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# Passive shoulder abduction range of motion at 3 months postoperatively is the most important prognostic factor for achieving full recovery of range of motion at 6 months after arthroscopic rotator cuff repair

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A R T I C L E I N F O

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*Level of evidence:* Level III; Retrospective Cohort Comparison; Prognosis Study

**Background:** After arthroscopic rotator cuff repair (ARCR), it is crucial for clinicians to predict the functional recovery in the early postoperative period for considering rehabilitation strategies. The aim of this study was to identify the prognostic factors in the early postoperative period for achieving full recovery of range of motion (ROM) at 6 months after ARCR.

**Methods:** This study included 184 patients who underwent ARCR. Patients were divided into the full recovery and nonrecovery groups using the Constant ROM score at 6 months postoperatively. The area under the curve for predicting the full recovery group was calculated for all independent variables such as demographic data, ROM, shoulder functional scores at preoperative and 3 months postoperative using receiver operating characteristic curve analysis. Multivariable logistic regression analysis was then performed using candidate variables with an area under the curve of 0.7 or greater to determine prognostic factors for full recovery at 6 months postoperatively. The same analysis as above was also performed by dividing the patients into groups according to their preoperative ROM.

**Results:** Multivariable logistic regression analysis revealed that preoperative active flexion, 3 months postoperative passive abduction, and internal rotation at 90° abduction ROM were significant prognostic factors of achieving full ROM recovery at 6 months postoperatively. Only passive abduction ROM at 3 months postoperatively was significantly extracted in the preoperative ROM limitation group.

**Conclusion:** This study demonstrated that passive abduction ROM at 3 months postoperatively was a significant prognostic factor of achieving full recovery of ROM at 6 months after ARCR.



Rotator cuff tears are a common shoulder disorder in the elderly individuals, resulting in shoulder pain, muscle weakness, and restricted range of motion (ROM).[14,16] Recently, arthroscopic rotator cuff repair (ARCR) has been widely performed as a standard procedure for rotator cuff tears, with highly favorable clinical outcomes.[3,8,19] However, the postoperative complications following ARCR have been reported to range from 2.5% to 14.3%.[27,29] The most prevalent of these is shoulder stiffness, responsible for persistent pain and reduced patient satisfaction in the postoperative period.[1,4,18,28]

McNamara et al[20] found that the shoulder ROM significantly decreased at 6 weeks postoperatively compared to preoperatively, however, ROM had almost fully recovered to preoperative level at 3 months postoperatively. On the contrary, Kurowicki et al[17] reported that following ARCR, there was a 74% improvement in pain and a 97.4% satisfaction with the procedure, while there was from a 40% to 60% improvement in functional score, 22% improvement in

The institutional review board of Orthopedic Hokushin Hospital approved this study (ID: 2303).

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shoulder elevation ROM, and 45% improvement in abduction ROM at 3 months postoperatively when total improvement at 1 year postoperatively was set as 100%. They also reported nearly an 80% improvement in both functional score and ROM excluding external rotation at 6 months postoperatively, and these outcomes reached the plateau at 1 year postoperatively. Several studies have reported positive clinical outcomes at 1 or 2 years following ARCR.[17,19,23] Furthermore, Nakamura et al[23] found that an active elevation of 110° at 3 months, and visual analogue scale pain score of less than 5 points at 2 months postoperatively were predictive factors for the Japanese Orthopaedic Association (JOA) score 2 years after ARCR.

Although good results at 1-2 years have been reported, outpatient rehabilitation can be a heavy burden on patients, and achieving good shoulder ROM earlier can enhance their quality of life while reducing medical costs, so, it is desirable that rehabilitation proceed so that good shoulder ROM is achieved by 6 months postoperatively. This underscores the importance of clinicians prioritizing early ROM improvement to alleviate patient's burden and increase satisfaction, while minimizing the risk of postoperative retear of the repaired tendon. Early postoperative prognostic factors, such as ROM and their corresponding target values, could serve as useful references for clinicians in achieving improved shoulder ROM at 6 months postoperatively. However, there is a scarcity of studies investigating this area.

Preoperative ROM has been found to impact postoperative ROM after ARCR.[5,20,24] Several studies have reported various time courses for changes in shoulder ROM during the postoperative rehabilitation period after ARCR, including patients with good ROM from preoperatively to postoperatively, patients with good ROM preoperatively but with poor postoperatively, and vice versa, patients with poor ROM preoperatively but with good postoperatively in clinical practice.[4,20] Despite our best rehabilitation efforts, we may still encounter patients who have good ROM preoperatively but poor postoperative outcomes or who remain poor ROM from preoperatively to postoperatively. Therefore, it is essential to predict the prognosis of postoperative shoulder function, including ROM during the early postoperative period for designing effective rehabilitation strategies after ARCR.

The primary aim of this study was to identify preoperative and early postoperative prognostic factors and these target values for achieving good ROM recovery at 6 months postoperatively after ARCR. Additionally, the study established the cutoff values of prognostic factors in nonretear ARCR patients. The secondary aim was to analyze the influences of preoperative ROM on postoperative ROM improvement and determine their respective cutoff values.

## Materials & methods

### *Participants*

This study was retrospective cohort study and prognostic factors research. We enrolled patients who underwent ARCR for partial- or full-thickness rotator cuff tears at our hospital from January 2018 to December 2022. Patients were excluded if we lost to follow-up until 6 months postoperatively or they did not complete preoperative, 3 or 6 months postoperative assessments or had (1) shoulder disorders other than rotator cuff tear, (2) a history of previous shoulder surgery, (3) symptoms due to cervical radiculopathy, or (4) neuromuscular disorders. Magnetic resonance imaging was conducted on all patients at 6 months postoperatively to evaluate cuff repair integrity. Since previous study has reported an association between improved ROM in the early postoperative period and cuff integrity of the repaired tendon,[20] we excluded the patients with a retear of the repaired tendon (Sugaya type 4 and 5)[30] from the analysis in order to achieve our study objective. Finally, we included 184 patients for analysis (Fig. 1). All patients signed informed consent forms, and this study was approved by the institutional review board of our institute (approval number: 2303).

### *Surgical procedures and rehabilitation protocols*

ARCR surgeries were conducted with patients in a beach chair position under general anesthesia. The method of suturing the tendon was either surface-holding repair[31] or suture bridge technique.[26] The number and type of anchors utilized were based on the condition and mobility of the tendon. All cases included acromioplasty while long head of biceps tenotomy, glenohumeral joint manipulation including capsulotomy, and distal clavicle resection were performed if necessary.

Immobilization using an abduction pillow brace was implemented for 6 weeks following surgery. All patients underwent active scapular exercises, active ROM exercise of the elbow, wrist, and finger from the first day after surgery. Passive ROM exercises and active-assisted ROM exercises were initiated 2 days after surgery. Active ROM exercises were permitted after removal of the shoulder brace at 6 weeks. Antigravity movements above shoulder level were allowed at 8 weeks after surgery and resistance exercise was permitted at 12 weeks. Heavy work and sports were approved for return after 6 months following surgery.

### *Outcome measures*

Demographic data, including age, sex and the dominance of operated shoulder, along with medical complications such as diabetes mellitus and hyperlipidemia and mechanism of injury, were recorded preoperatively. We assessed the size of the tendon tear through an intraoperative evaluation, and classified full-thickness tears according to the Cofield classification,[7] with small tears defined as less than 1 cm, medium tears ranging from 1 to 3 cm, large tears ranging from 3 to 5 cm, and massive tears measuring over 5 cm. The degree of fatty infiltration of the supraspinatus and infraspinatus muscles was evaluated using magnetic resonance imaging according to the Goutallier classification.[10]

Active and passive ROM of shoulder flexion, abduction, external rotation at side of the body, and only passive ROM of external and internal rotation at 90° abduction position were measured using a goniometer preoperatively and at 3 and 6 months postoperatively. Hand-behind-back movement was scored using the lower item of the Constant shoulder score to determine the spinal level reached by the thumb tip. As objective shoulder functional score, physical therapist and physician evaluated Constant shoulder score preoperatively and at 6 months postoperatively. Additionally, as patients-reported outcome measures, the Disabilities of the Arm, Shoulder, and Hand were evaluated preoperatively and at 6 months postoperatively.

### *Data reduction and statistical analysis*

For the primary aim of this study, full recovery of ROM was defined as a score of 38 or 40 on the ROM item in the Constant score at 6 months postoperatively. Patients were categorized into 2 groups based on this definition: recovery group (38 or 40 points) and nonrecovery group (less than 36 points). We chose the ROM item from the Constant shoulder score to assess full recovery because it measures 4 directions of motion: flexion, abduction, external rotation, and hand-behind-back motion. It has a scoring system of 0-10 with increments of 2 points for each direction of motion, making it an equitable tool for any direction.

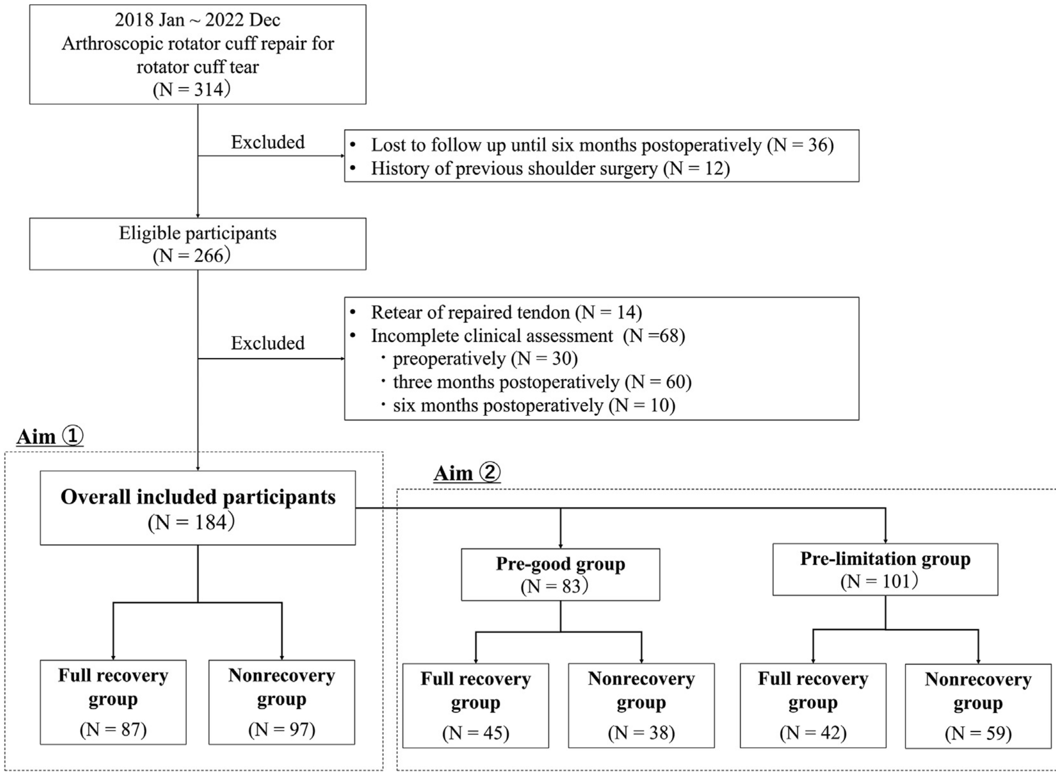


**Figure 1** Flowchart of participants selection and classification.

Moreover, for the hand-behind-back motion, this study defined full recovery as a score of 8 or higher in the Constant shoulder score, given that Th12 or higher is considered a perfect score in the JOA score.

Independent variables included demographic data, medical complications, tendon tear size, mechanism of injury, degree of fatty infiltration, ROM, and shoulder functional score—assessed preoperatively and at 3 months postoperatively. The dependent variable was the achievement of full ROM recovery at 6 months after surgery. Area under the curves (AUCs) and cutoff values were calculated for all independent variables except for demographic data, medical complications, and tendon tear size using receiver operating characteristic (ROC) curve analysis with the Youden index. We defined AUC ranges of 0.5-0.7 for low accuracy, 0.7-0.9 for moderate accuracy, and 0.9-1.0 for high accuracy. To determine which cutoff values of the independent variables could more accurately predict the dependent variable and to minimize the effect of multicollinearity as much as possible, the independent variables were screened using the criterion of AUC greater than 0.7 and correlation analysis between each variable. participants above the cutoff value were assigned a value of 1, while those below were assigned a value of 0, then, we conducted multivariable logistic regression analysis on the screened independent variables, as well as demographic data, tendon tear size, mechanism of injury, degree of fatty infiltration, and medical complication morbidity, all of which exhibited significant differences between the recovery and nonrecovery groups. Sensitivity and specificity were calculated based on the cutoff values of the independent variables obtained through multivariable logistic regression analysis. Demographic data, medical complications, and tendon tear size were compared between the recovery and nonrecovery group using a chi-square test and independent t-test, respectively, in the entire participant cohort.

Additionally, for the secondary aim of investigating the influence of preoperative ROM on the predictive factors and their cutoff values preoperatively and at 3 months for achieving full recovery of ROM at 6 months postoperatively, the participants were segregated into 2 groups based on their preoperative ROM, with the study by Namdari et al[25] on the essential ROM for activities of daily living as a reference. The preoperative good group (pregood) was defined as individuals with a ROM of at least 120° of active flexion, 130° of active abduction, and 60° of passive external rotation in 90° abduction position preoperatively. Any others were categorized as the preoperative limitation group (prelimitation) (Fig. 1). The same analysis as the first aim was conducted in each group, and cutoff values and prognostic ability were calculated preoperatively and at 3 months postoperatively for achieving full recovery of ROM at 6 months postoperatively. According to the STROBE guidelines, we performed comparisons between the available data at each time period and the present study data, as well as between the data including retears of the repaired tendon and the present study data, and these results are shown in the Supplementary Tables. All statistical analysis was done utilizing the R software program (version 4.3.0; R Foundation for Statistical Computing, Vienna, Austria), and the significance level was set at .05.

## Results

### *Preoperative and early postoperative prognostic factors for achieving good recovery of ROM at 6 months postoperatively*

Out of 184 patients, 87 patients were allocated to the recovery group, while the remaining 97 were in the nonrecovery group. The recovery group had a higher proportion of females and fewer diabetes mellitus patients compared with nonrecovery group (Table I). Active and passive ROM, objective and

**Table I**
Preoperative and intraoperative characteristics and range of motion and shoulder functional score at 6 mo postoperatively in overall participants, recovery, and nonrecovery groups.

| | Overall (N = 184) | Recovery (N = 87) | Nonrecovery (N = 97) | *P* value |
|---|---|---|---|---|
| Sex | | | | |
| Male | 93 (50.5%) | 36 (41.3%) | 57 (58.8%) | **.018** |
| Female | 91 | 51 | 40 | |
| Age (SD) | 63.3 (9.1) | 62.0 (9.5) | 64.4 (8.8) | .074 |
| Operation side | | | | |
| Dominant | 127 (69.0%) | 66 (75.9%) | 61 (62.9%) | .057 |
| Nondominant | 57 | 21 | 36 | |
| Tear size | | | | |
| Partial | 32 (17.3%) | 13 (14.9%) | 19 (19.6%) | .407 |
| Small | 15 (8.2%) | 6 (6.9%) | 9 (9.3%) | .556 |
| Medium | 131 (71.2%) | 64 (73.6%) | 67 (69.1%) | .502 |
| Large | 4 (2.2%) | 3 (3.5%) | 1 (1.0%) | .262 |
| Massive | 2 (1.1%) | 1 (1.1%) | 1 (1.0%) | .938 |
| Mechanism of injury | | | | |
| Traumatic | 31 (16.8%) | 14 (16.1%) | 17 (17.6%) | .795 |
| Nontraumatic | 153 (83.2%) | 73 (83.9%) | 80 (82.4%) | |
| Fatty infiltration | Mean (SD) | | | |
| SSP | 0.20 (0.41) | 0.15 (0.36) | 0.25 (0.43) | .071 |
| ISP | 0.14 (0.35) | 0.09 (0.29) | 0.19 (0.39) | .052 |
| Surgical technique | | | | |
| Suture bridge | 49 (26.6%) | 25 (28.7%) | 27 (27.8%) | .955 |
| Surface-holding | 135 (73.4%) | 62 (71.3%) | 70 (72.2%) | |
| Sugaya type | | | | |
| 1 | 165 (89.7%) | 75 (86.2%) | 90 (92.8%) | .143 |
| 2 | 16 (8.7%) | 10 (11.5%) | 6 (6.2%) | .202 |
| 3 | 3 (1.6%) | 2 (2.3%) | 1 (1.0%) | .498 |
| Complications | | | | |
| Diabetes mellitus | 36 (19.6%) | 9 (10.3%) | 24 (24.7%) | **.011** |
| Hyperlipidemia | 40 (21.7%) | 14 (16.1%) | 26 (26.8%) | .786 |
| **PO6m** | Mean (SD) | | | |
| Flexion | | | | |
| Active | 152.4 (13.0) | 160.4 (8.6) | 145.2 (12.1) | **<.001** |
| Passive | 160.2 (12.5) | 167.1 (6.7) | 154.1 (13.4) | **<.001** |
| Abduction | | | | |
| Active | 151.1 (17.6) | 162.1 (9.5) | 141.2 (17.4) | **<.001** |
| Passive | 158.1 (15.9) | 167.6 (8.6) | 149.5 (16.0) | **<.001** |
| Ext rot 1 | | | | |
| Active | 48.7 (13.8) | 53.6 (10.9) | 44.3 (14.6) | **<.001** |
| Passive | 51.4 (13.2) | 56.1 (11.4) | 47.1 (13.4) | **<.001** |
| Ext rot 2 | | | | |
| Passive | 75.9 (13.9) | 81.4 (10.0) | 71.0 (15.1) | **<.001** |
| Int rot 2 | | | | |
| Passive | 46.4 (14.2) | 52.5 (10.3) | 40.8 (15.0) | **<.001** |
| HBB | 7.2 (1.6) | 8.2 (0.7) | 6.3 (1.7) | **<.001** |
| Constant | 71.9 (7.9) | 74.9 (6.5) | 69.3 (8.2) | **<.001** |
| DASH | 10.8 (11.1) | 9.9 (10.4) | 11.5 (11.6) | .559 |

*SD*, standard deviation; *SSP*, supraspinatus muscle; *ISP*, infraspinatus muscle; *Ext rot 1*, external rotation at body side; *Ext rot 2*, external rotation at 90° abduction; *Int rot 2*, internal rotation at 90° abduction; *HBB*, hand-behind-back; *Constant*, Constant shoulder score; *DASH*, the Disabilities of the Arm, Shoulder, and Hand.
A *P*-value of .05 or less was defined as significant (bold).

subjective score preoperatively and at 3 and 6 months postoperatively for both the recovery and nonrecovery groups are shown in Tables I and II.

The independent variables with an AUC greater than 0.7 were preoperative active and passive flexion ROM, and 3 months postoperative active and passive flexion, abduction, and passive internal rotation at 90° abduction ROM (Table II). No objective or subjective shoulder score items had an AUC greater than 0.7 preoperatively and at 3 months postoperatively. Multivariable logistic regression analysis identified preoperative active flexion, 3 months postoperative passive abduction, and internal rotation at 90° abduction ROM as significant prognostic factors (Table III). The cutoff values, sensitivities and specificities for each prognostic factor were as follows: preoperative active flexion had a cutoff value of 147° and sensitivity and specificity of 63.2% and 75.2%, respectively. Likewise, 152°, 60.9%, and 80.4% for 3 months postoperative passive abduction and 37°, 65.5%, and 64.9% for 3 months postoperative passive internal rotation at 90° abduction, respectively.

*Influences of preoperative ROM on postoperative ROM improvement*

Among 184 patients, 83 patients were grouped into the pregood group and the remaining 101 patients were grouped into the prelimitation group. Within these groups, 45 and 42 patients, respectively, achieved full ROM recovery. Although the proportion of full recovery in the pregood group was greater than that in the prelimitation group, the difference was not significant ($P = .088$) (Table IV). In the prelimitation group, the recovery group showed higher proportions of females, dominant hand on the operated side, and lower proportions of Sugaya type 1, and diabetes mellitus ($P < .05$).

The independent variables with an AUC greater than 0.7 in the pregood group were active and passive flexion and

**Table II**
Range of motions and shoulder functional scores preoperatively and at 3 mo postoperatively, and AUCs and cut off values in overall participants, recovery, and nonrecovery group.

| Mean (SD) | Overall | Recovery | Nonrecovery | AUC | Cutoff value |
|---|---|---|---|---|---|
| **Preoperative** | | | | | |
| Flexion | | | | | |
| Active | 133.3 (30.9) | 142.0 (31.4) | 125.5 (28.5) | **0.717** | **147.5°** |
| Passive | 148.5 (22.4) | 154.9 (21.9) | 142.7 (21.2) | **0.707** | **152.5°** |
| Abduction | | | | | |
| Active | 120.5 (41.9) | 126.9 (43.5) | 114.8 (39.7) | 0.605 | 147.5° |
| Passive | 136.3 (33.8) | 144.5 (33.7) | 128.9 (32.3) | 0.658 | 152.5° |
| Ext rot 1 | | | | | |
| Active | 47.9 (16.5) | 50.6 (16.7) | 45.5 (16.1) | 0.574 | 52.5° |
| Passive | 52.1 (15.4) | 55.0 (15.2) | 49.6 (15.2) | 0.583 | 52.5° |
| Ext rot 2 | | | | | |
| Passive | 75.4 (19.6) | 79.8 (17.3) | 71.5 (20.8) | 0.626 | 77.5° |
| Int rot 2 | | | | | |
| Passive | 43.5 (19.7) | 49.8 (16.0) | 37.9 (21.1) | 0.682 | 47.5° |
| HBB | 6.6 (2.6) | 7.3 (2.6) | 6.0 (2.4) | 0.656 | 7.0 |
| Constant | 55.0 (16.2) | 57.2 (15.4) | 53.1 (16.7) | 0.574 | 57.7 |
| DASH | 25.2 (18.2) | 24.8 (18.2) | 25.6 (18.3) | 0.513 | 24.6 |
| **PO3m** | | | | | |
| Flexion | | | | | |
| Active | 141.1 (16.3) | 147.5 (13.1) | 135.3 (16.7) | **0.732** | **147.5°** |
| Passive | 154.9 (10.4) | 159.6 (7.2) | 150.7 (11.0) | **0.751** | **155.5°** |
| Abduction | | | | | |
| Active | 131.5 (24.7) | 140.9 (21.3) | 123.1 (24.7) | **0.719** | **137.5°** |
| Passive | 144.8 (20.9) | 153.2 (18.7) | 137.3 (20.2) | **0.762** | **152.5°** |
| Ext rot 1 | | | | | |
| Active | 40.4 (12.4) | 44.1 (10.8) | 37.0 (12.9) | 0.666 | 42.5° |
| Passive | 43.5 (19.7) | 46.7 (11.3) | 40.6 (13.1) | 0.631 | 47.5° |
| Ext rot 2 | | | | | |
| Passive | 67.2 (14.5) | 71.7 (12.1) | 63.1 (15.3) | 0.661 | 67.5° |
| Int rot 2 | | | | | |
| Passive | 36.5 (13.3) | 41.4 (12.4) | 32.1 (12.6) | **0.709** | **37.5°** |
| HBB | 5.3 (2.0) | 6.0 (1.7) | 4.6 (2.0) | 0.698 | 5.0 |

*AUC*, area under the curve; *SD*, standard deviation; *Ext rot 1*, external rotation at body side; *Ext rot 2*, external rotation at 90° abduction; *Int rot 2*, internal rotation at 90° abduction; *HBB*, hand-behind-back; *Constant*, Constant shoulder score; *DASH*, the Disabilities of the Arm, Shoulder, and Hand.
A *P*-value of .05 or less was defined as significant (bold).

**Table III**
Independent prognostic factors of full recovery of range of motion at 6 mo postoperatively in overall participants.

| Prognostic factors | OR | Cut off value | 95% CI Lower | Upper | *P* value |
|---|---|---|---|---|---|
| Preactive flexion | **5.123** | 147.5° | 2.432 | 11.251 | **<.001** |
| PO3m passive abduction | **5.068** | 152.5° | 2.304 | 11.652 | **<.001** |
| PO3m passive int rot 2 | **2.266** | 37.5° | 1.037 | 4.983 | **.041** |

*Pre*, preoperative; *PO*, postoperative; *OR*, odds ratio; *95% CI*, 95% confidence interval; *int rot 2*, internal rotation at 90° abduction position.
A *P*-value of .05 or less was defined as significant (bold).

abduction ROM preoperatively and at 3 months preoperatively, and active external rotation at body side and passive internal rotation at 90° abduction at 3 months postoperatively (Table V). On the other hand, the prelimitation group had no variables with an AUC greater than 0.7 preoperatively. However, at 3 months postoperatively, an AUC for active, passive flexion, passive abduction, and internal rotation at 90° abduction all exceeded 0.7 (Table V). Multivariable logistic regression analysis identified preoperative active flexion and passive abduction, as well as passive abduction and internal rotation at 90° abduction at 3 months postoperatively as significant prognostic factors in the pregood group (Table VI). The cutoff values, sensitivity, and specificity were as follows: preoperative active flexion had a cutoff value of 152° and sensitivity and specificity of 82.2% and 68.4%, respectively. Similar to the above, 162°, 73.3%, and 63.1% for preoperative passive abduction; 152°, 64.4%, and 81.5% for 3 months postoperative passive abduction; and 37°, 75.5%, and 63.1% for 3 months postoperative internal rotation at 90° abduction, respectively (Table VI). For the prelimitation group, the multivariable logistic regression analysis revealed that the only significant variable was 3 months postoperative passive abduction. The cutoff value, sensitivity, and specificity were 142°, 80.9%, and 59.3%, respectively (Table VI).

## Discussion

The main finding of this study was that preoperative active flexion, 3 months postoperative passive abduction, and internal rotation at 90° abduction position were significant prognostic factors for achieving full ROM recovery at 6 months postoperatively. Moreover, the study indicated that the preoperative ROM affected both preoperative and 3 months postoperative ROM, which were crucial for achieving full ROM recovery at 6 months postoperatively. We presented for the first time the ROM and its cutoff value required for achieving a good ROM at 6 months postoperatively. Although there have been multiple reports on factors associated with shoulder stiffness following ARCR,[1,2,4,6,11,18,20,24,28] there are few reports on the required ROM and the cutoff value during the postoperative recovery period necessary to attain a good recovery of ROM.[32] To optimize patient satisfaction, surgeons and therapists should strive to efficiently attain favorable clinical outcomes and restore shoulder function as soon as possible while minimizing the probability of retear.

We found that passive abduction and internal rotation at 90° abduction position ROM at 3 months postoperatively were significant prognostic factors for achieving full recovery of ROM at 6

**Table IV**
Preoperative and intraoperative characteristics and ROM and shoulder functional score at 6 mo postoperatively of the pregood and prelimitation groups.

| | Pregood (N = 83) | | | Prelimitation (N = 101) | | |
|---|---|---|---|---|---|---|
| | Recovery (N = 45) | Nonrecovery (N = 38) | *P* value | Recovery (N = 42) | Nonrecovery (N = 59) | *P* value |
| Sex | | | | | | |
| Male | 22 (48.9%) | 23 (60.5%) | .289 | 14 (33.3%) | 34 (57.6%) | **.016** |
| Female | 23 | 15 | | 28 | 25 | |
| Age (SD) | 61.6 (7.8) | 63.6 (8.1) | .254 | 62.5 (11.2) | 65.0 (9.2) | |
| Proportion of recovery (%) | 54.2 | | | 41.5 | | .088 |
| Operation side | | | | | | |
| Dominant | 34 (75.6%) | 28 (73.7%) | .845 | 32 (76.2%) | 33 (55.9%) | **.036** |
| Nondominant | 11 | 10 | | 10 | 26 | |
| Tear size | | | | | | |
| Partial | 7 (15.6%) | 8 (21.0%) | .517 | 6 (14.3%) | 11 (18.6%) | .564 |
| Small | 3 (6.7%) | 3 (7.9%) | .829 | 3 (7.1%) | 6 (10.2%) | .599 |
| Medium | 34 (75.6%) | 26 (68.5%) | .469 | 30 (71.4%) | 41 (69.5%) | .834 |
| Large | 1 (2.1%) | 1 (2.6%) | .904 | 2 (4.8%) | 0 (0) | .090 |
| Massive | 0 (0) | 0 (0) | NA | 1 (2.4%) | 1 (1.7%) | .807 |
| Mechanism of injury | | | | | | |
| Traumatic | 4 (8%) | 4 (10.5%) | .801 | 10 (23.8%) | 13 (22.0%) | .834 |
| Nontraumatic | 41 (92%) | 34 (89.5%) | | 32 (76.2%) | 46 (78.0%) | |
| Fatty infiltration | Mean (SD) | | | | | |
| SSP | 0.07 (0.25) | 0.16 (0.37) | .289 | 0.24 (0.43) | 0.32 (0.47) | .361 |
| ISP | 0.04 (0.21) | 0.13 (0.34) | .238 | 0.14 (0.35) | 0.24 (0.43) | .243 |
| Surgical technique | | | | | | |
| Suture bridge | 13 (28.9%) | 12 (31.6%) | .790 | 12 (28.6%) | 15 (25.4%) | .993 |
| Surface-holding | 32 (71.1%) | 26 (68.4%) | | 30 (71.4%) | 44 (74.6%) | |
| Sugaya type | | | | | | |
| 1 | 39 (86.7%) | 32 (84.2%) | .751 | 36 (85.7%) | 58 (98.3%) | **.014** |
| 2 | 5 (11.1%) | 5 (13.2%) | .775 | 5 (11.9%) | 1 (1.7%) | **.032** |
| 3 | 1 (2.2%) | 1 (2.6%) | .904 | 1 (2.4%) | 0 (0) | .234 |
| Complications | | | | | | |
| Diabetes mellitus | 5 (11.1%) | 6 (15.8%) | .531 | 4 (9.5%) | 18 (30.5%) | **.012** |
| Hyperlipidemia | 6 (13.3%) | 11 (28.9%) | .079 | 8 (19.0%) | 15 (25.4%) | .451 |
| **PO6m outcome** | | | | | | |
| Flexion | | | | | | |
| Active | 161.7° (7.5) | 146.3° (11.1) | **<.001** | 159.0° (9.6) | 144.5° (12.8) | **<.001** |
| Passive | 168.3° (5.8) | 154.1° (17.3) | **<.001** | 165.8° (7.3) | 154.1° (10.2) | **<.001** |
| Abduction | | | | | | |
| Active | 163.9° (8.2) | 147.1° (12.9) | **<.001** | 160.1° (10.5) | 137.5° (18.9) | **<.001** |
| Passive | 169.3° (7.3) | 155.4° (11.6) | **<.001** | 165.8° (9.6) | 145.8° (17.4) | **<.001** |
| Ext rot 1 | | | | | | |
| Active | 54.6° (10.5) | 42.8° (13.9) | **<.001** | 52.5° (11.4) | 45.3° (15.1) | **.011** |
| Passive | 58.1° (11.1) | 45.8° (12.8) | **<.001** | 54.0° (11.3) | 47.9° (13.8) | **.019** |
| Ext rot 2 | | | | | | |
| Passive | 83.6° (8.9) | 75.8° (13.3) | **.007** | 79.0° (10.7) | 67.9° (15.5) | **<.001** |
| Int rot 2 | | | | | | |
| Passive | 54.0° (9.8) | 41.1° (12.7) | **<.001** | 50.9° (10.6) | 40.7° (16.5) | **<.001** |
| HBB | 8.3 (0.8) | 6.6 (1.4) | **<.001** | 8.1 (0.6) | 6.1 (1.9) | **<.001** |
| Constant | 74.7 (6.6) | 71.1 (7.7) | **.023** | 75.2 (6.5) | 68.2 (8.3) | **<.001** |
| DASH | 8.8 (8.3) | 10.2 (8.9) | .405 | 11.1 (12.2) | 12.4 (13.1) | .855 |

*ROM,* range of motion; *SD*, standard deviation; *SSP*, supraspinatus muscle; *ISP*, infraspinatus muscle *Ext rot 1*, external rotation at body side; *Ext rot 2*, external rotation at 90° abduction; *Int rot 2*, internal rotation at 90° abduction; *HBB*, hand-behind-back; *Constant*, Constant shoulder score; *DASH*, the Disabilities of the Arm, Shoulder, and Hand. A *P*-value of .05 or less was defined as significant (bold).

months postoperatively. Specifically, passive abduction was significant prognostic factor for all groups. Nakamura et al demonstrated that active elevation at 3 months postoperatively was a predictive factor for JOA score 2 years after ARCR and its cutoff value was 110°.[23] Similar to this study, Tonotsuka et al[32] reported that the patients with elevation more than 120° and external rotation more than 20° at 3 months postoperatively had better shoulder function at 2 years postoperatively. Although the similarity between the previous study and the present study was that the shoulder ROM at 3 months postoperatively influenced the subsequent improvement of ROM, the present study newly showed that passive abduction and internal rotation at 90° abduction position at 3 months postoperatively were extracted as prognostic factors of ROM recovery not only at 2 years but also at 6 months postoperatively. The ROM item of the Constant shoulder score using for grouping in this study consists of 4 directions, including flexion, abduction, external rotation and hand-behind-back, and 4 directions are scored equally unlike the scoring distribution in the ROM item of the JOA score. In the present study, although the AUC exceeded 0.7 for active and passive flexion ROM at 3 months postoperatively as well as passive abduction and internal rotation ROM, only passive abduction and internal rotation ROM were extracted as prognostic factors in the multivariable logistic regression analysis. Therefore, it was possible that passive abduction and internal rotation ROM may be more important for full recovery at 6 months postoperatively.

Good passive abduction ROM indicated that patients had sufficient soft tissue flexibility around the glenohumeral joint to allow the greater tuberosity of the humerus to pass smoothly under the acromion.[15] Posterior shoulder tightness caused deficits in shoulder internal rotation and horizontal adduction,[21,22] and anterosuperior translation of the humerus head, causing to subacromial impingement during elevation.[12] Thus, good internal rotation ROM might be associated with good elevation, the hand-behind-back and cross-body motion in activities of daily living. According to

**Table V**
Range of motion and shoulder functional score preoperatively and at 3 mo postoperatively in pregood and prelimitation.

| Mean (SD) | Pregood | | AUC | Cut off value | Prelimitation | | AUC | Cut off value |
|---|---|---|---|---|---|---|---|---|
| | Recovery | Nonrecovery | | | Recovery | Nonrecovery | | |
| **Preoperative** | | | | | | | | |
| Flexion | | | | | | | | |
| Active | 160.4 (8.6) | 147.1 (10.6) | **0.835** | **152.5**° | 122.3 (34.9) | 111.6 (27.8) | 0.626 | 137.5° |
| Passive | 165.2 (12.6) | 158.0 (21.9) | **0.735** | **162.5**° | 143.8 (24.5) | 132.8 (20.3) | 0.668 | 152.5° |
| Abduction | | | | | | | | |
| Active | 162.0 (10.8) | 153.6 (10.8) | **0.711** | **162.5**° | 89.3 (32.2) | 89.9 (30.4) | 0.506 | 87.5° |
| Passive | 168.0 (10.6) | 158.4 (11.5) | **0.739** | **162.5**° | 119.4 (31.8) | 109.8 (26.6) | 0.588 | 112.5° |
| Ext rot 1 | | | | | | | | |
| Active | 57.2 (17.2) | 51.3 (10.9) | 0.636 | 57.5° | 43.6 (12.9) | 41.7 (17.8) | 0.514 | 32.5° |
| Passive | 61.3 (14.6) | 54.6 (11.6) | 0.639 | 62.5° | 48.2 (12.6) | 46.4 (16.4) | 0.484 | 47.5° |
| Ext rot 2 | | | | | | | | |
| Passive | 85.6 (10.9) | 82.5 (10.9) | 0.579 | 87.5° | 70.7 (21.3) | 62.4 (22.7) | 0.610 | 67.5° |
| Int rot 2 | | | | | | | | |
| Passive | 52.7 (13.2) | 42.2 (20.9) | 0.671 | 47.5° | 45.3 (19.0) | 34.5 (20.7) | 0.658 | 37.5° |
| HBB | 8.3 (1.8) | 7.4 (1.8) | 0.659 | 8.9 | 6.1 (2.9) | 5.2 (2.3) | 0.613 | 7.0 |
| Constant | 66.8 (8.4) | 65.7 (8.8) | 0.545 | 63.4 | 46.9 (14.5) | 44.9 (15.5) | 0.542 | 49.0 |
| DASH | 19.4 (15.3) | 17.5 (14.7) | 0.547 | 18.2 | 30.5 (19.5) | 30.3 (18.6) | 0.505 | 25.9 |
| **PO3m** | | | | | | | | |
| Flexion | | | | | | | | |
| Active | 148.0 (11.7) | 137.4 (16.8) | **0.703** | **147.5**° | 147.0 (14.6) | 133.9 (16.7) | **0.744** | **142.5**° |
| Passive | 160.1 (7.1) | 151.9 (9.3) | **0.763** | **157.5**° | 159.1 (7.4) | 149.8 (11.9) | **0.737** | **155.5**° |
| Abduction | | | | | | | | |
| Active | 144.2 (19.0) | 127.9 (21.7) | **0.748** | **137.5**° | 137.4 (23.1) | 120.0 (26.1) | 0.692 | 137.5° |
| Passive | 153.6 (21.5) | 140.8 (15.9) | **0.788** | **152.5**° | 152.7 (15.3) | 135.2 (22.3) | **0.746** | **142.5**° |
| Ext rot 1 | | | | | | | | |
| Active | 47.1 (9.7) | 36.6 (13.5) | **0.722** | **42.5**° | 40.8 (11.1) | 37.3 (12.5) | 0.599 | 37.5° |
| Passive | 50.1 (10.9) | 40.3 (14.1) | 0.691 | 47.5° | 43.1 (10.7) | 40.8 (12.5) | 0.561 | 47.5° |
| Ext rot 2 | | | | | | | | |
| Passive | 74.7 (11.0) | 64.5 (16.1) | 0.696 | 72.5° | 68.5 (12.4) | 62.3 (14.8) | 0.607 | 67.5° |
| Int rot 2 | | | | | | | | |
| Passive | 44.2 (12.2) | 32.9 (11.7) | **0.749** | **37.5**° | 38.3 (12.0) | 31.5 (13.2) | **0.701** | **32.5**° |
| HBB | 5.9 (1.7) | 4.6 (1.9) | 0.685 | 4.9 | 6.1 (1.7) | 4.6 (2.2) | 0.698 | 5.1 |

*SD*, standard deviation; *AUC*, area under the curve; *Ext rot 1*, external rotation at body side; *Ext rot 2*, external rotation at 90° abduction; *Int rot 2*, internal rotation at 90° abduction; *HBB*, hand-behind-back; *Constant*, Constant shoulder score; *DASH*, the Disabilities of the Arm, Shoulder, and Hand.

**Table VI**
Independent prognostic factors and their predictive ability of full recovery of range of motion at 6 mo postoperatively in pregood and prelimitation group.

| Prognostic factors | OR | Cut off value | 95% CI | Upper | *P* value |
|---|---|---|---|---|---|
| | | | Lower | | |
| **Pregood group** | | | | | |
| Preactive flexion | **5.793** | 152.5° | 1.703 | 21.878 | **.006** |
| Prepassive abduction | **7.175** | 162.5° | 1.954 | 32.699 | **.005** |
| PO3m passive abduction | **4.488** | 152.5° | 1.313 | 16.920 | **.020** |
| PO3m passive int rot 2 | **7.900** | 37.5° | 2.151 | 36.171 | **.003** |
| **Prelimitation group** | | | | | |
| PO3m passive abduction | **4.058** | 142.5° | 1.363 | 13.281 | **.015** |
| PO3m passive int rot 2 | 2.765 | 32.5° | 0.899 | 9.153 | .081 |

*Pre*, preoperative*; PO*, postoperative*; OR*, odds ratio; *95% CI*, 95% confidence interval; *int rot 2*, internal rotation at 90° abduction position.

previous study, the strength of the repaired supraspinatus tendon gradually improved after 3 months postoperation.[9] Moreover, no difference in supraspinatus muscle activity was found between the healthy control and patients 3 months after ARCR.[13] Considering the above, it may be important to improve the passive shoulder motion, especially abduction and internal rotation, to their cutoff values by 3 months postoperatively to achieve a full recovery of ROM at 6 months postoperatively. Particularly, for the patients with preoperative limitation of ROM, 142° of passive abduction at 3 months postoperatively may be a goal in rehabilitation after ARCR.

Preoperative active flexion was a prognostic factor of full recovery at 6 months postoperatively in overall patients and in the pregood group but not in the prelimitation group. In other words, the influence of the preoperative ROM was different between the pregood and prelimitation groups. Preoperative ROM was reported to affect postoperative recovery of ROM after ARCR.[4,20,24] In contrast to previous studies showing that preoperative ROM affects postoperative ROM in the same motion,[20,24] the present study indicated that preoperative active flexion was the most prognostic factor for full ROM recovery in multiple directions at 6 months postoperatively. Although the proportion of participants with full recovery was not different between the 2 groups in the present study, the factors necessary to achieve good ROM recovery at 6 months postoperatively differed between the groups. In the pregood group, because the average preoperative ROM has already exceeded the target ROM at 3 months postoperatively, it is important to try to maintain the preoperative ROM after ARCR to prevent shoulder stiffness. On the other hand, in the prelimitation group, regardless of good or poor preoperative ROM, the goal would be to achieve a good passive abduction ROM at 3 months postoperatively.

During rehabilitation course after ARCR, there are a variety of patients as follows: who progress well from the preoperative to postoperative stage, those who do well preoperatively but develop limitations postoperatively, those who do poorly preoperatively but do well postoperatively, and those who continue to do poorly preoperatively and postoperatively.[4,20] Although clinical outcomes after ARCR are not evaluated solely by ROM, adequate postoperative ROM is an essential factor in reducing postoperative pain and difficulty with activities of daily living.[6] We believe that the relevant ROM factors and their cutoff values for each group to achieve good postoperative ROM improvement without retear of the repaired tendon shown in the present study would be helpful to clinicians in the rehabilitation after ARCR.

The limitations of this study should be considered. First, this study was conducted in a single center. A multicenter study would be necessary for external validity. Second, there were 2 different rotator cuff suture methods performed for the patients in the present study. However, there was no significant difference in the proportion of suturing methods between the recovery and non-recovery group, so its influence was likely to be minimal. Third, we used only the ROM item of the Constant shoulder score to classify groups in terms of the degree of postoperative recovery. It was possible that different results would have been obtained if other shoulder functional scores had been used for classifying groups. Fourth, there were few patients with large and massive rotator cuff tear. A previous study reported that postoperative ROM was affected by the tear size of the involved tendon, and patients with single tendon tear had better postoperative ROM than those with multiple tendon tears.[18] If there were more patients with large or massive cuff tear in the present study, the cutoff values of ROM for achieving full recovery at 6 months postoperatively might have been different from those in this study. Fifth, selection bias may have occurred because we excluded participants who were lost to follow-up or had missing preoperative or postoperative data. However, we did not consider the risk of selection bias to be high, since there were no significant differences between the present study data and all available data at each time point (*supplementary tables*). Sixth, in this study, multivariable analysis was performed by selecting variables in univariate using ROC curves, cutoff values, and correlation analysis for the purpose of calculating target values and avoiding multicollinearity. We considered the prognosis using cutoff values calculated from ROC curves to be clinically useful; however, there was a possibility of type 1 and 2 errors in this method. Finally, the duration and frequency of rehabilitation may have varied from patient to patient. The physiotherapist in charge of the patient consulted with the physician and determined the duration and frequency according to the patient's condition, which may have influenced the results.

## Conclusions

The present study investigated which direction of ROM was the best predictive factor for achieving good ROM recovery at 6 months postoperatively and examined their cutoff values in patients without retear after ARCR, and the influence of preoperative ROM on these predictive factors and cutoff values. Multivariable logistic regression analysis identified preoperative active flexion and 3 months postoperative passive abduction and internal rotation at 90° abduction ROM as prognostic factors for achieving full recovery of ROM at 6 months postoperatively. On the other hand, in the patients with preoperative ROM limitation, preoperative ROM was not a prognostic factor, and only passive abduction ROM at 3 months postoperatively was a predictive factor. It may be important to improve the soft tissue flexibility around the glenohumeral joint to allow the greater tuberosity of the humerus to pass smoothly under the acromion by 3 months after ARCR.

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## Supplementary data

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