

# Risk Factors for Loss of Active Shoulder Range of Motion in Massive Rotator Cuff Tears

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**Background:** Patients with massive rotator cuff tears often exhibit loss of active range of shoulder motion, which can interfere with activities of daily living. The risk factors for loss of motion remain largely unknown.

**Purpose:** To clarify the predictive factors that affect the range of motion in chronic massive rotator cuff tears using multivariate analyses.

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

**Methods:** The authors retrospectively reviewed 204 consecutive patients who were evaluated at their institution with chronic massive rotator cuff tears. In this study, the dependent variable was determined to be active anterior elevation limited to  $\leq 90^\circ$  or external rotation (ER) with the arm at the side limited to  $\leq 0^\circ$ . Explanatory variables included age; sex; affected side; duration of symptoms; smoking history; existence of diabetes, hypertension, or rheumatoid arthritis; involved tendons; presence of a 3-tendon tear; rupture of the long head of biceps tendon; superior migration of the humeral head; and cuff tear arthropathy. Baseline variables that were observed to be significant in the univariate analyses were included in multivariate models, which used logistic regression to identify independent predictors of loss of motion.

**Results:** Overall, 73 patients (35.8%) exhibited limited anterior elevation, and 27 (13.2%) exhibited limited ER. Multivariate analyses showed that inferior subscapularis tear (odds ratio [OR], 14.66; 95% CI, 2.95-72.93;  $P = .001$ ), smoking (OR, 4.13; 95% CI, 1.94-8.79;  $P < .001$ ), superior migration of humeral head (OR, 3.92; 95% CI, 1.80-8.53;  $P = .001$ ), and 3-tendon tear (OR, 3.29; 95% CI, 1.32-8.20;  $P = .011$ ) were significantly associated with the loss of anterior elevation. Teres minor tear (OR, 73.37; 95% CI, 9.54-564.28;  $P < .001$ ) and superior migration of the humeral head (OR, 3.55; 95% CI, 1.04-12.19;  $P = .044$ ) were significantly associated with loss of ER.

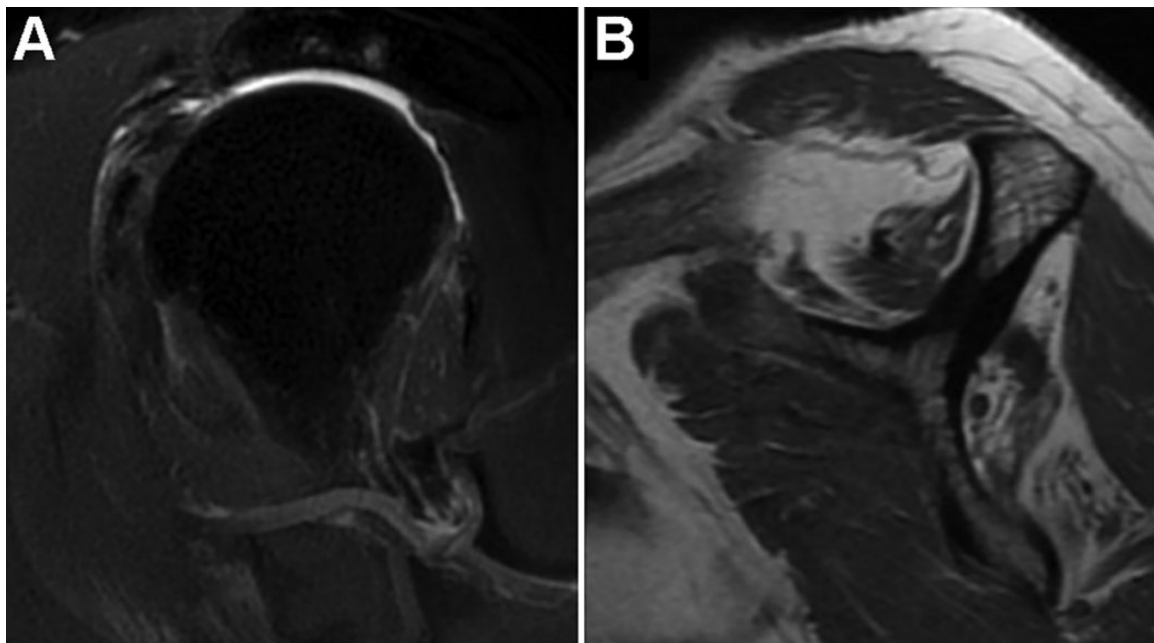
**Conclusion:** In the current study, a history of smoking, type of torn tendons, and superior migration of the humeral head were associated with loss of active shoulder motion. In particular, the status of inferior subscapularis or teres minor contributed to the onset of pseudoparalysis in massive rotator cuff tears.

**Keywords:** shoulder; massive rotator cuff tear; range of motion; pseudoparalysis; subscapularis; teres minor; superior migration; smoking

Massive rotator cuff tears have various tear patterns with a wide variety of symptoms and pathologies.<sup>6,7</sup> Patients with massive rotator cuff tears sometimes exhibit a loss of active range of shoulder motion with a preserved passive range of motion as a clinical presentation.<sup>7</sup> In particular, the inability to elevate the arm beyond  $90^\circ$  without limitation of passive motion or neurologic impairment is called pseudoparalysis.<sup>23</sup> Additionally, external rotation (ER) of the

shoulder is also greatly involved in activities of daily living, such as brushing the hair and washing the face; thus, the inability to achieve active ER of the adducted arm beyond  $0^\circ$  or  $30^\circ$  without stiffness and neurologic impairment is often defined as pseudoparalysis of ER.<sup>8,21</sup> Since pseudoparalysis severely interferes with activities of daily living,<sup>7,21</sup> it is important to identify the factors associated with a loss of range of motion in massive rotator cuff tears.

Few reports are available on the risk factors for loss of shoulder motion.<sup>2,6,19</sup> To date, fatty infiltration of the rotator cuff<sup>19</sup> and superior migration of the humeral head<sup>2</sup> have been reported to affect the loss of active shoulder range of



**Figure 1.** Magnetic resonance imaging (A) fat-suppressed T2-weighted oblique sagittal scan and (B) T1-weighted oblique sagittal scan of patients with massive rotator cuff tears. (A) We defined massive rotator cuff tears as when  $\geq 2$  tendons were involved. (B) We evaluated inferior subscapularis tear and teres minor tear based on the fatty infiltration into these muscles.

motion in patients with massive rotator cuff tear. In addition, Collin et al<sup>6</sup> divided the rotator cuff into 5 sections by differentiating the subscapularis (SSc) into superior SSc and inferior SSc and showed that a 3-tendon tear or an entire SSc tear is associated with pseudoparalysis of active shoulder elevation. Although multiple factors are thought to affect loss of shoulder motion in cases with massive rotator cuff tears, these factors have not been fully elucidated.

This study aimed to clarify the predictive factors affecting the active range of anterior elevation and ER in massive rotator cuff tears using multivariate analyses.

## METHODS

### Patients

This retrospective study was approved by the institutional review board of our institution. Informed consent was waived. A total of 214 patients from 2 institutions (a university hospital and a general hospital) who were diagnosed with massive rotator cuff tears between April 2011 and March 2021 were retrospectively reviewed. Based on a previous report,<sup>9,10</sup> a complete tear of  $\geq 2$  tendons in the rotator cuff, confirmed

using magnetic resonance imaging (MRI), was defined as a massive rotator cuff tear in this study (Figure 1A). The inclusion criterion was a chronic massive rotator cuff tear  $>6$  months after the onset of symptoms. The exclusion criteria were limited passive shoulder range of motion, septic arthritis of the shoulder, or history of a previous shoulder surgery.

### Outcome Measures

The dependent variables were the loss of active anterior elevation and ER. Based on the previous definition of pseudoparalysis,<sup>10</sup> we defined the active elevation of the shoulder limited to  $\leq 90^\circ$  and active ER at the side limited to  $\leq 0^\circ$  as loss of range of motion in this study. Explanatory variables included age; sex; affected shoulder side; duration of symptoms; smoking history; existence of diabetes, hypertension, and rheumatoid arthritis; kinds of involved tendon; presence of a 3-tendon tear<sup>6</sup>; rupture of the long head of biceps (LHB) tendon; superior migration of the humeral head; and cuff tear arthropathy (CTA).

Active anterior elevation and ER with the arm in  $0^\circ$  of abduction were evaluated in the upright position. Two orthopaedic surgeons (N.M. and S.O.) with  $>10$  years of

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experience in shoulder surgery assessed the range of shoulder motion using a goniometer; no residents or fellows were involved. Another examiner (R.F.) with 10 years of experience in shoulder surgery, who was blinded to the results of the range of shoulder motion, assessed the explanatory variables, including the medical history and the plain radiographic and MRI findings. Medical history was evaluated using past clinical notes. We defined superior migration of the humeral head as an acromiohumeral interval (AHI)  $\leq 6$  mm on plain radiograph in the standing or sitting position.<sup>17,22</sup> We defined CTA as cases where Hamada classification<sup>12</sup> type 4 or 5 arthritic changes were confirmed using plain radiographic images. Inferior fibers of the SSc and teres minor (TM) attach to the humerus as a muscle, and it is difficult to determine the presence of tear; therefore, inferior SSc and TM tears were defined as fatty infiltration into these muscles beyond Goutallier classification<sup>11</sup> grade 2.<sup>6</sup> Fatty infiltration of the rotator cuff was evaluated using T1-weighted sagittal oblique MRI immediately lateral to the attachment of the scapular spine to the body of the scapula (Figure 1B).<sup>8,15</sup> LHB tendon rupture was evaluated using axial T2-weighted MRI. Plain radiographs and MRI data were acquired within 3 months of the initial physical examination.

### Statistical Analysis

All statistical analyses were conducted using the SPSS software (Version 26.0; IBM Corp). In univariate analyses, we used Student *t* test to compare the average of continuous values (age and duration of symptoms), whereas chi-square test was used to compare the proportion of discrete variables (sex; affected side; history of trauma; smoking; medical history of diabetes, hypertension, and rheumatoid arthritis; type of involved tendons; presence of 3-tendon tear, LHB tendon rupture; superior migration of the humeral head; and CTA). Significant baseline variables in the univariate analyses were included in the multivariable models. Multivariate analyses were performed using logistic regression analysis to identify independent predictors of loss of active shoulder motion. Regression model fit was estimated using the Hosmer-Lemeshow goodness-of-fit test. The threshold for significance was set at  $P < .05$ .

## RESULTS

From the initial sample of 214 patients, 2 patients with a limited passive range of motion, 2 with septic arthritis of the shoulder, and 6 with a history of shoulder surgery were excluded from the study. Thus, 204 patients (111 women and 93 men) were ultimately included. The mean age of the study patients at the time of injury was  $72.6 \pm 8.9$  years (range, 45-89 years). The affected side was the right in 140 patients and the left in 64 patients. Three patients in the study, all of whom had a  $>2$ -month interval between the injection and the measurement, were treated with a corticosteroid injection before range of motion measurement. Supraspinatus (SSP) tendon tears were observed in 204 patients; infraspinatus (ISP) tendon tears, in 156 patients;

TABLE 1  
Patient Characteristics (N = 204)<sup>a</sup>

Characteristic	
Age, y	72.6 $\pm$ 8.9
Sex: female	111 (54.4)
Affected side: right	140 (68.6)
Duration of symptoms, y	3.0 $\pm$ 3.6
History of trauma	77 (37.7)
Diabetes	41 (20.1)
Hypertension	90 (44.1)
RA	12 (5.9)
3-tendon tear	66 (32.4)
LHB tendon rupture	60 (29.4)
Range of motion: elev, deg	109 $\pm$ 47
Range of motion: ER, deg	36 $\pm$ 24
Superior migration of humeral head	83 (40.7)
CTA	57 (27.9)

<sup>a</sup>Data are presented as mean  $\pm$  SD or No. of patients (%). CTA, cuff tear arthropathy; elev, anterior elevation; ER, external rotation; LHB, long head of biceps; RA, rheumatoid arthritis.

superior SSc tendon tears, in 99 patients; inferior SSc tears, in 18 patients; and TM tears, in 17 patients. Three or more tendons were involved in 66 patients (32.4%). LHB tendon ruptures were observed in 60 patients (29.4%). The mean ranges of active shoulder motion were  $109^\circ \pm 47^\circ$  (range,  $20^\circ$ - $180^\circ$ ) in anterior elevation and  $36^\circ \pm 24^\circ$  (range,  $40^\circ$ - $80^\circ$ ) in ER (Table 1). Active anterior elevation  $\leq 90^\circ$  was confirmed in 73 patients (35.8%), active ER  $\leq 0^\circ$  was confirmed in 27 patients (13.2%), and both active elevation  $\leq 90^\circ$  and ER  $\leq 0^\circ$  were confirmed in 15 patients (7.4%).

### Loss of Active Anterior Elevation

In the univariate analyses, smoking history ( $P < .001$ ), superior SSc tear ( $P = .012$ ), inferior SSc tear ( $P < .001$ ), 3-tendon tear ( $P < .001$ ), LHB tendon ruptures ( $P = .006$ ), and superior migration of the humeral head ( $P = .001$ ) were significantly associated with loss of active anterior elevation. A 3-tendon tear showed loss of anterior elevation in 38 of 66 patients (57.6 %).

Multivariate analysis showed that inferior SSc tear (OR, 14.66; 95% CI, 2.95-72.93;  $P = .001$ ), a history of smoking (OR, 4.13; 95% CI, 1.94-8.79;  $P < .001$ ), superior migration of the humeral head (OR, 3.92; 95% CI, 1.80-8.53;  $P = .001$ ), and a 3-tendon tear (OR, 3.29; 95% CI, 1.32-8.20;  $P = .011$ ) were risk factors for the loss of active anterior elevation (Table 2). The Hosmer-Lemeshow goodness-of-fit test showed no significant difference from good model fit ( $P = .957$ ).

### Loss of Active ER

In the univariate analyses, ISP tear ( $P = .009$ ), superior SSc tear ( $P = .035$ ), TM tear ( $P < .001$ ), 3-tendon tear ( $P = .006$ ), and superior migration of the humeral head ( $P < .001$ ) were significantly associated with loss of active ER. In particular, a 3-tendon tear including SSP, ISP, and TM showed a high rate of pseudoparalysis of ER (15 of 17 patients; 88.2%).

TABLE 2  
Univariate and Multivariate Predictors of Loss of Anterior Elevation<sup>a</sup>

Variable	Univariate Predictors			Multivariate Predictors	
	Elev $\leq 90^\circ$ (n = 73) <sup>b</sup>	Elev $> 90^\circ$ (n = 131) <sup>b</sup>	P	OR (95% CI)	P
Age, y	73.3 $\pm$ 10.4	72.3 $\pm$ 7.9	.491	—	—
Sex, female/male	45/28	66/65	.122	—	—
Affected side, right/left	47/26	93/38	.330	—	—
Duration of symptoms, y	2.6 $\pm$ 2.5	3.3 $\pm$ 4.1	.162	—	—
Trauma	26	50	.718	—	—
Smoking	35	31	<b>&lt;.001</b>	4.13 (1.94-8.79)	<b>&lt;.001</b>
Diabetes	18	23	.225	—	—
Hypertension	36	50	.122	—	—
RA	4	8	.855	—	—
ISP tear	57	99	.685	—	—
Superior SSc tear	44	55	<b>.012</b>	1.16 (0.51-2.62)	.729
Inferior SSc FI	16	2	<b>&lt;.001</b>	14.66 (2.95-72.93)	<b>.001</b>
TM FI	8	9	.311	—	—
3-tendon tear	38	28	<b>&lt;.001</b>	3.29 (1.32-8.20)	<b>.011</b>
LHB tendon rupture	30	30	<b>.006</b>	0.60 (0.25-1.46)	.266
Superior migration of humeral head	41	42	<b>.001</b>	3.92 (1.80-8.53)	<b>.001</b>
CTA	24	33	.241	—	—

<sup>a</sup>Bolded *P* values indicate statistical significance ( $P < .05$ ). Dashes indicate no analyses performed. CTA, cuff tear arthropathy; Elev, anterior elevation; FI, fatty infiltration; ISP, infraspinatus; LHB, long head of biceps; OR, odds ratio; RA, rheumatoid arthritis; SSc, subscapularis; TM, teres minor.

<sup>b</sup>Data in these columns are presented as mean  $\pm$  SD or No. of patients.

TABLE 3  
Univariate and Multivariate Predictors of Loss of ER<sup>a</sup>

Variable	Univariate Predictors			Multivariate Predictors	
	ER $\leq 0^\circ$ (n = 27) <sup>b</sup>	ER $> 0^\circ$ (n = 177) <sup>b</sup>	P	OR (95% CI)	P
Age, y	71.4 $\pm$ 8.8	72.9 $\pm$ 8.9	.438	—	—
Sex, female/male	18/9	83/84	.170	—	—
Affected side, right/left	22/5	118/59	.122	—	—
Duration of symptoms, y	3.5 $\pm$ 3.9	3.0 $\pm$ 3.6	.501	—	—
Trauma	13	63	.209	—	—
Smoking	7	59	.444	—	—
Diabetes	4	37	.462	—	—
Hypertension	13	73	.499	—	—
RA	0	12	.163	—	—
ISP tear	26	130	<b>.009</b>	1.64 (0.10-27.58)	.730
Superior SSc tear	8	91	<b>.035</b>	0.58 (0.06-5.29)	.628
Inferior SSc FI	2	16	.781	—	—
TM FI	15	2	<b>&lt;.001</b>	73.37 (9.54-564.28)	<b>&lt;.001</b>
3-tendon tear	15	51	<b>.006</b>	1.64 (0.10-27.58)	.730
LHB tendon rupture	7	53	.670	—	—
Superior migration of humeral head	21	62	<b>&lt;.001</b>	3.55 (1.04-12.19)	<b>.044</b>
CTA	11	46	.112	—	—

<sup>a</sup>Bolded *P* values indicate statistical significance ( $P < .05$ ). Dashes indicate no analyses performed. CTA, cuff tear arthropathy; ER, external rotation; FI, fatty infiltration; ISP, infraspinatus; LHB, long head of biceps; OR, odds ratio; RA, rheumatoid arthritis; SSc, subscapularis; TM, teres minor.

<sup>b</sup>Data in these columns are presented as mean  $\pm$  SD or No. of patients.

In the multivariate analysis, TM tear (OR, 73.37; 95% CI, 9.54-564.28;  $P < .001$ ) and superior migration of the humeral head (OR, 3.55; 95% CI, 1.04-12.19;  $P = .044$ ) were risk factors for the loss of active ER (Table 3). The Hosmer-Lemeshow goodness-of-fit test showed no significant difference from good model fit ( $P = .979$ ).

## DISCUSSION

In this study, we conducted a multivariate analysis to clarify the predictive factors affecting active range of motion in massive rotator cuff tears. As a result, this study identified smoking history, inferior SSc tear, 3-tendon tear, and

superior migration of the humeral head as risk factors for the loss of anterior elevation. On the other hand, TM tear and superior migration of the humeral head were identified as risk factors for the loss of ER.

The present study revealed that inferior SSc tear had a significant influence on the range of active anterior elevation in massive rotator cuff tears. The upper two-thirds and lower one-third of the SSc are known to adhere to the lesser tuberosity as a tendon and muscle, respectively,<sup>5,14</sup> and these 2 fibers are also innervated by different nerves; the former is controlled by the upper subscapular nerves, while the latter is controlled by the lower subscapular nerves. Therefore, superior and inferior SSc are thought to have different functions.<sup>6</sup> A recent analysis using electromyograms showed that inferior SSc activity was significantly greater than that of superior SSc during flexion and abduction of the shoulder and was particularly activated in the initial stage of elevation,<sup>24</sup> suggesting a major role of the inferior SSc in the initial stage of shoulder elevation. In a past clinical study,<sup>6</sup> while patients with SSP tears and superior SSc tears were not found to have pseudoparalysis, a significantly larger proportion (80%) of patients with SSP tears and superior and inferior SSc tears were found to have pseudoparalysis. Furthermore, Rhee et al<sup>19</sup> reported that patients with pseudoparalysis had significantly more severe atrophy of the inferior SSc than did those without pseudoparalysis. These findings and our results suggest that rupture and fatty infiltration of the inferior SSc, which play major roles in the initial stage of anterior elevation, may lead to decreased muscle strength in anterior elevation and contribute to the occurrence of pseudoparalysis.

In addition, a 3-tendon tear was also identified as a risk factor for loss of elevation in this study. In this study, a 3-tendon tear showed a high rate (57.6%) of pseudoparalysis. Collin et al<sup>6</sup> divided the rotator cuff into 5 sections by differentiating the SSc into superior SSc and inferior SSc and showed that pseudoparalysis was highly observed in patients with 3-tendon (SSP + superior SSc + inferior SSc, SSP + superior SSc + ISP, or SSP + ISP + TM) tears. The present results were consistent with past literature and indicated the importance of preventing the progression from a 2-tendon tear to a 3-tendon tear for preservation of active elevation in the management of the massive rotator cuff tears.

The relationship between smoking and the range of shoulder motion in patients with massive rotator cuff tears has not been clarified, but a possible hypothesis can be proposed. Smoking has been reported to be associated with the development of rotator cuff tears and tear size in a dose-dependent manner.<sup>1,4</sup> As a mechanism underlying this association, nicotine in tobacco, which functions as a vasoconstrictor that decreases oxygen supply to the tendons, has been proposed to cause degeneration of tendons.<sup>4</sup> In fact, smokers have been reported to have poor tendinosis grades in the rotator cuff.<sup>18</sup> These findings raise the possibility that larger tear sizes and more advanced degeneration of tendons in smokers affected the loss of range of shoulder motion. However, the mechanism of loss of elevation in patients with a massive rotator cuff tear and a

smoking history remains unclear, and further studies are necessary to clarify this relationship.

TM tear was identified as a risk factor for loss of ER at the sides in this study. In ER at the sides, the ISP mainly takes on this role. In a previous report, fatty infiltration to the ISP at Goutallier grade  $\geq 3$  was significantly associated with the loss of ER at the sides.<sup>2</sup> While ISP is thought to take on ER at the sides, ER at abduction is associated with dysfunction of TM, which is regarded as a compensatory muscle for ISP.<sup>3</sup> An analysis using MRI confirmed a high prevalence (48%-54%) of compensatory hypertrophy of TM in patients with ISP tears, presumably for compensation for the reduced range of ER.<sup>13</sup> In a clinical study, compensatory TM hypertrophy yielded lower failure rates for non-operative treatment within 1 year in patients with massive rotator cuff tears involving SSP and ISP tears.<sup>25</sup> In a different clinical study, patients with SSP, ISP, and TM tears were evaluated with significant decreases in the range of motion not only for ER at 90° of abduction but also for ER at 0° of abduction compared with patients who only had SSP and ISP tears.<sup>6</sup> These findings suggest that TM status contributes to the functional outcomes in patients with SSP and ISP tears. In the present study, 28 out of 155 patients (18.1%) with SSP and ISP tears were evaluated with pseudoparalysis of ER; however, patients with TM tears in addition to SSP and ISP tears were evaluated with pseudoparalysis of ER even more frequently (15 of 17 patients; 88.2%). Therefore, the presence of TM tear in addition to SSP and ISP tear is thought to be a strong predictor of the decrease of ER.

Superior migration of the humeral head was associated with loss of both elevation and ER in this study. Narrowing of the AHI, indicating superior migration of the humeral head, was thought to reflect the presence of rotator cuff tears, especially multiple-tendon rotator cuff tears involving the ISP.<sup>17,20</sup> In a previous study, patients with massive rotator cuff tears and a reduced range of motion in elevation and ER had a significantly narrower AHI than did patients with massive rotator cuff tears without a reduction in the range of motion.<sup>2</sup> The underlying mechanism is unknown; however, since the percentage of patients with superior migration of the humeral head increased as the stage of fatty infiltration of the SSP and ISP advanced,<sup>17</sup> superior migration of the humeral head may reflect severe fatty infiltration of the involved muscle and long duration from the onset of tendon rupture, which can explain the reduction of the range of anterior elevation and ER in this study. Additionally, the results of this study suggested that superior migration of the humeral head may reflect poor function of the remaining musculature.

This study had some limitations. First, since this was an observational study, there might be effects of residual confounding due to possible bias from intergroup differences in factors that were not measured. For example, the duration of symptoms had no effect on the range of shoulder motion in this study; however, patients underwent various treatments before visiting our hospital, including follow-up observation, rehabilitation, and pharmacotherapy. These variations might have had an effect on the range of motion. In addition, since the range of motion was

measured by 2 shoulder surgeons, bias due to interexaminer discrepancy is possible. Moreover, since this was a retrospective study, the data for factors that also might have affected the range of shoulder motion, such as body mass index and arm dominance, could not be obtained.

A second limitation was that superior migration of the humeral head was defined as AHI  $\leq 6$  mm in this study; however, we did not quantitatively evaluate the relationship between the degree of superior migration and range of motion. We also did not evaluate the dose dependence or time dependence of the relationship between smoking history and range of motion. Third, a previous study has shown that the pain of rotator cuff tears improved within 6 months of nonoperative management<sup>16</sup>; therefore, we included patients with chronic massive rotator cuff tears at  $>6$  months after the onset of symptoms in order to minimize the likelihood of limiting the range of motion due to pain. However, since we did not perform a lidocaine test, we might not have completely excluded such cases. Finally, patients were mainly evaluated at our institution for the purpose of surgical intervention. Thus, there were fewer cases of asymptomatic massive rotator cuff tears and more cases of massive rotator cuff tears with pseudoparalysis in this study, which may decrease the generalizability of our findings.

## CONCLUSION

Our results demonstrated that several factors, including smoking history, type of torn tendons, and superior migration of the humeral head, were reciprocally associated with loss of active shoulder motion. In particular, the status of inferior SSc or TM contributed to the onset of pseudoparalysis in massive rotator cuff tears.

## REFERENCES

- Baumgarten KM, Gerlach D, Galatz LM, et al. Cigarette smoking increases the risk for rotator cuff tears. *Clin Orthop Relat Res*. 2010; 468(6):1534-1541. doi:10.1007/s11999-009-0781-2
- Berhouet J, Collin P, Benkalfate T, et al. Massive rotator cuff tears in patients younger than 65 years: epidemiology and characteristics. *Orthop Traumatol Surg Res*. 2009;95(4 suppl 1):S13-S18. doi:10.1016/j.otsr.2009.03.006
- Burkhart SS. Arthroscopic treatment of massive rotator cuff tears: clinical results and biomechanical rationale. *Clin Orthop Relat Res*. 1991;267:45-56.
- Carbone S, Gumina S, Arceri V, Campagna V, Fagnani C, Postacchini F. The impact of preoperative smoking habit on rotator cuff tear: cigarette smoking influences rotator cuff tear sizes. *J Shoulder Elbow Surg*. 2012;21(1):56-60. doi:10.1016/j.jse.2011.01.039
- Cleeman E, Brunelli M, Gothelf T, Hayes P, Flatow EL. Releases of subscapularis contracture: an anatomic and clinical study. *J Shoulder Elbow Surg*. 2003;12(3):231-26. doi:10.1016/s1058-2746(02)00035-6
- Collin P, Matsumura N, Lädermann A, Denard PJ, Walch G. Relationship between massive chronic rotator cuff tear pattern and loss of active shoulder range of motion. *J Shoulder Elbow Surg*. 2014;23(8): 1195-1202. doi:10.1016/j.jse.2013.11.019
- Cvetanovich GL, Waterman BR, Verma NN, Romeo AA. Management of the irreparable rotator cuff tear. *J Am Acad Orthop Surg*. 2019; 27(24):909-917. doi:10.5435/JAAOS-D-18-00199
- Fuchs B, Weishaupt D, Zanetti M, Hodler J, Gerber C. Fatty degeneration of the muscles of the rotator cuff: assessment by computed tomography versus magnetic resonance imaging. *J Shoulder Elbow Surg*. 1999;8(6):599-605. doi:10.1016/s1058-2746(99)90097-6
- Gerber C, Fuchs B, Hodler J. The results of repair of massive tears of the rotator cuff. *J Bone Joint Surg Am*. 2000;82(4):505-515. doi:10.2106/0004623-200004000-00006
- Gerber C, Wirth SH, Farshad M. Treatment options for massive rotator cuff tears. *J Shoulder Elbow Surg*. 2011;20(2 suppl): S20-S29. doi:10.1016/j.jse.2010.11.028
- Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures: pre- and postoperative evaluation by CT scan. *Clin Orthop Relat Res*. 1994;304:78-83.
- Hamada K, Yamanaka K, Uchiyama Y, Mikasa T, Mikasa M. A radiographic classification of massive rotator cuff tear arthritis. *Clin Orthop Relat Res*. 2011;469(9):2452-2460. doi:10.1007/s11999-011-1896-9
- Kikukawa K, Ide J, Kikuchi K, Morita M, Mizuta H, Ogata H. Hypertrophic changes of the teres minor muscle in rotator cuff tears: quantitative evaluation by magnetic resonance imaging. *J Shoulder Elbow Surg*. 2014;23(12):1800-1805. doi:10.1016/j.jse.2014.03.014
- Klapper RC, Jobe FW, Matsuura P. The subscapularis muscle and its glenohumeral ligament-like bands: a histomorphologic study. *Am J Sports Med*. 1992;20(3):307-310. doi:10.1177/036354659202000312
- Kuzel BR, Grindel S, Papandrea R, Ziegler D. Fatty infiltration and rotator cuff atrophy. *J Am Acad Orthop Surg*. 2013;21(10):613-623. doi:10.5435/JAAOS-21-10-613
- Merolla G, Paladini P, Saporito M, Porcellini G. Conservative management of rotator cuff tears: literature review and proposal for a prognostic. Prediction score. *Muscles Ligaments Tendons J*. 2011;1(1): 12-19.
- Nové-Josserand L, Edwards TB, O'Connor DP, Walch G. The acromiohumeral and coracohumeral intervals are abnormal in rotator cuff tears with muscular fatty degeneration. *Clin Orthop Relat Res*. 2005; 433:90-96. doi:10.1097/01.blo.0000151441.05180.0e
- Park JH, Oh KS, Kim TM, et al. Effect of smoking on healing failure after rotator cuff repair. *Am J Sports Med*. 2018;46(12):2960-2968. doi:10.1177/0363546518789691
- Rhee YG, Cho NS, Song JH, Park JG, Kim TY. Volumetric evaluation of the rotator cuff musculature in massive rotator cuff tears with pseudoparalysis. *J Shoulder Elbow Surg*. 2017;26(9):1520-1526. doi:10.1016/j.jse.2017.03.017
- Siow MY, Mitchell BC, Hachadorian M, et al. Association between rotator cuff tears and superior migration of the humeral head: an MRI-based anatomic study. *Orthop J Sports Med*. 2021;9(6): 23259671211009846.
- Tokish JM, Alexander TC, Kissenberth MJ, Hawkins RJ. Pseudoparalysis: a systematic review of term definitions, treatment approaches, and outcomes of management techniques. *J Shoulder Elbow Surg*. 2017;26(6):e177-e187. doi:10.1016/j.jse.2017.02.024
- Werner CM, Conrad SJ, Meyer DC, Keller A, Hodler J, Gerber C. Interobserver agreement and interobserver correlation of radiologic acromiohumeral distance measurements. *J Shoulder Elbow Surg*. 2008;17(2):237-240. doi:10.1016/j.jse.2007.06.002
- Werner CM, Steinmann PA, Gilbert M, Gerber C. Treatment of painful pseudoparesis due to irreparable rotator cuff dysfunction with the Delta III reverse-ball-and-socket total shoulder prosthesis. *J Bone Joint Surg Am*. 2005;87(7):1476-1486. doi:10.2106/JBJS.D.02342
- Wickham J, Pizzari T, Balster S, Ganderton C, Watson L. The variable roles of the upper and lower subscapularis during shoulder motion. *Clin Biomech (Bristol Avon)*. 2014;29(8):885-891. doi:10.1016/j.clinbiomech.2014.07.003
- Yoon TH, Kim SJ, Choi CH, Yoon SP, Chun YM. An intact subscapularis tendon and compensatory teres minor hypertrophy yield lower failure rates for non-operative treatment of irreparable, massive rotator cuff tears. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(10): 3240-3245. doi:10.1007/s00167-019-05403-8