SHOULDER FUNCTION WITH COMPLETE AND INCOMPLETE POST-OPERATIVE REHABILITATION IN SUBJECTS AFTER ARTHROSCOPIC ROTATOR CUFF REPAIR: A CROSS-SECTIONAL COMPARATIVE STUDY

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ABSTRACT

Background: Arthroscopic rotator cuff repair (ARCR) is a commonly performed surgical procedure to restore shoulder functionality and alleviate pain in individuals with rotator cuff tears. Despite successful surgical repair, postoperative rehabilitation is critical for optimal functional recovery. However, compliance to a full six-month structured rehabilitation protocol varies among patients, leading to questions regarding its impact on shoulder function and muscle activity.

Methods: A cross-sectional comparative study was conducted on 20 subjects (10 with complete postoperative rehabilitation and 10 with incomplete rehabilitation) who had undergone ARCR. Participants were assessed 6–8 months post-surgery using the American Shoulder and Elbow Surgeons (ASES) score for shoulder pain/function, universal goniometry for range of motion (ROM), surface electromyography (sEMG) for key shoulder and arm muscles (supraspinatus, infraspinatus, teres minor, biceps, and triceps), and muscle length tests (pectoralis minor, levator scapulae). Comparative analyses (independent t-tests, Levene's test) examined differences between groups.

Results: The complete rehabilitation group demonstrated significantly higher mean ASES scores (91.3 vs. 71.8), increased shoulder flexion (178° vs. 150°, $p < 0.001$), abduction (173.5° vs. 145°, $p < 0.001$), **and notably superior internal rotation (72.5° vs. 56.5°, $p < 0.001$) and external rotation (81° vs. 63.1°, $p < 0.001$)** compared to the incomplete group. sEMG amplitudes for the rotator cuff muscles were significantly higher (e.g., supraspinatus 553.7 µV vs. 454.4 µV, $p < 0.001$). Pectoralis minor length was also significantly better in the complete group (8.81 cm vs. 8.06 cm, $p = 0.003$). Levator scapulae length and elbow ROM were not significantly different between groups.

Conclusion: Complete six-month rehabilitation following ARCR yields superior outcomes in shoulder ROM (including internal rotation), rotator cuff muscle activation, pectoralis minor flexibility, and overall shoulder function compared to incomplete rehabilitation. These findings highlight the pivotal role of sustained and structured physiotherapy to optimize surgical outcomes.

Keywords: Arthroscopic Rotator Cuff Repair, Postoperative Rehabilitation, Shoulder Function, Range of Motion, Surface Electromyography, Rotator Cuff Muscles

INTRODUCTION

Rotator cuff **tears** are among the most common causes of shoulder pain and functional limitations, significantly impacting daily activities and work tasks [1]. Surgical treatment, especially arthroscopic rotator cuff repair (ARCR), has become the standard approach for managing full-thickness tears, relieving pain, and restoring function. Even with advancements in arthroscopic techniques, the success of the surgery is closely linked to postoperative rehabilitation protocols designed to promote optimal tendon healing, regain range of motion (ROM), and improve muscle strength [2,3].

Typically, a rotator cuff rehabilitation protocol consists of progressive phases. The initial phases focus on joint protection and passive mobilization, followed by active-assisted range of motion exercises, and eventually strengthening and proprioceptive tasks [4]. Following these phases is crucial for achieving functional recovery. Inconsistent or infrequent participation in supervised rehabilitation can hinder the healing of the repaired tendon, limit improvements in ROM, and decrease muscle performance [5]. Furthermore, poor adherence often results in compensatory movement patterns, which can lead to ongoing shoulder pain and dysfunction [6].

Surface electromyography (sEMG) serves as a valuable tool for assessing muscle activation patterns during specific shoulder movements, allowing clinicians to monitor improvements in neuromuscular control [7]. Likewise, validated clinical outcome measures, such as the American Shoulder and Elbow Surgeons (ASES) score, are essential for objectively tracking changes in both pain and function [8]. In addition to these functional assessments, evaluating muscle length—particularly of the pectoralis minor and levator scapulae—offers insights into postural adaptations and imbalances that may develop due to insufficient rehabilitation [9].

Despite the well-documented advantages of consistent rehabilitation, patient adherence can vary significantly, often influenced by various factors. This study therefore aims to compare shoulder function in subjects with complete versus incomplete postoperative rehabilitation following ARCR, emphasizing its impact on range of motion, muscle activation, muscle length, and shoulder function outcomes [2,4,5,8,10].

MATERIALS AND METHODS

Study Design and Ethical Approval

A cross-sectional comparative study design was adopted. After obtaining ethical committee clearance, subjects were recruited from the Department of Orthopedics and the Department of Physiotherapy. Written informed consent was obtained from all participants prior to data collection.

Participants and Recruitment

A sample of 20 patients who reported to the orthopedic and physiotherapy outpatient departments over a 6-month study period was recruited using purposive sampling. Patients were stratified into two groups (10 each) based on the completion of a structured six-month postoperative rehabilitation protocol after ARCR.

Inclusion Criteria

- Adults (male and female) aged >18 years who underwent ARCR.
- **Complete rehabilitation group:** Subjects who consistently followed a six-month postoperative rehabilitation protocol.
- **Incomplete rehabilitation group:** Subjects who missed or skipped sessions during the first to sixth month of rehabilitation.

Exclusion Criteria

- Bilateral shoulder fractures or bilateral rotator cuff repairs.
- Polytrauma.
- Other major upper-limb injuries/surgeries that could confound results.

Rehabilitation Protocol

A standardized three-phase rehabilitation protocol, extending from postoperative day 1 (POD 1) to postoperative week 24 (POW 24), was instituted:

1. **Phase 1 (POD 1 to ~POW 4):** Emphasis on sling immobilization, pain control, and gentle, non-aggressive exercises (finger, wrist, elbow).
2. **Phase 2 (POW 5 to ~POW 12):** Gradual weaning from sling, initiation of active-assisted to active range of motion exercises, isometric strengthening, and introduction of low-resistance strengthening.
3. **Phase 3 (POW 12 to ~POW 24):** Progressive strengthening using Therabands and light weights, proprioceptive training, and advanced functional exercises.

Subjects who completed these phases without deviation or missing ≥3 consecutive weeks of therapy were categorized into the **complete rehabilitation group**. Those who skipped or missed any phase for ≥3 consecutive weeks were assigned to the **incomplete rehabilitation group**.

Outcomes and Instrumentation

1. **ASES Score (American Shoulder and Elbow Surgeons Score):**
   - 100-point scale (pain: 50 points; ADLs: 50 points).
   - Higher scores indicate better shoulder function and lower pain [8].
2. **Shoulder and Elbow Range of Motion (ROM):**
   - Measured using a universal goniometer (flexion, extension, abduction, **internal rotation, external rotation**; elbow flexion, extension).
   - Procedures followed standard goniometric landmarks [9].
3. **Surface Electromyography (sEMG):**
   - A portable sEMG (Pheezee device) measured muscle activation in supraspinatus, infraspinatus, teres minor, biceps, and triceps.
   - Electrodes placed on cleaned skin parallel to muscle fiber orientation [7].

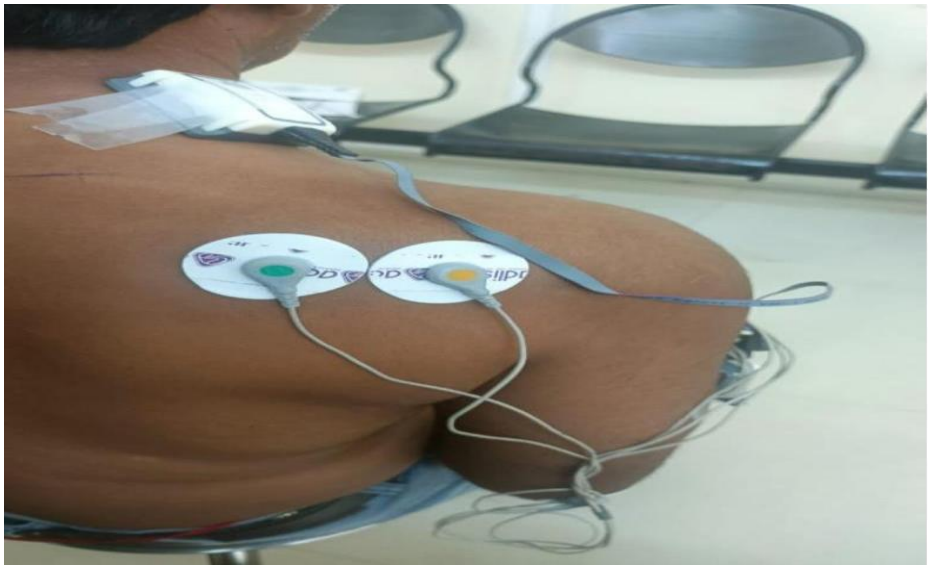
Electrode Placement Illustrations

- **Supraspinatus:** Electrodes placed over the suprascapular region, approximately above the spine of the scapula.
- **Infraspinatus:** Electrodes placed 4 cm below the spine of the scapula, over the infraspinous fossa.
- **Teres Minor:** Electrodes placed approximately one-third the distance from the posterior portion of the acromion process to the inferior angle of the scapula, near the lateral border.
- **Biceps:** Electrodes placed mid-belly of the biceps brachii, parallel to fiber orientation. Reference on bony prominence near elbow.
- **Triceps:** Electrodes placed on the long head or lateral head belly parallel to fibers; reference on the lateral epicondyle or another bony landmark around the elbow.

4. **Muscle Length Tests (Pectoralis Minor, Levator Scapulae):**
   - Measured with a Vernier caliper from bony landmarks (coracoid process to 4th rib for pectoralis minor; C2 transverse process to superior angle of scapula for levator scapulae).
   - Reported as a ratio of muscle length to participant's height × 100 [9].

Statistical Analysis

Data were summarized as mean ± standard deviation (SD) for continuous variables. Independent t-tests (with or without equal variance assumption via Levene's test) evaluated differences between groups. Categorical variables were compared using chi-square tests as appropriate. Statistical significance was set at $p < 0.05$.



Electrode placement for Infraspinatus

Electrode placement for Teres minor

Electrode placement for supraspinatus

Electrode placement for triceps

Electrode placement for biceps

RESULTS

Overview of Findings

Twenty participants (10 complete rehabilitation, 10 incomplete rehabilitation) were included. Both groups were comparable in age (mean ~48 years) and gender distribution. The primary differences emerged in shoulder ROM (including **internal rotation**), muscle activation of the rotator cuff, pectoralis minor length, and ASES functional scores.

Demographic Data and Group Allocation

All 20 participants had undergone arthroscopic rotator cuff repair 6–8 months prior. The complete rehabilitation group had a mean age of 48.4 ± 5.1 years, while the incomplete group's mean age was 47.7 ± 6.85 years. Gender distribution was not significantly different, with the majority being male across both groups.

Range of Motion and Functional Score Comparisons

Participants in the complete rehabilitation group exhibited significantly greater shoulder flexion (178° vs. 150°, $p < 0.001$), abduction (173.5° vs. 145°, $p < 0.001$), **internal rotation (72.5° vs. 56.5°, $p < 0.001$)**, and external rotation (81° vs. 63.1°, $p < 0.001$) compared to those in the incomplete group. Elbow ROM was largely unaffected by the completion of the protocol, with both groups achieving near-normal flexion (131.5°) and full extension (0°). The ASES score was significantly higher in the complete group (91.3 ± 4.19) than in the incomplete group (71.8 ± 3.65), underlining the impact of full rehabilitation on pain relief and ADLs.

Muscle Activation (sEMG) and Muscle Length Tests

Rotator cuff muscle activation levels were substantially higher in the complete rehabilitation group, notably in the supraspinatus (553.7 ± 45.67 µV vs. 454.4 ± 42.35 µV, $p < 0.001$) and infraspinatus (308 ± 19.37 µV vs. 235.4 ± 26.87 µV, $p < 0.001$). Biceps and triceps amplitudes did not differ significantly, suggesting these muscles were less dependent on specialized postoperative exercises in this timeframe. Notably, pectoralis minor length was significantly greater in the complete group (8.81 ± 0.51 cm vs. 8.06 ± 0.47 cm, $p = 0.003$), indicating a more favorable postural alignment. Levator scapulae length did not differ significantly.

Summary of Statistical Tests

Levene's test confirmed unequal variances for several shoulder ROM measures, but t-tests consistently showed superior values in the complete rehabilitation group. The most pronounced differences ($p < 0.001$) were in ASES scores and shoulder flexion, abduction, **internal**, and external rotations. These findings strongly support the hypothesis that consistent rehabilitation correlates with better shoulder function, muscle performance, and flexibility after ARCR.

TABLE 1. Descriptive Statistics for Complete Rehabilitation Group (n=10)

Variable	Mean	SD
Shoulder Flexion (°)	178	2.58
Shoulder Abduction (°)	173.5	3.37
Shoulder Internal Rotation (°)	72.5	3.1
Shoulder External Rotation (°)	81	3.94
ASES Score	91.3	4.19
Supraspinatus EMG (µV)	553.7	45.67
Pectoralis Minor Length (cm)	8.81	0.51

TABLE 2. Descriptive Statistics for Incomplete Rehabilitation Group (n=10)

Variable	Mean	SD
Shoulder Flexion (°)	150	7.82
Shoulder Abduction (°)	145	7.45
Shoulder Internal Rotation (°)	56.5	3.2
Shoulder External Rotation (°)	63.1	2.77
ASES Score	71.8	3.65
Supraspinatus EMG (µV)	454.4	42.35
Pectoralis Minor Length (cm)	8.06	0.47

TABLE 3. Independent t-test Results Comparing Complete vs. Incomplete Rehabilitation

Variable	Mean Diff	p-value
Shoulder Flexion (°)	28.0	< 0.001 ***
Shoulder Abduction (°)	28.5	< 0.001 ***
Shoulder Internal Rotation (°)	16.0	**< 0.001 *****
Shoulder External Rotation (°)	17.9	< 0.001 ***
ASES Score	19.5	< 0.001 ***
Supraspinatus EMG (µV)	99.3	< 0.001 ***
Pectoralis Minor Length (cm)	0.755	0.003 **

SURFACE ELECTROMYOGRAPHY (sEMG)

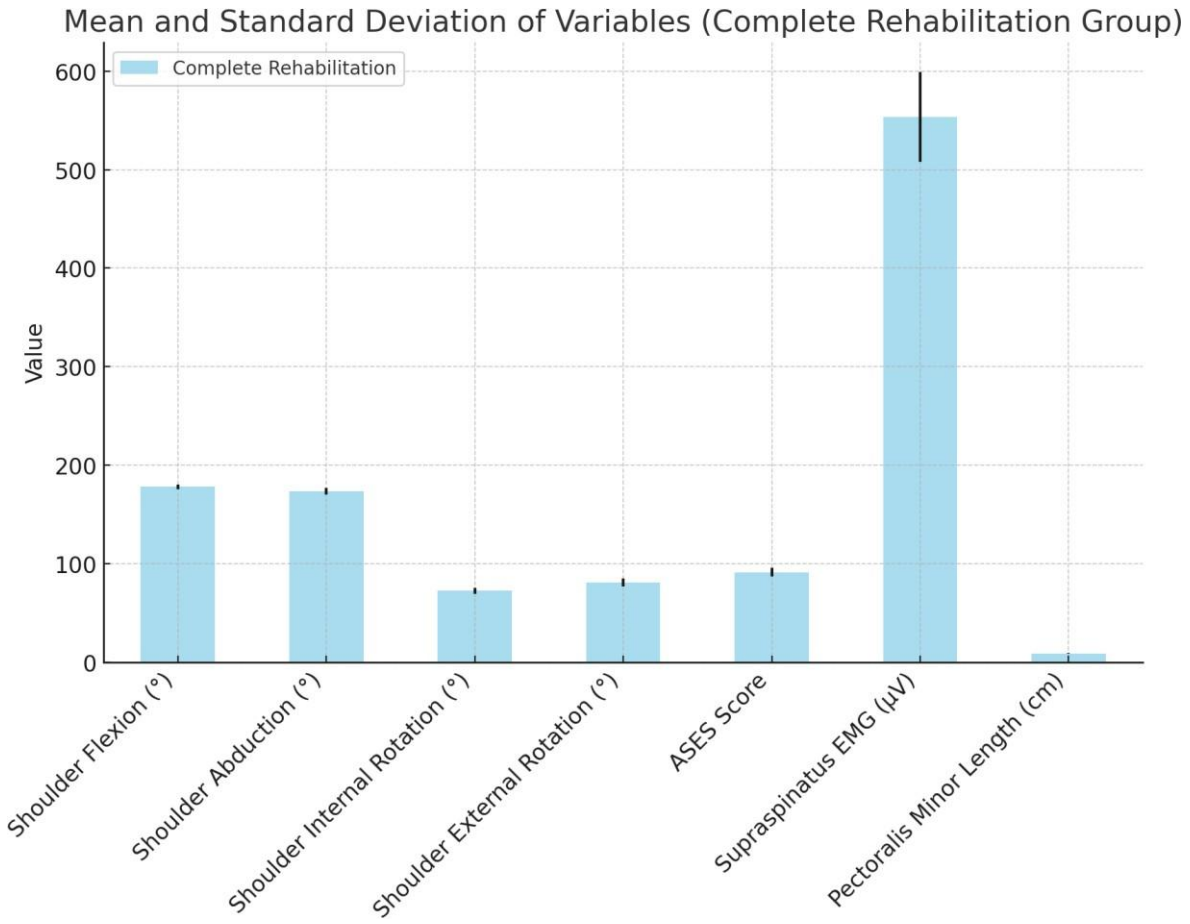
A portable sEMG **(Pheezee device)** measured muscle activation in supraspinatus, infraspinatus, teres minor, biceps, and triceps. Electrodes were placed on cleaned skin parallel to the muscle fiber orientation [7].

Electrode Placement Illustrations

- **Supraspinatus**: Over the suprascapular region, approximately above the spine of the scapula.
- **Infraspinatus**: Approximately 4 cm below the spine of the scapula in the infraspinous fossa.

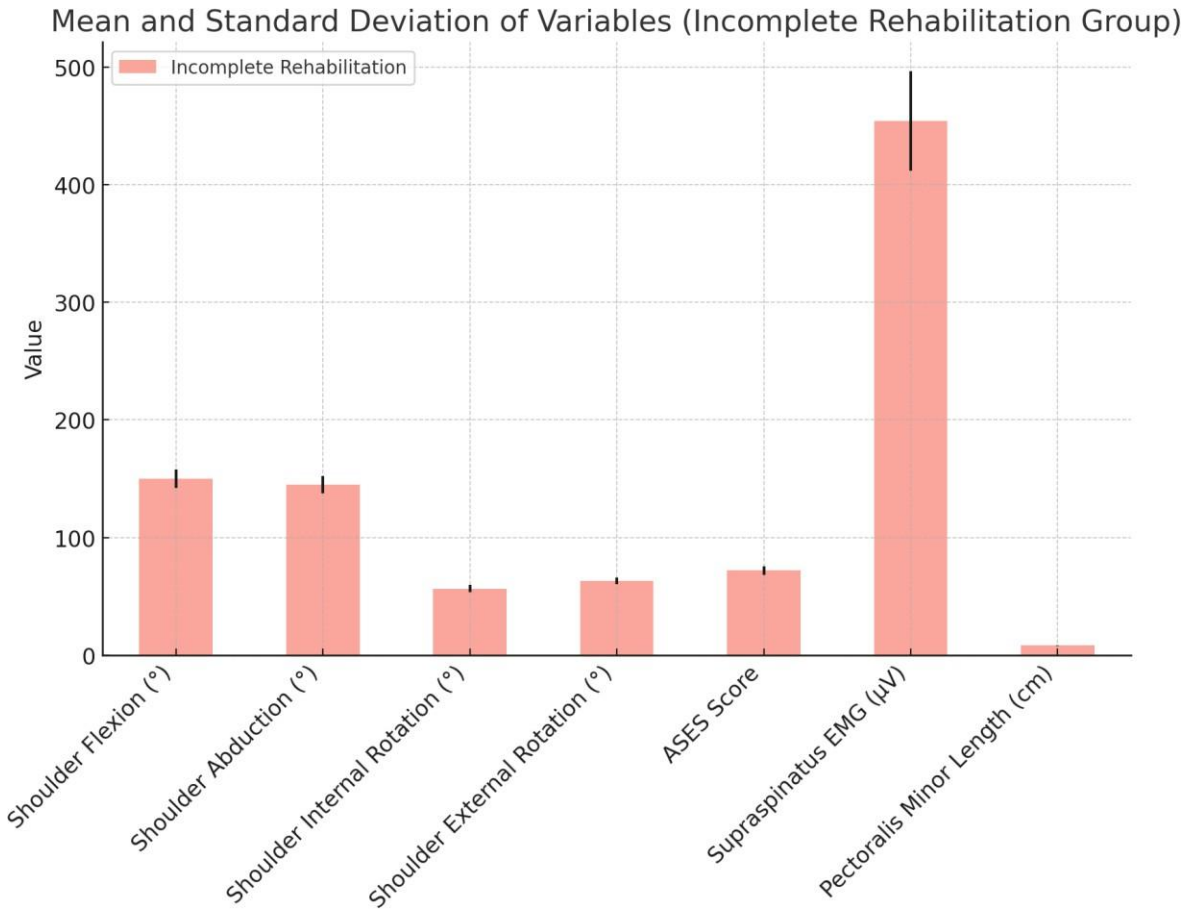
- **Teres Minor**: About one-third the distance from the posterior edge of the acromion to the inferior angle of the scapula, near the lateral border.
- **Subscapularis**: *If needed/possible*, place electrodes near the anterior axillary fold (slightly inferior to the coracoid process), aligned with subscapularis fibers. Due to its deep location, superficial sEMG can be challenging; alternative methods (e.g., fine-wire EMG) may be used in some studies.
- **Biceps**: Mid-belly of the biceps brachii, parallel to fiber orientation, with a reference on a bony prominence near the elbow.
- **Triceps**: Over the long head or lateral head belly, parallel to fibers; reference near the lateral epicondyle.

Figure 1: Mean and Standard Deviation of Variables (Complete Rehabilitation Group)



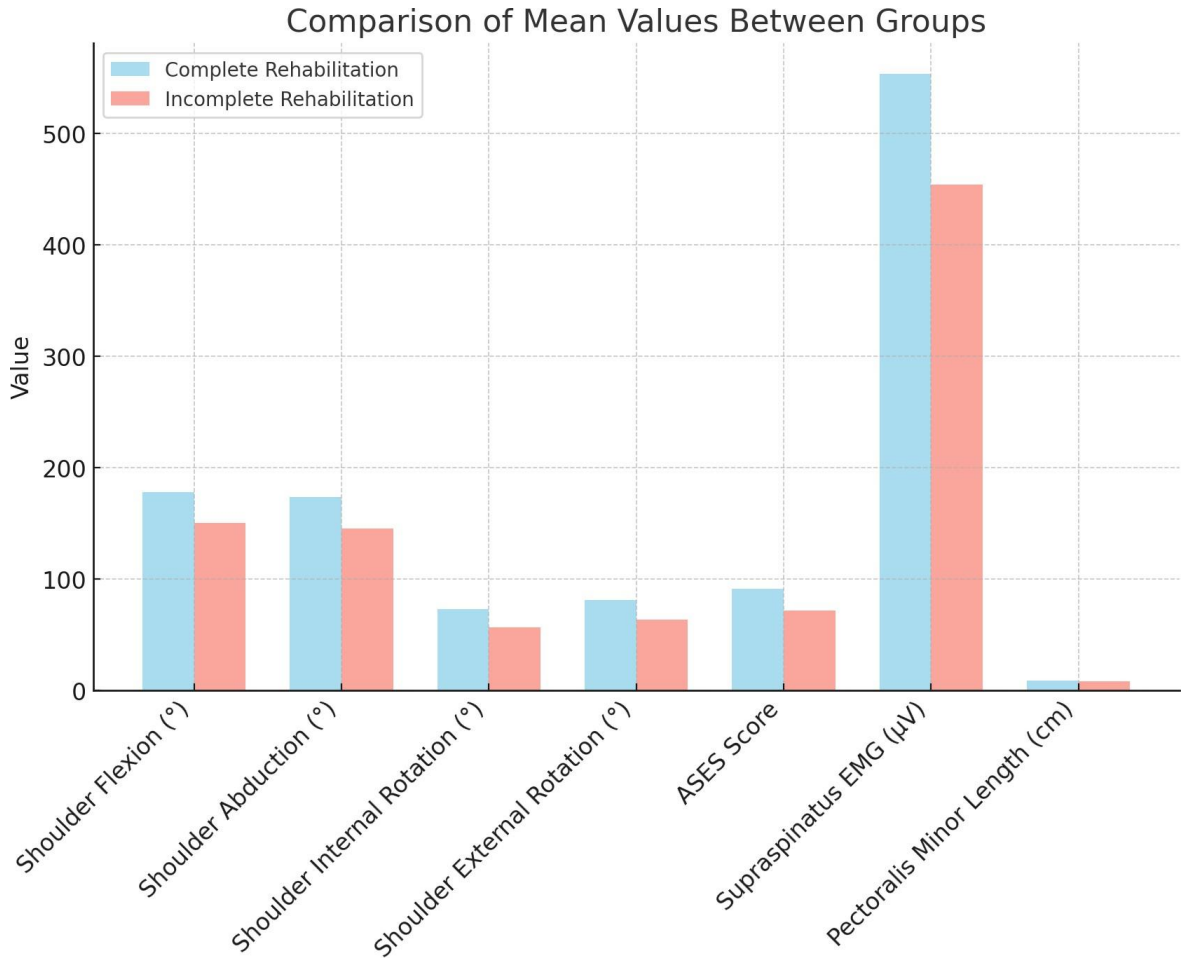
Here is a bar graph showing the mean and standard deviation of different variables in the Complete
Rehabilitation Group. The error bars represent the standard deviation for each variable.

Figure 2: Mean and Standard Deviation of Variables (Incomplete Rehabilitation Group)



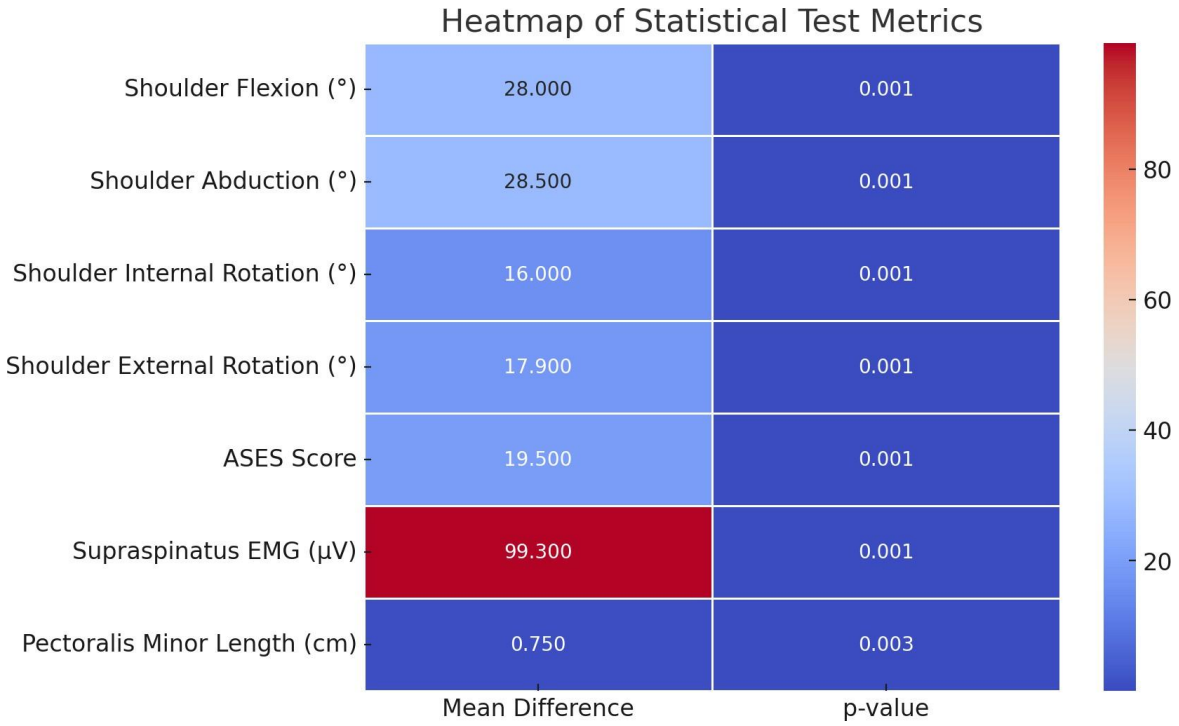
Here is a bar graph showing the mean and standard deviation of different variables in the incomplete Rehabilitation Group Here is a bar graph showing the mean and standard deviation of different variables in the incomplete Rehabilitation.

Figure 3: Comparison of mean values between groups



Sky Blue bars represent complete rehabilitation group (first set of data).
Salmon bars represent incomplete rehabiliation group (second set of data).

Figure 4: Heatmap of statistical test metrics



Here is a heatmap of p-value significance, t-value, and mean difference for each test. The color scale ranges so that easy comparison of the variation of values may be made across tests. Lower p-values and higher t- values or mean differences are indicated by stronger colors-thus, showing that greater effects occur or that significance lies in such areas.

DISCUSSION

The current research establishes that patients who adhered to a holistic, systematic rehabilitation regimen for six months after arthroscopic rotator cuff repair (ARCR) experienced enhanced shoulder function, increased rotator cuff muscle activation, and increased flexibility of postural muscles compared to patients who did not adhere to the rehabilitation. These findings support previous studies showing that prolonged and consistent physiotherapy is crucial in the maintenance of tendon health, joint mobility, and prevention of re-injury [2,5,6].

Improved ASES scores in the completely rehabilitated group reflect pain relief and improvement in ADLs. Early protective stages of rehabilitation help avoid overloading the repaired tendon, providing a basis for graduated loading [4,6,8]. Our findings indicated greater flexion, abduction, and both internal and external rotation of the shoulder, consistent with earlier evidence that progressive ROM exercise is advantageous to glenohumeral recovery [1,3]. Conversely, the incompletely rehabilitated group exhibited large deficits in these movements, highlighting how omitting important phases of rehabilitation can result in inadequate tissue adaptation and persistent impairment of movement [2,5].

The sEMG findings show that activation levels of rotator cuff muscles—particularly the supraspinatus, infraspinatus, and teres minor—were higher in patients who adhered to the full protocol, implying increased neuromuscular re-education and strength gain [7]. The lack of significant differences in biceps and triceps activation may be due to their synergistic involvement in daily arm functions, which are less directly targeted by specialized rotator cuff exercises. Maintaining or improving pectoralis minor length in the complete group suggests that a systematic rehabilitation program can prevent the adaptive shortening of anterior shoulder structures that predispose to impingement and scapular dyskinesia [9]. Although no significant differences in levator scapulae length were found, subtle scapular imbalances remain a concern and could be addressed with more sensitive kinematic analyses in future research.

Limitations of this study include a relatively small sample size and a cross-sectional design, limiting the ability to infer long-term causality. Nevertheless, the findings underline the significance of rigorous, phase-based physiotherapy to optimize functional and biomechanical recovery after ARCR. Close monitoring of patient adherence, along with robust patient education, is vital to ensure maximal benefit.

CONCLUSION

In this comparative cross-sectional study, patients undergoing a full six-month rehabilitation regimen following arthroscopic rotator cuff repair had better shoulder function, ROM (including internal rotation), and muscle recruitment than those undergoing incomplete rehabilitation. In particular, higher ASES scores, improved pectoralis minor muscle length, and greater rotator cuff activation were noted in the group receiving full rehabilitation. These observations illustrate the crucial role of prolonged, phase-appropriate physiotherapy to achieve optimal surgical outcomes and underscore the importance of patient compliance in promoting optimal functional recovery.

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