Comparison of scapular upward rotation during arm elevation in the scapular plane in healthy volunteers and patients with rotator cuff tears pre- and post-surgery.

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ABSTRACT

Background: Function loss caused by rotator cuff tears alters the scapular orientation, however, few prior studies have reported on scapular movements after rotator cuff repair. The purpose was to determine the scapular orientations before and after rotator cuff repair.

Methods: We recruited 14 healthy controls, 10 small and six massive rotator cuff tear in patients. The scapular upward rotation during arm elevation was analyzed using fluoroscopic imaging.

Findings: Before surgery, both rotator cuff groups demonstrated greater scapular upward rotation compared to healthy controls. Two months postoperation, the analyses showed significant differences between the patients with small rotator cuff tears and healthy controls at arm elevations of 90°, and between patients with both rotator cuff tear groups and healthy controls at arm elevations of 120°. At five months post-operation, significant differences still existed between the healthy controls and both rotator cuff groups. In regard to the temporal effects in the patients with small rotator cuff tearss, the scapular upward rotation decreased significantly over time (2-5 months postoperation) at arm elevations of 120°. We did not identify a main effect owing to time in the patients with massive rotator cuff tears.

Interpretation: In patients with small rotator cuff tears, scapular upward rotation was reduced over the period of 2–5 months postoperation, however, the patients with massive rotator cuff tears showed greater scapular upward rotation throughout the experimental period. The results suggested that the execution of the rehabilitation program should consider that the tear size could affect scapular motion.

Keywords: Rotator cuff tear, Scapular kinematics, Tear size, 2D/3D registration technique

1. Introduction

Rotator cuff tears (RCT) occur in 25-50% of the people who are more than 60 years old (Milgrom et al., 1995; Yamamoto et al., 2010). In these cases, the tear size, muscle atrophy, and fatty degenerations of torn rotator cuff muscles worsen with time (Björkenheim, 1989; Melis et al., 2010; Nakagaki et al., 1994; Safran et al., 2011., Zingg et al., 2007), and a surgical procedure is thus the optimal remedy. Previous studies reported that the clinical outcomes after rotator cuff repairs were good or excellent (Deniz et al., 2014; Galatz et al., 2004; Nobuhara et al., 1994; Wolf et al., 2004), however, there were a few studies that reported on the scapular kinematics after operation. Paletta et al. (1997) reported that 86% of the RCT patients demonstrated normal glenohumeral-scapulothoracic motion during shoulder abduction two years after the operation, and Kolk et al. (2016) reported that scapular lateral and upward rotations during shoulder abduction were normalized one year after rotator cuff repair in small-sized and middle-sized RCT patients. Thus, these studies clarified that a period of approximately one to two years after surgery would be required for RCT to improve the scapular movements during the arm elevation to a normal level. However, it was not clear whether shoulder kinematics could normalize within one year postoperation (postop). In regard to the biological aspects, the remodeling process of the insertion occurred 5-6 months after implantation (McCormack et al., 2014; Uhthoff et al., 2000). Hence, scapular kinematics may be restored during this period along with the biological recovery.

In addition, patients with massive RCT showed poor integrity and severe atrophy of rotator cuff muscles, thereby resulting in unsatisfactory clinical outcomes and high rates of recurrent tearing after surgery (Deniz et al., 2014; Gladstone et al., 2007). Therefore, the clarification of the restoration process of the shoulder function in the case of massive RCT and after repair of the rotator cuff muscles is thus needed. Scibek et al. (2009) reported the increased reliance on scapular contributions to overall humeral elevation with increasing rotator cuff tear size, however, there were no available data on scapular movements in massive RCT postoperatively.

The purpose of our study was to identify the recovery process of scapular upward rotation in the RCT patients within five months after surgery. Secondly, we aimed to clarify the difference in the scapular upward rotation with increases in the rotator cuff tear size postoperatively. We hypothesized that scapular movements in patients with small RCTs could normalize for the arm elevation range of 30–90° five months post-surgery owing to the occurrence of the remodeling phase (McCormack et al., 2014; Via et al., 2013). The improvement in the supraspinatus muscle strength and relief from subacromial pain could contribute to the normalization of scapular kinematics. Conversely, we expected that adequate restoration of scapular kinematics could not be observed in the overall arm elevation in patients with massive RCTs five months post-surgery because the fatty degeneration of rotator cuff muscles does not improve even after a successful rotator cuff repair, as reported by a previous study (Deniz et al., 2014; Gladstone et al., 2007). Therefore, excessive contraction of the deltoid or upper fiber of the trapezius muscle to recover the function of the rotator cuff muscles.

2. Methods

2.1. Participants

We recruited 14 healthy men without any shoulder pain and 21 male patients who were diagnosed with RCT and underwent surgery at Nobuhara Hospital (Hyogo, Japan) from June 2014 to June 2016. The patients were excluded if they could not elevate their arms by more than 120° in the scapular plane, or if they suffered from comorbid disease of the cervical spine, or rheumatoid arthritis. Additionally, two patients with re-tears of rotator cuffs after surgery, and three patients who lost contact within five months after surgery owing to the completion of the treatment, were not enrolled in this study. Therefore, the studied group included 16 patients, which were divided into two groups in accordance to the tear size. Massive tear is defined as the conditions that L×H is more than 5.6 cm^2 (where L is the length of the tear region at the attachment site of the tendon and H is the depth to the tendon end; two or more tears are present and the diameter of exposed humeral head is more than 3cm or the circumstance of the ruptured region is more than 9 cm) (Nobuhara, 2003). The small RCT group consisted of 10 patients {mean age, 62.7 years; 8 patients with full-thickness tear of the supraspinatus (SSP), and two patients with partial-tear of the thickness of the SSP}, and the massive RCT group which consisted of six patients {mean age, 64.5 years; six patients with full-thickness tears of the SSP, infraspinatus (ISP), and subscapularis (SSC) muscles}(Table 1). Before the surgery, all patients received medical treatment including steroid injections, medication, or rehabilitation at an orthopedic hospital. This study was approved by the governing Institutional Review Board, and informed consent was obtained from all subjects before participation.

2.2. Surgical procedure and Rehabilitation

All the RCT were surgically treated by open rotator cuff repairs with the McLaughlin procedure, and physical therapists started the rehabilitation program on the day after surgery with finger, wrist, and elbow exercises. At four days, gentle passive exercises of shoulder elevation and external rotation were initiated. Since the SSP or ISP muscles had been treated, aggressive shoulder internal rotation and extension stretching were avoided within the period spanning 6-8 weeks after operation. In order to strengthen the rotator cuff muscles, active shoulder exercises were initiated without any gravity forces at three weeks, and gravity load exercises began at six weeks. In the case of the massive RCT patients with severe atrophy or degeneration of the torn rotator cuff, rehabilitation program was delayed for 1-2 weeks. The patients were permitted to perform activities during their daily lives after 2-3 months using their involved arms, and to engage in sports activities or heavy physical works after 5-6 months. A physical therapist with 11 years of experience was involved with the rehabilitation in 14 patients, while each of the other two patients received rehabilitation from physical therapists with 13 and 20 years experiences, respectively.

2.3. Data collection

Motion analyses were performed using fluoroscopic movies (Stenoscop 6000, GE Medical Systems, Chicago, America) at 30 Hz while subjects elevated their arms in the scapular plane at a rate of 5 s per cycle along with the use of the metronome. Subjects sat perpendicular to the fluoroscopy to minimize the measurement errors and were instructed to elevate their arms from a resting position to the maximum they could reach. The scapular plane was set up in the corresponding arm-dependent positions by the physical therapist and a pole was placed along this scapular plane. The subjects were asked to elevate their arms three times, and the data collected during the third repetition was used for the analysis. Before the trial, the subjects practiced this arm elevation movement several times to prevent excessive trunk motion with instructions from physical therapists. The motion analyses for the RCT patients was performed in the preoperational stage, at two months, and five months after surgery. CT (Multislice CT ECLOS, Hitachi Healthcare Ltd, Chiba, Japan) scans were conducted to reconstruct the three-dimensional images of the humerus and scapula using a commercially available software program (Mimics 14, Materialise Inc., Leuven, Belgium). To achieve this, we used acquired images from the fluoroscopic movies at 30° arm elevation increments. The contour lines of the humerus and scapula were then extracted manually and the three-dimensional bone models from the CT data were matched with the fluoroscopic images using a two dimensional/three dimensional (2D/3D) registration technique (Figure 1).

2.4. Data processing

The calibration frame was set perpendicular to the fluoroscopic image system and recorded by fluoroscopy to create the global coordinate system. Humerus and scapular coordinate systems were set to calculate scapular upward rotation during arm elevation, as recommended by the International Society of Biomechanics (Wu et al., 2005). In the set coordinate system for the humerus, the origin matched the center of the humeral head and the Y-axis line was determined along the direction of the vector pointing from the origin to the midpoint of the medial and lateral epicondyles. The X-axis line was vertical to the plane formed by the center, and medial and lateral epicondyles. The Z-axis was calculated by the vectorial outer product of the unit vectors along the X- and Y-axes. The center of the humerus was computed by the spherical approximation of the surface in the humeral head. In the scapular coordinate system, the origin was coincident with the acromial angle, and the Z-axis line was determined by the vector from the medial extent of the scapular spine to the acromial angle. The X-axis line was vertical to the plane formed by the acromial angle, the medial extent of scapular spine, and the inferior angle of the scapula. The Y-axis was calculated by the outer vectorial product of the Z- and X-axes. The scapular upward rotation was calculated using the Euler angles that expressed the rotation of the humeral coordinate system to the scapular coordinate system. Each scapular angle was analyzed based on the angle subtended at the corresponding arm-dependent position. Additionally, shoulder elevation angle was determined by the fluoroscopic images manually. And, we reconfirmed the shoulder elevation angle using the rotation of humerus coordinate system relative to the global coordinate system after the registration process. The humeral root-mean-square orientation error was 3.7° and the mean-square position error was 1.8 mm. Correspondingly, the scapular root-mean-square error of the orientation was 1.7° and the mean-square error of position was 1.0 mm. The root-mean-square error of the orientation of the humerus with respect to the scapula was 3.9°, and the mean-square error of position was 2.5 mm.

2.5.Statistical analysis

Two-way Analysis of variance (ANoVA) was used to compare the scapular upward rotation before and after surgery among these groups, and *post hoc* analyses were performed using the Tukey test when required. To investigate the influence of time (preoperation, two months and five months after surgery) on the scapular kinematics in each RCT group, we used repeated measures, and *post hoc* Tukey tests were used for further significant testing. In this study, we analyzed the effects of group and time on the scapular kinematics, and the statistical analyses were conducted without the effect of arm position. Statistical significance was set at $P < 0.05$.

3. **Results**

The scapular upward rotation angle among the three studied groups at preoperation (preop), two months after surgery, and five months after surgery, are presented in Table 2.

3.1. Scapular upward rotation preoperatively

Comparing the scapular upward rotation among the healthy controls and RCT groups before surgery, there was no interaction effect for the group×arm position ($P = 0.44$). We found that the main effect was attributed to the group ($P < 0.01$) and that there were significant differences between the healthy controls and small RCT patients ($P < 0.01$), and between the healthy controls and massive RCT patients ($P < 0.01$). No significant difference was observed between the two RCT groups ($P = 0.17$)(Figure 2).

3.2. Scapular upward rotation at two months after surgery

The analysis of the scapular upward rotation among the healthy controls and RCT groups two months postope showed an interaction effect for the group×arm position ($P = 0.03$). We did observe a main effect for the group ($P < 0.01$). *Post hoc* analyses indicated significant differences in the scapular upward at a 90° arm elevation (P = 0.04), while the small RCT patients showed greater scapular upward rotation compared to the healthy controls (mean values of healthy controls *vs.* small RCT: 34.2° *vs.* 40.7°, P = 0.02). Conversely, there were no significant differences between the healthy controls and massive RCT patients (P = 0.36), and between the RCT groups (P = 0.98). *Post hoc* analyses also identified significant differences in the scapular upward rotation at an arm elevation of 120°, and both RCT groups demonstrated greater scapular upward rotation compared to the healthy controls (mean values of healthy controls *vs.* small RCT, massive RCT: 48.2° *vs.* 61.2°, 61.3°, P < 0.01)(Figure 3).

3.3.Scapular upward rotation at five months after surgery

For the comparison of the scapular upward rotation among the healthy controls and RCT groups five months after surgery, we noted no interaction effect for the group×arm position (P = 0.76), there was a main effect for the group (P < 0.01). Significant differences were found between the healthy controls and small RCT patients (P = 0.04), and between the healthy controls and massive RCT patients (P < 0.01). However, there were not any significant differences between the RCT groups (P = 0.48)(Figure 4).

3.4. Scapular upward rotation in each RCT group

The investigation of the temporal influences on the scapular upward rotation in the small RCT patients indicated that the main effect was observed at an arm elevation of 120° (P = 0.01), and the mean values of scapular upward rotation decreased significantly over time from 61.2° at two months after surgery to 52.4° at five months after surgery (P = 0.01). We did not identify a main effect owing to time at all arm elevation angles in the massive RCT patients.

4. Discussion

This study examined the scapular upward rotation during arm elevations in small and massive RCT patients before surgery, two months postop, and at five months postop. As a result, the small RCT patients demonstrated greater scapular upward rotation before and at two months after surgery, compared with the healthy controls. Furthermore, excessive scapular upward rotation decreased at two to five months postop although the scapular movement did not recover to the same level as that of the healthy controls. To the best of our knowledge, this is the first study to show the scapular kinematics outcomes of the RCT patients before surgery and within a period less than five months postop.

Our study clarified that the small and massive RCT patients showed greater scapular upward rotation than that of the healthy controls. Previous studies have reported that the small and massive RCT patients yielded greater scapular upward rotations during arm elevations compared to the healthy controls (Scibek et al., 2009; Mell et al., 2005), Conversely, some studies have reported there were not any significant differences of scapular movements during arm elevation between the healthy controls and RCT patients. The results of these studies are controversial because of the static analyses, two-dimensional measurements, and small sample sizes (Paletta et al., 1997; Kijima et al., 2015; Ohl et al., 2015; Yamaguchi et al., 2000). The hypofunction of torn rotator cuff muscles and pain might cause greater scapular upward rotation during arm elevation in the RCT patients before surgery. Casterlein et al. (2017) reported that experimental shoulder pain induced by the injection of hypertonic saline in the SSP reduced the activity of the ISP during arm elevation. McCully et al. (2006) also demonstrated that the suprascapular nerve block is an appropriate model of dysfunction of the SSP and ISP with increased scapular upward rotation and external rotation during arm elevation in the scapular plane. These results indicated that dysfunction and pain of the rotator cuff muscles might have induced greater scapular upward rotation motions during arm elevations in the RCT patients before surgery in our study.

The greater scapular upward rotation at a 90-120 degrees of arm elevation were seen in patients with small RCT patients, and the massive RCT patients showed greater scapular upward rotations at a 120 degrees of arm elevation at two months postop compared to the healthy controls. Although there was no study of scapular orientation in the RCT patients two months postop, Bey et al. (2011) reported that the humerus on the repaired side in the case of the RCT patients 3 months after the repair of the SSP tendon tear was positioned more superiorly on the glenoid than the contralateral side during shoulder abduction. Likewise, postoperative bone marrow edema disappeared at 5-6 months after arthroscopic repair surgery (Pfalzer et al., 2017; Stahnke et al., 2016). Although the surgical procedure adopted in our study was different, the reasons for the increased scapular upward rotation at 90–120° of arm elevation observed in patients with RCTs two months post-op reported herein may be attributed to the superior humeral migration and bone marrow edema in order to avoid the acromial impingement of the swollen, repaired tendon. Thus the RCT patients in this study showed greater scapular movement during arm elevation in this period, regardless of the tear size. Therefore, active range of motion exercises should be performed carefully, and therapists may need to construct an alternative rehabilitation program to include exercise paradigms by eliminating gravity from the executed motion for cases with greater scapular motion patterns.

The scapular upward rotation at a 120 degrees of arm elevation in the small RCT patient group reduced at two months to five months after surgery, although they still exhibited slightly greater scapular upward rotations compared with healthy controls ($P = 0.04$). Conversely, the massive RCT patients demonstrated greater scapular upward rotation than the healthy controls throughout the experimental period. Paletta et al. (1997) reported that 12 out of 14 patients in the small and massive RCT cases demonstrated normal glenohumeral kinematics during arm elevations at two years after surgery. Additionally, Kolk et al. (2016) clarified that scapular kinematics in the cases of the patients with small and middle RCT normalized toward a symmetrical scapular motion pattern one year after surgery. Thus, these studies clarified that it could take one to two years to restore the scapular orientation during arm elevations in the same manner as the normal controls after surgery for RCT. Our study showed that the scapular upward rotation in the cases of patients with small RCT decreased at two months to five months after surgery although there were still differences compared with the healthy controls. The reduction in the scapular upward rotation at 120° of arm elevation in patients with small RCTs two–five months post-op may be attributed to the absence of bone marrow edema, relief from subacromial pain, and improvement in the repaired cuff muscle strength. Previous studies demonstrated that postoperative bone marrow edema disappeared at 5-6 months after surgery (Pfalzer et al., 2017; Stahnke et al., 2016). Furthermore, Kurowicki et al. (2017) clarified that 89% improvement in pain was seen in the small and middle RCT patients at six months after surgery. In fact, nine out of 10 small RCT patients in this study were relieved of pain. With regard to the shoulder muscle strength, Shin et al. (2016) reported that it took six months for patients with small RCTs to recover and reach the muscle strengths of an uninjured contralateral shoulder for flexion, and for internal and external rotations. In conclusion, and based on these previous studies, the scapular upward rotation in patients with small RCTs decreased five months post-surgery because of the absence of bone marrow edema, relief from acromial pain, and improvement in rotator cuff strength. Conversely, the patients with massive RCT demonstrated greater scapular upward rotation compared to the healthy controls at five months after surgery. Gladstone et al. (2007) reported that fatty infiltration and muscle atrophy before surgery affect the functional outcome one year after rotator cuff repair, and neither fatty infiltration nor muscular atrophy were reversed after surgery. Additionally, Deniz et al. (2014) demonstrated that the functional outcome 24-43 months after surgery was affected negatively by the preoperative and postoperative fatty degeneration, and that the preoperative fatty degeneration and atrophy of rotator cuff muscles did not improve even after a successful surgery. These previous studies suggest that the scapular upward rotation was greater in the massive RCT patients in this study because preoperative atrophy and degeneration might deteriorate the function of rotator cuff muscles even after a successful repair. This could lead to excessive contraction of the deltoid or upper fiber of the trapezius muscle to recover the function of the repaired rotator cuff muscles. Further studies are needed to clarify when or by how much the function of rotator cuff muscles have been restored postoperatively

This study is associated with some limitations. First, the healthy controls were younger than the RCT patients. Yamaguchi et al. (2000) reported that the scapular upward rotation during arm elevation was similar between the young healthy controls and asymptomatic RCT patients. Hence, we thought that aging had little influence on the scapular movements if the subjects did not have any symptoms. The other reason was that we would like to exclude the influence of RCT on the control group. Milgrom et al. (1995) demonstrated that the prevalence rate of RCT was approximately 50 % of asymptomatic adults between 60-69 years and 5% of asymptomatic adults between 30-39 years, therefore we recruited healthy subjects under 30 years. However, since some previous studies showed that increased thoracic kyphosis altered the scapular movements during arm elevation (Finley and Lee, 2003; Kebaetse et al., 1999), we should have considered the effects of aging on scapular movements. Secondly, the sample size of massive RCT group was small. Post hoc power analysis indicated that a sample size of 10 subjects in every group would be necessary (effect size 0.4, α error 0.05, Power 0.8). Although significantly greater scapular upward rotation was seen in massive RCT patients compared to healthy group, a study in large size of massive RCT patients might reveal the difference which was not found in this study. Lastly, only scapular upward rotation was analyzed in the frontal plane with single fluoroscopy because of the small measurement error. The measurement error using biplane fluoroscopy was calculated for orientation (0.1-0.7°) and position (0.2-0.3 mm) (Millett et al., 2016). Therefore, further studies are needed to analyze the multidirectional movements of the scapula using the proposed method associated with small measurement errors.

5. Conclusion

We analyzed the scapular upward rotation during arm elevation in patients with small and massive RCT with a 2D/3D registration technique preoperatively, and at two and five months after surgery. Consequently, the small RCT patients yielded greater scapular upward rotation two months after surgery. The scapular upward rotation decreased over the period of 2-5 months postop although the scapular upward rotation was greater compared to healthy controls. Additionally, patients with massive RCT demonstrated greater scapular upward rotation before operation and at two and five months postop.

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Highlight

- The scapular upward rotation during arm elevation was analyzed.
- Rotator cuff tears patients participated at preop, two and five months postop.
- The patients with small tears showed greater movement at two months postop.
- However, this movement decreased over the period of 2-5 months postop.
- The massive tears led to greater motion throughout the experimental period.

Figure and Table Legends

Figure 1 An example of an arm elevation measurement and 2D/3D registration technique. (2D/3D; two dimensional/ three dimensional)

Upper left: Subjects elevated their arm at a rate of 5 s per cycle with the metronome targeting the pole which was placed along the scapular plane.

Upper right: Three-dimensional images of humerus and scapula reconstructed from the Computed tomography data.

Bottom left: Segmentation of humerus and scapula using manually placed contour lines in fluoroscopic images.

Bottom right: Three-dimensional bone model from the Computed tomography data were matched with the fluoroscopic images using a 2D/3D registration technique.

Figure 2 Scapular upward rotation for healthy controls and RCT patients preoperatively (RCT; Rotator Cuff Tear)

*Significant differences between healthy controls, small RCT (p = .003), and massive RCT (p < .001)

Figure 3 Scapular upward rotation for healthy controls and each RCT patients two months after surgery (RCT; Rotator Cuff Tear)

*Significant difference at an arm elevation of 90° between healthy controls and small RCT patients (p = .017)

**Significant differences at an arm elevation of 120° between healthy controls, small RCT (P < *.001*), and massive RCT patients (p < *.001*)

Figure 4 Scapular upward rotation for healthy controls and RCT patients five months after surgery (RCT;Rotator Cuff Tear)

*Significant differences between healthy controls, small RCT (p = .048), and massive RCT patients (p = .004)

Table 1 Demographic profile data of RCT patients and healthy subjects. Values are means followed by standard deviation and 95 percent confidence intervals in parentheses. (RCT; Rotator Cuff Tear, CI; Confidence intervals, SSP; Supraspinatus muscle, ISP; Infraspinatus muscle, SSC; Subscapularis muscle, mo; months, op; operation).

*Significant differences between healthy controls and RCT patients (P < 0.01)

Table 2 Scapular upward rotation for all groups before operation at two- and five-months post-operation. Values are means followed by standard deviation and 95 percent confidence intervals in parentheses. (RCT; rotator cuff tear, CI; confidence intervals, op; operation, mo; months, ANoVA; Analysis of variance)

*: Two-way ANoVA indicated no significant interaction effect for the group×arm position. The main effect was identified as the group compared to healthy controls (P< 0.01).

†: Two-way ANoVA indicated a significant interaction effect of group×arm position (P= 0.03), and *post hoc* analyses revealed significant differences compared with healthy controls (P< 0.05).

§: A repeated measure ANoVA and *post hoc* Tukey tests yielded a significant difference compared at two months postop (P= 0.01).

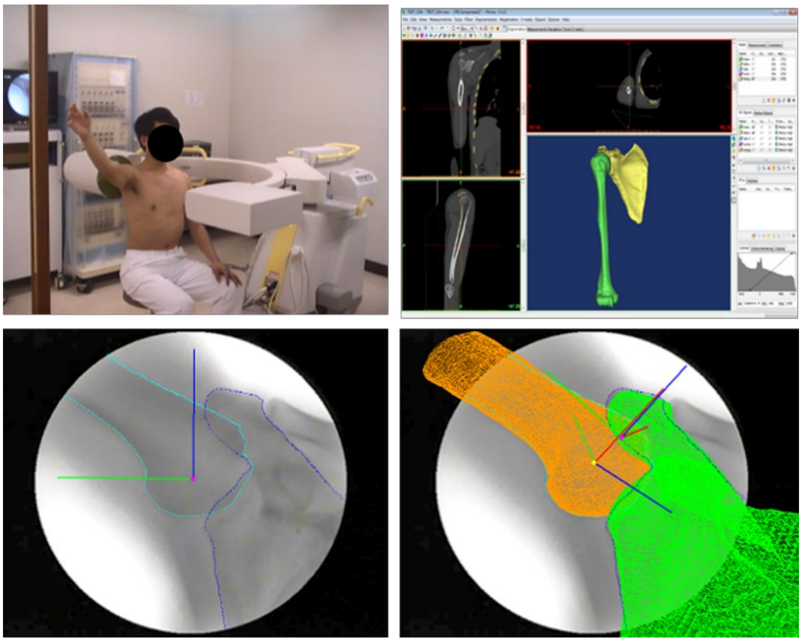

Figure 1

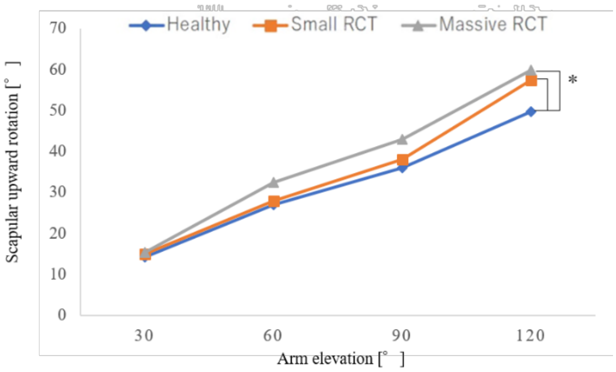
Healthy
Small RCT
Massive RCT
*
Scapular upward rotation [°]
0
10
20
30
40
50
60
70
30
60
90
120
Arm elevation [°]

Figure 2

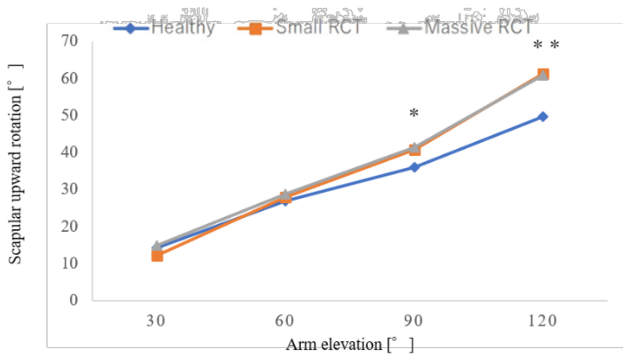
Healthy
Small RCT
Massive RCT
Scapular upward rotation [°]
Arm elevation [°]
70
60
50
40
30
20
10
0
30
60
90
120
*
* *

Figure 3

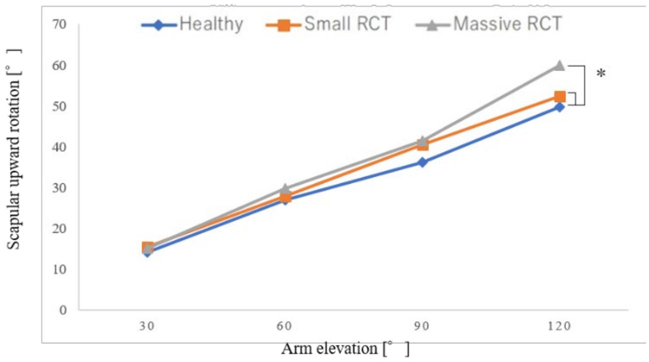
Healthy
Small RCT
Massive RCT
*
Scapular upward rotation [°]
0
10
20
30
40
50
60
70
30
60
90
120
Arm elevation [°]

Figure 4

Table 1

	Small RCT (n=10)	Massive RCT (n=6)	Healthy (n=14)	*P* value
Age (y)	62.7 (7.7; 57.2-68.1)	64.5 (9.5; 54.5-74.4)	24.7 (4.5; 22.1-27.3)	< 0.01*
Body mass index (kg/m²)	23.9 (2.5; 22.5-25.2)	23.5 (1.1; 21.8-25.2)	21.3 (1.9; 20.2-22.4)	0.01
Period until repair (mo)	5.8 (4.1; 3.4-8.1)	2.5 (2.1; 0.5-5.6)		0.04
Tear	SSP full-thickness tear: 8 SSP partial-thickness tear: 2	SSP, ISP and SSC full-thickness tear: 6		
Goutallier stage	Stage I: 7 Stage II: 2 Stage III: 1	Stage I: 2 Stage II: 3 Stage III: 1		0.35
Active scaption (°)	Preope: 147.9 (15.6; 136.7-159.1) Postope 2 mo: 149.4 (12.2; 140.7-158.2) Postope 5 mo: 151.2 (13.6; 141.4-160.9)	Preope: 157.0 (8.4; 148.2-165.8) Postope 2 mo: 156.9 (9.4; 147.1-166.8) Postope 5 mo: 161.1 (14.5; 145.9-176.2)	159.0 (10.3; 153.0-164.9)	0.10 0.12 0.22
Pain during arm elevation	Preope: 10/10 Postope 2 mo: 5/10 Postope 5 mo: 1/10	Preope: 6/6 Postope 2 mo: 2/6 Postope 5 mo: 0/6	0/14	1 0.52 0.42

Table 2

Arm elevation	Small RCT	Massive RCT	Healthy
30°			
Preope *	14.9 (5.5; 10.9-18.9)°	15.3 (2.6; 12.5-18.1)°	12.4 (8.0; 7.3-17.5)°
Postope 2 mo	12.2 (6.0; 7.9-16.6)°	14.9 (3.4; 11.3-18.5)°	
Postope 5 mo *	15.5 (6.2; 11.0-19.9)°	15.0 (4.0; 10.7-19.2)°	
60°			
Preope *	27.9 (6.5; 23.2-32.6)°	32.3 (9.5; 22.3-42.4)°	24.7 (6.1; 20.8-28.6)°
Postope 2 mo	27.8 (4.8; 24.3-31.3)°	28.7 (11.7; 16.3-41.0)°	
Postope 5 mo *	27.9 (9.7; 20.9-34.9)°	29.6 (12.1; 16.9-42.4)°	
90°			
Preope *	38.1 (7.5; 32.7-43.5)°	42.9 (10.2; 32.1-53.6)°	34.2 (4.0; 31.6-36.8)°
Postope 2 mo	40.7 (5.5; 36.8-44.7)° †	41.5 (11.5; 29.4-53.5)°	
Postope 5 mo *	40.4 (9.0; 33.9-46.9)°	41.4 (13.2; 27.6-55.3)°	
120°			
Preope *	57.3 (3.5; 54.8-59.8)°	59.8 (7.1; 52.4-67.3))°	48.2 (4.3; 45.5-51.0)°
Postope 2 mo	61.2 (5.4; 57.3-65.1)° †	61.3 (4.3; 56.7-65.9)° †	
Postope 5 mo *	52.4 (10.5; 44.8-59.9)° §	59.8 (8.5; 50.8-68.8)°	