groups showed significant improvement in the range of motion (adduction and abduction) and the muscle strength (adduction and abduction) within the shoulder joint compared with those observed before treatment ($p < 0.05$). After 16 weeks of treatment, the range of motion (adduction and abduction) and shoulder muscle strength (adduction and abduction) further improved compared to those observed after 8 weeks of treatment ($p < 0.05$). After 8 weeks and 16 weeks of treatment, the University of California shoulder joint scores in both groups were significantly better compared to those before treatment ($p < 0.05$), and the VAS score significantly decreased ($p < 0.05$), with the effects after 16 weeks of treatment being better than those observed after 8 weeks ($p < 0.05$). Additionally, there was no difference in the overall incidence of complications between the two groups ($p > 0.05$).
CONCLUSIONS: Early scapular training, following rotator cuff injury, is beneficial in functional recovery of shoulder joint function, which improves rehabilitation outcomes and ultimately promotes patient prognosis.

Keywords: scapula training; arthroscopic rotator cuff repair; early functional training; shoulder function

Introduction

The rotator cuff is a complex of joint capsule and tendon tissue surrounding the shoulder joint, consisting of four muscles. Its primary functions include stabilizing the glenoid joint, maintaining shoulder joint mobility, and supporting daily activities. Rotator cuff injuries are among the most common causes of shoulder pain, affecting a significant portion of patients, with incidence increasing with age from 4% in young adults to 32% in older individuals [1, 2]. The early clinical manifestations of rotator cuff injury typically involve anterolateral shoulder pain at rest or during the night, along with limited abduction and lifting of the upper limb, muscle atrophy around the shoulder joint, and potential complications include impaired shoulder joint functions (such as flexion, extension, rotation), axillary nerve damage, muscle weakness, and muscle atrophy; these complications can significantly affect the patient's daily life, leading to sleep abnormalities and mood disorders due to associated pain [3, 4].

Research shows that rotator cuff injury primarily arises from the impingement theory [5] and the degeneration and trauma hypothesis [6]. The impingement theory is more commonly linked to acute injuries, where the tendon cuff is compressed against the coracoacromial arch during shoulder joint abduction in strenuous exercise, resulting in congestion, edema, degeneration, and ultimately tendon rupture [7]. On the other hand, the degeneration and trauma theory are based on age-related changes, as rotator cuff tissues in older individuals often develop degenerative lesions, with various factors contributing to degeneration or chronic tearing [8]. However, in young patients with acute rotator cuff injuries or in older patients with mobility needs, conservative management may provide limited relief from severe pain and functional impairments. In cases of prolonged and severe symptoms, surgery may be necessary.

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Arthroscopic rotator cuff repair surgery has become a common approach for treating rotator cuff injuries; and this non-invasive surgery, involving small incisions, helps reduce pain and improve recovery [9, 10]. In the early postoperative stage, patients generally need to wear an arm sling for 2 to 6 weeks. During this period, muscle atrophy, scarring, joint adhesions, and limited activities may occur. Weakness in the muscles of the joint often leads to compensation by other muscles, causing abnormal scapula movement, which can interfere with the establishment of the correct shoulder joint movement pattern, so early rehabilitation exercises are needed after arthroscopic rotator cuff injury [11]. The scapula is crucial in supporting the weight of the arm and allowing flexible and coordinated arm movement function. Maintaining scapula stability is crucial to ensure the normal range of motion of the shoulder strap joint. Early scapular training helps position the shoulder strap joint correctly and stably, ensuring effective transmission of the body's motion chain.

Despite significant advancements in surgical methods, the incidence of joint stiffness after rotator cuff repair is between 4.9% and 32.7% [12]. The healing process of rotator cuff injuries includes three histological stages: the inflammatory phase (1 week), the proliferative period (2–3 weeks), the and maturity or refactoring phase (12–26 weeks) [13]. In addition to postoperative recovery, successful surgery must be balanced against the risk of concurrent joint stiffness and repair failure. Finding the most appropriate post-operative rehabilitation method can be challenging throughout the recovery. Given this context, we evaluated the effect of early scapular rehabilitation training for patients after rotator cuff injury, aiming to examine its potential benefits. This approach aims to enhance healing at the surgical site, restore shoulder function, and eliminate the adverse effects of trauma and surgery.

Methods

Study Subjects

The clinical data for this retrospective study were obtained from 74 patients who underwent rotator cuff repair between July 2022 and June 2024. Patients were divided into two groups: the control group (n = 35) underwent routine rehabilitation, and the exposure group (n = 39) received scapular training and exercise for 16 weeks. This study was approved by the Yantaishan Hospital Ethics Committee (approval No. 2024126) and followed the Declaration of Helsinki and institutional guidelines. All patients and their families provided written informed consent.

Inclusion criteria for study participants were set as follows: (1) Patients with unilateral rotator cuff injuries confirmed by X-ray and Magnetic Resonance Imaging (MRI); (2) Those with rotator cuff injuries classified as partial-thickness and full-thickness cut; (3) Patients with Neer's pathological stages of rotator cuff injury from stage I to III [14]; (4) Patients who undergone arthroscopic rotator cuff repair. However, patients with secondary scapular dysfunction, shoulder joint mobility disorder due to central nervous system or peripheral nerve injury, multiple or concurrent upper limb fractures, and cognitive impairments were excluded.

Treatment Approaches

Surgical Intervention

All patients in this study received rotator cuff repair conducted by the chief physician. The procedures were minimally invasive and performed entirely under arthroscopy, allowing for the accurate identification of the rotator cuff position and release of the surrounding soft tissues, as well as precise suturing of the tendon [15]. Rehabilitation training was started within 24 hours after surgery, and patients were instructed to wear an external shoulder rotation brace (B5, Orthopaedic Rehabilitation Equipment Co; Model: DPA-7-6). After the procedure, the shoulder joint was positioned in an abduction resting position, maintaining an abduction angle of 30° to 45°.

Treatment Regimen for the Control Group

Routine rehabilitation training after rotator cuff repair was performed following the principle of gradual enhancement. The critical exercises included were as follows:

(1) Early muscle strengthening exercises focused on hand grasping and stretching; however, pronation and supination movements were conducted for the forearm. (2) Early range of motion exercises involved a gradual increase in shoulder range of motion, aiming for 45° external rotation 45° internal rotation, and 110° forward flexion. These exercises were performed to improve scapular and distal muscle strength and mobility. (3) In pendulum exercises, the patient was instructed to lean forward, allowing their arms to hang, then carefully swing the arms back and forth, left, and right, and in circles clockwise and counterclockwise. This movement was ensured to be passive, with the torso initiating a small arc of motion in the shoulder across different planes. (4) During the wall climbing exercise, the patients were directed to stand facing a wall, using their fingers on the affected side to climb the wall step by step. They were advised to perform 10 to 20 rounds each time.

The routine training was conducted 4 times a day for 16 weeks.

Exposome Treatment Regimens

Early scapula-specific rehabilitation training was divided into 4 stages: passive training stage (0–4 weeks), muscle strengthening training (4–6 weeks), scapular stability training (6–12 weeks), and intensive training (after 12 weeks).

Passive training stage (0–4 weeks): This training phase included passive forward bending and passive external rotation exercises. In the farmer training stage, the patients were positioned supine, and the affected arm was abducted at 30°–45°. The forearm of the affected side was grasped by the unaffected hand, passively helping to elevate the affected limb. Range of motion exercises were performed 3–5 times a day, ensuring to avoid pain during the training. However, during the passive external rotation exercises, the affected arm was abducted at 30°–45° with a towel roll placed under the upper arm to keep the humeral head level with the scapula. A treatment stick horizontally was held in the unaffected hand to assist gently rotate the affected shoulder externally.

Shoulder blades muscle strengthening training (4–6 weeks): This training included freehand scapula resistance exercises, isometric contraction of rotator cuff muscles, and isometric contraction exercises for deltoid muscles. During freehand scapula resistance training, in a lateral decubitus position with the healthy side down, the rehabilitation therapist assists the patient in performing scapula extension, retraction, elevation, and depression exercises. As the training progressed, gentle resistance was applied with bare hands to improve scapular activities through resistance exercise. Furthermore, in the isometric contraction of rotator cuff muscles, the patients were positioned supine, with the shoulder joint abducted at 30°–45°, and a pillow or folded towel was placed under the distal upper arm. Gentle resistance was applied to the forearm in all directions, allowing the patient to perform rhythmic stability exercises against freehand resistance, inducing mild isometric contraction of rotator cuff muscles. However, in isometric contraction exercises for deltoid muscles, the patient was examined in a standing position. A towel roll was placed between the elbow and torso (under the armpit) to maintain a gentle abduction (modified neutral position). The elbow was flexed at 90°, and the side of the shoulder was pressed against the wall. The patient resisted the wall to perform isometric contraction targeting the deltoid and rotator cuff muscle.

Scapular stability training (6–12 weeks): This session included elbow flexion, shoulder extension, and scapulothoracic exercises. In the former training phase, the upper arm was used as the axis of rotation, and the forearm was moved in adduction and abduction along a horizontal position as much as possible. This training was performed 12–36 repetitions per session, 3–5 times daily. However, during scapulothoracic exercises, shoulder sinking and scapular retraction movements were focused. Tool-assisted active exercises were performed to assist in the external rotation of the affected shoulder.

Intensive training (after 12 weeks): Dumbbell exercises and posterior joint capsule stretching were conducted in this training. In the dumbbell exercises, 2–3 kg dumbbells were held in the affected arm to perform shoulder abduction and lifting training, which could be done to the rhythm of music. Each session consisted of 8 segments per set, performed 2 times a day. However, during posterior joint capsule stretching, the patient in the lateral decubitus position with the shoulder flexed at 90°, and the unaffected hand grasped and stabilized the affected arm. The posterior joint capsule was stretched using body weight, gradually increasing the intensity while avoiding severe pain.

These training programs were developed by the rehabilitation physician and therapist under the guidance of the rehabilitation team. The exercises described above followed the different stages of rehabilitation, 4 times a day over 16 weeks.

Physical Factor Therapy

Both experimental groups underwent a physical factor treatment protocol, including the following therapies: (1) Cold therapy: An ice-water mixture placed in a water bag and applied to the shoulder joint for 5–20 minutes, 4 times a week post-surgery. (2) Ultrasound therapy (4 weeks after surgery): Continuous ultrasound was performed using the Ultrasound Pulse Conductivity Therapy Instrument LH-6000B (Desktop). The parameters were adjusted to 0.76–1.5 W/cm^2 for 30 minutes per session, 1 time/day, for 2 weeks. (3) Medium-frequency electrotherapy (started 4 weeks after surgery): The Benao Computerized Medium-Frequency Therapy Device (BA2008-III) was used to place electrodes on the affected shoulder site. Muscle contraction was induced for 0.3 h per session, once a day.

Precautions and Treatment Contraindications

In addition to rehabilitation training, patients were instructed to wear a brace to maintain the shoulder in an abduction resting position for immobilization. Active movement of the operated shoulder was forbidden. During training, patients were directed to avoid exceeding the range of motion prescribed by physicians and rehabilitation therapists.

Data Collection

The range of motion for shoulder adduction, abduction, and muscle strength around the shoulder joint was evaluated and compared utilizing the Visual Analogue Scale (VAS) and the University of California-Los Angeles (UCLA) shoulder scale before surgery, as well as 8 weeks and 16 weeks after surgery.

Shoulder Adduction and Abduction Range of Motion

For assessing the shoulder range of motion, a universal goniometer was used. While determining forward flexion and extension in a seated or standing patient, the axis of the goniometer was placed on the acromion of the lateral surface of the humerus. The fixed arm was aligned with the body (midaxillary line), while the movable arm was balanced with the humeral shaft. For abduction, the axis was placed at the posterior acromion, with the fixed arm being parallel to the body (spine) and the movable arm aligned with the humeral shaft. The above assessments and tests were performed by the same person during the follow-up

Table 1. Comparison of baseline data between the two groups ($\bar{x} \pm s$)/(n, %).

	Control group (n = 35)	Exposure group (n = 39)	χ^2/t	p-value
Age (years)	59.05 ± 7.28	59.46 ± 7.27	0.242	0.809
Sex			0.025	0.873
Male	20 (57.14)	23 (58.97)		
Female	15 (42.86)	16 (41.03)		
BMI (kg/m^2)	21.60 ± 1.59	21.28 ± 1.60	0.854	0.396
Duration of the disease (months)	21.97 ± 2.16	22.76 ± 2.22	–1.559	0.123
Extent of injury			0.103	0.748
Partial layer damage	28 (80.00)	30 (76.92)		
Full-thickness injury	7 (20.00)	9 (23.08)		
Neer somatotype			0.106	0.948
Stage I	11 (31.43)	12 (30.77)		
Stage II	7 (20.00)	9 (23.08)		
Stage III	17 (48.57)	18 (46.15)		
ASA surgical classification			0.434	0.804
Stage II	17 (48.57)	16 (41.03)		
Stage III	12 (34.29)	15 (38.46)		
Stage IV	6 (17.14)	8 (20.51)		
Combined disease			0.054	0.815
Yes	17 (48.57)	20 (51.28)		
No	18 (51.43)	19 (48.72)		

Note: Combined diseases refer to chronic diseases such as hypertension, coronary heart disease and diabetes. BMI, Body Mass Index; ASA, American Society of Anesthesiologists.

period. In the neutral position, the shoulder's horizontal adduction angle was 0–135º, and the abduction angle was 0–180º [16].

Assessment of Muscle Strength around the Shoulder Joint

The patient sat in a chair with their feet flat on the floor, arms hanging naturally at their sides. The assessor stood beside the patient, supporting the upper arm, and patients were instructed to lift the upper arm forward, adduct, abduct, and then slowly lower it. Muscle strength was assessed based on the American College of Physicians criteria, which evaluated the muscle's ability to resist gravity and external forces. Muscle grading criteria were as follows: Grade 0, no muscle contraction; Grade 1, slight muscle contractions; Grade 2, which can resist gravity but not external forces; Grade 3, which can resist particular external forces but cannot maintain posture; Grade 4, which can resist moderate external forces but not maximum external forces; Grade 5, which can resist maximum external force [17].

Visual Analogue Scale (VAS)

The VAS is a simple and widely used tool in clinical pain assessment. It effectively reflects changes in a patient's pain over time and is a well-recognized scale for assessing pain levels. This scale ranges from 0 to 10, with 0 indicating no pain and 10 representing severe pain. During this assessment, the patients were allowed to mark their pain level on a line corresponding to a score from 0 to10 points depending on their current pain experience. Higher scores indicated more severe pain. This scale is subjective, and its reliability, determined by Cronbach's α, was 0.768 [18].

The University of California-Los Angeles (UCLA) Shoulder Scale

The final test score for rotator cuff injury repair was based on a total of 35 points, classified as follows: 10 points for pain, 10 points for function, 5 points for active forward flexion range of motion, 5 points for forward flexion strength test, and 5 points for patient satisfaction. The evaluation was divided into 3 levels: excellent (34–35), good (29–33), and poor (<29). Pain, functional activity, and satisfaction were subjectively evaluated by the patient, while forward flexion range of motion and muscle strength were objectively rated by physician's physical examination. The Cronbach's α ranged from 0.85 to 0.95 [19].

Postoperative Complications

The occurrence of postoperative complications in both groups, including axillary nerve injury, joint stiffness, adhesive capsulitis, and rotator cuff tear, was recorded, and the complication rate was calculated for each group.

Statistical Analysis

Statistical analysis was performed using IBM SPSS (IBM Corp., Armonk, NY, USA, version 27.0) statistical software. The data were analyzed using the D'Agostino Pear-

Table 2. Comparison of shoulder range of motion and muscle strength between the two groups ($\bar{x} \pm s$).

Measurements	Duration	Control group (n = 35)	Exposure group (n = 39)	$t^{\#}$	p-value
Shoulder adduction (°)	Before surgery	42.17 ± 3.79	42.56 ± 4.36	–0.411	0.683
	8 weeks post-surgery	55.00 ± 4.64^{a}	66.41 ± 9.21^{a}	6.608	<0.001
	16 weeks post-surgery	89.02 ± 5.81^{ab}	111.51 ± 3.08^{ab}	20.068	<0.001
F		881.767	1264.017		
p		<0.001	<0.001		
Shoulder joint abduction (°)	Before surgery	42.40 ± 3.74	42.58 ± 3.88	0.214	0.832
	8 weeks post-surgery	54.40 ± 3.71^{a}	71.87 ± 6.25^{a}	14.401	<0.001
	16 weeks post-surgery	97.77 ± 10.81^{ab}	113.64 ± 4.28^{ab}	8.458	<0.001
F		615.563	2054.888		
p		<0.001	<0.001		
Shoulder adductor strength (grade)	Before surgery	1.60 ± 0.49	1.51 ± 0.50	0.746	0.458
	8 weeks post-surgery	1.85 ± 0.64^{a}	2.56 ± 0.50^{a}	5.273	<0.001
	16 weeks post-surgery	2.85 ± 0.87^{ab}	3.87 ± 0.76^{ab}	5.302	<0.001
F		32.151	197.063		
p		<0.001	<0.001		
Shoulder abductor strength (grade)	Before surgery	1.57 ± 0.50	1.51 ± 0.50	0.499	0.619
	8 weeks post-surgery	2.34 ± 0.68^{a}	2.69 ± 0.52^{a}	2.488	0.014
	16 weeks post-surgery	2.40 ± 0.60^{ab}	3.89 ± 0.71^{ab}	9.648	<0.001
F		23.098	215.640		
p		<0.001	<0.001		

Note: $^{\#}$ t means Waller Duncan t-test. a, $p < 0.05$, compared to before surgery; b, $p < 0.05$, compared to 8 weeks post-surgery.

son normality test and the homogeneity of variance test. Continuous quantitative data following a normal distribution were expressed as Mean ± SD, and the qualitative data were expressed as percentages (n, %). Based on the characteristics of the data, within-group comparisons were performed utilizing paired samples t-tests, analysis of variance (ANOVA) used one-way ANOVA and post hoc test applied Waller Duncan t-tests in multivariate analysis of variance (MANOVA). The significance level of 0.05 was adjusted for all analyses, corresponding to a 95% confidence interval.

Results

Comparison of Baseline Data between the Two Groups

There were no significant differences regarding the mean age, gender distribution, Body Mass Index (BMI), duration of the disease, severity of the injury, and pathological stage of Neer rotator cuff injury between the two groups, indicating that the study groups were matched correctly ($p > 0.05$, Table 1).

Evaluation of Shoulder Range of Motion and Muscle Strength

There were no significant differences in range of motion and muscle strength between the two groups ($p > 0.05$). However, after 8 weeks of postoperative treatment, both groups exhibited substantial improvement in the shoulder range of motion (adduction and abduction) and muscle strength (adduction and abduction) compared to pretreatment levels ($p < 0.05$). Furthermore, after 16 weeks of treatment, the range of motion (adduction and abduction) and muscle strength (adduction and abduction) of the shoulder joint demonstrated significant improvement compared to those after 8 weeks of treatment ($p < 0.05$). A comparison of shoulder range of motion and muscle strength is shown in Table 2.

Comparison of VAS and UCLA Shoulder Scale

After 8 weeks and 16 weeks of treatment, the University of California shoulder joint scores in both groups were significantly better than those before treatment ($p < 0.05$), the VAS score significantly decreased ($p < 0.05$). Furthermore, the effects after 16 weeks of treatment were better than those observed after 8 weeks ($p < 0.05$). The detailed results are shown in Table 3.

Occurrence of Complications between the Two Groups

After 16 weeks of treatment, the complication rate in the exposure group was lower than in the control group, with adhesive capsulitis being the typical complication in the control group (Table 4). However, the comparison between the two groups did not show statistically significant results ($p > 0.05$).

Table 3. Comparison of VAS and the University of California shoulder scores ($\bar{x} \pm s$).

Measurements	Duration	Control group (n = 35)	Exposure group (n = 39)	$t^{\#}$	p-value
VAS score	Before surgery	4.91 ± 0.81	5.00 ± 0.68	0.489	0.626
	8 weeks post-surgery	4.22 ± 0.42^{a}	2.92 ± 0.73^{a}	9.166	<0.001
	16 weeks post-surgery	2.28 ± 0.51^{ab}	1.23 ± 0.58^{ab}	8.184	<0.001
F		150.500	107.373		
p		<0.001	<0.001		
UCLA shoulder scale	Before surgery	23.14 ± 2.35	22.92 ± 2.41	0.396	0.693
	8 weeks post-surgery	25.00 ± 2.33^{a}	29.20 ± 2.40^{a}	7.603	<0.001
	16 weeks post-surgery	29.05 ± 2.72^{ab}	32.38 ± 1.13^{ab}	–6.988	<0.001
F		66.2302	240.115		
p		<0.001	<0.001		

Note: VAS, Visual Analogue Scale; UCLA, The University of California-Los Angeles. # t means Waller Duncan t-test. a, $p < 0.05$, compared to before surgery; b, $p < 0.05$, compared to 8 weeks post-surgery.

Table 4. Incidence of complications between the two groups (n, %).

	Axillary nerve injury	Joint stiffness	Adhesive capsulitis	Rotator cuff tear	Total incidence
Control group (n = 35)	1 (2.86)	1 (2.86)	2 (5.71)	1 (2.86)	5 (14.29)
Exposure group (n = 39)	1 (2.56)	1 (2.56)	0 (0.00)	1 (2.56)	3 (7.69)
χ^2					0.288
p					0.591

Discussion

Arthroscopic rotator cuff repair is crucial for radical rotator cuff tears in young patients with acute injuries, elderly patients with mobility challenges, and patients with severe pain and functional limitations that do not respond to conservative treatment [20]. This procedure involves eliminating damaged rotator cuff tissue and fixing the relatively healthy tissue to its appropriate insertion point [21]. However, after surgery, patients commonly suffer from functional disorders such as joint stiffness and muscle atrophy. Early scapular rehabilitation can reduce pain, maintain and increase joint mobility, enhance muscle strength, and improve daily living capabilities and overall quality of life.

The primary aim of this study is to evaluate the effect of early scapular rehabilitation on functional recovery after rotator cuff repair. Usually, rehabilitation focuses only on the shoulder joint itself, often neglecting the importance of the scapula. The scapula plays a vital role in shoulder joint function and glenohumeral stability. Research indicates that 68% to 100% of patients with shoulder injuries indicate changes in scapular position and movement [22]. Therefore, we explored whether scapular movement, strengthening training of the periscapular muscles, and scapular stability training can significantly alleviate shoulder pain associated with rotator cuff injuries and prevent postoperative complications.

The scapula is located at the back of the thoracic cage and is central to the skeletal system of the upper extremity, and the ability to control the scapula is essential for the proper functioning and athletic stability of the shoulder joint [23]. This stability plays a crucial role in the power transfer, range of motion, and precision of movement in the upper extremities. Through active and passive activities, as well as stability and resistance training for the scapula, the patient can experience relief from shoulder pain, establish an accurate scapulohumeral rhythm, and create a solid foundation for subsequent rehabilitation efforts.

Researchers recommend isometric strength training for patients with calcific rotator cuff tendonitis after shoulder injury surgery and resistance training starting 6 weeks postoperatively [24]. Additionally, several studies advocate for scapulohumeral strength training, especially focusing on rotator cuff muscle, which can improve glenohumeral stability, increase shoulder range of motion, and enhance the overall efficacy of treatment [25, 26].

Our study reveals that, after 8 weeks of treatment, there were substantial improvements in shoulder range of motion (adduction and abduction) and shoulder muscle strength (adduction and abduction) compared to those before treatment. However, after 16 weeks of treatment, patients showed further improvement in shoulder range of motion (adduction and abduction) and shoulder muscle strength (adduction and abduction) compared to the 8-week treatment level. Restoring range of motion suggests a recovery in muscle strength, neuromuscular control, pain arc, and overall functional capacity, and early passive range of motion exercises are believed to reduce postoperative stiffness and improve function [27]. After 8 weeks of treatment, there was significant improvement in shoulder muscle strength (adduction and abduction). The aim of muscle strength training is not only to increase muscle fibers but to help muscles adapt to changes, thereby enhancing muscle strength. It is necessary to incorporate resistance exercises that can bear larger weights and engage in closed-chain exercises [28]. During the first 8 weeks of treatment, resistance exercises were avoided to prevent shoulder tears and complications. Additionally, human muscle fibers are usually classified based on myosin heavy chain (MHC) subtypes, characterized by a range of contraction speeds from slow to fast. The muscle strength evaluation usually follows grading criteria from 0 to 5, making it difficult to detect subtle improvements in muscle strength due to difficulty in applying accurate data capture for approximate grading [29]. However, the follow-up findings at 16 weeks indicated significant improvement in the range of motion and muscle strength. The underlying reason for this improvement seems to be the application of scapula stability exercises, including stretching and strengthening. These trainings emphasize proper scapular positioning and kinematics, facilitating energy transfer and serving as a base for muscle activation in the power chain. Our findings align with the outcomes from Tang *et al.* [30], which similarly indicate that targeted scapula stability movement can improve shoulder function and correct shoulder movement disorders.

After 8 and 16 weeks of treatment, the VAS scores and the University of California shoulder scores were significantly improved in both study groups compared to their pre-treatment levels. Importantly, the effect after 16 weeks of treatment was better than those observed after 8 weeks. During postoperative rehabilitation, it is essential to protect the repair site, promote tendon-to-bone healing, and minimize the gap at the tendon margins [31]. However, individual pain tolerance varies, and even mild pain can affect recovery time after surgery; therefore, a lower pain response can be helpful for the recovery process [32]. After 16 weeks of treatment, the incidence of complications in the exposed group was lower than in the control group. Early intervention with scapular rehabilitation appeared to prevent the occurrence of joint stiffness and misuse syndrome, while ideal exercises for shoulder rehabilitation enhanced the activation of the trapezius muscle and reduced complication rates. Maintaining continuous communication with the surgical team during rehabilitation after rotator cuff repair is essential. Understanding the management of complications, the healing potential of repaired tendons, and the anatomy of the shoulder complex is crucial. In the initial stages, the primary focus should be reducing pain and inflammation, followed by gradually returning to a range of motion. As the range of motion improves, progression from passive to active assisted and then to active movements allows for the gradual introduction of pressure to the healing structures. Early scapular rehabilitation and intervention can prevent joint stiffness and misuse syndrome. The optimal exercises for shoulder rehabilitation can enhance the activation of the trapezius muscle and reduce complications.

It is noteworthy to acknowledge the limitations in this study, such as the single center source and the relatively small number of cases, which may limit the generalizability of the findings. Additionally, the study did not investigate the long-term postoperative outcomes for the patients. Future studies should address these limitations and explore the long-term effects of different rehabilitation training methods on patients.

Conclusions

In summary, during the rehabilitation process after rotator cuff repair, it is crucial first to analyze the primary causes of shoulder joint disease and then develop a targeted scapular training program based on the causes. Moreover, a comprehensive assessment of all joints within the shoulder complex should be essential. Especially for patients with an early-stage shoulder injury, scapular position and movement are crucial for shoulder joint function. Early scapular mobilization and expansion of the range of motion significantly impact shoulder joint mobility. Early scapular training after rotator cuff injury is beneficial in functional recovery, improves rehabilitation outcomes, and ultimately enhances patient prognosis.

Availability of Data and Materials

The datasets analyzed during the current study were available from the corresponding author on reasonable request.

Author Contributions

MY conceptualized the research study. MY and ZT performed the research. MY and ZT analyzed the data. MY wrote the manuscript. Both authors contributed to editorial important changes in the manuscript. Both authors read and approved the final manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study has been approved by the Yantaishan Hospital Ethics Committee, approval No. 2024126. Informed consent was obtained from all patients in the study cohort, with patient data sourced exclusively from the hospital case system. All procedures were conducted in accordance with the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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