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ORIGINAL ARTICLE

# Critical shoulder angle in an East Asian population: correlation to the incidence of rotator cuff tear and glenohumeral osteoarthritis

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**Background:** Focus has recently been on the critical shoulder angle (CSA) as a factor related to rotator cuff tear and osteoarthritis (OA) in the European population. However, whether this relationship is observed in the Asian population is unclear.
**Methods:** The correlation between the CSAs measured on anteroposterior radiographs and the presence or absence of rotator cuff tears or OA changes was assessed in 295 patients. Rotator cuff tears were diagnosed with magnetic resonance imaging or ultrasonography. OA findings were classified using the Samilson-Prieto classification. The CSAs among the patients with rotator cuff tears, OA changes, and those without pathologies were compared. Multivariable analyses were used to clarify the potential risks for these pathologies.
**Results:** The mean CSA with rotator cuff tear (33.9° ± 4.1°) was significantly greater than that without a rotator cuff tear (32.3° ± 4.5°; $P = .002$). Multivariable analysis also showed that a greater CSA had a significantly increased risk of rotator cuff tears, with the odds ratio of 1.08 per degree. OA findings showed no significant correlation to the CSAs.
**Conclusions:** Our study demonstrates that the CSA is greater in those with a rotator cuff tear than in those without a tear or OA changes, which may be an independent risk factor for the incidence of rotator cuff tears in the Japanese population.
**Level of evidence:** Level III; Cross-Sectional Design; Prognosis Study


**Keywords:** Critical shoulder angle; shoulder; rotator cuff tear; osteoarthritis; East Asian; radiograph

Shoulder pathologies, including rotator cuff disease and glenohumeral osteoarthritis (OA), are multifactorial.[12,16,26] In addition to aging or habitual factors,[13,21] focus has been on anatomic variation of the acromion for the potential relation to these shoulder pathologies. For stratifying or quantifying the acromial variation, several assessments, including the acromial type,[3] the acromial tilt,[1] and the acromial index,[22] have been suggested.

The Oshu City Mizusawa Hospital Institutional Review Board approved this study (OCMH-H29-1).

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More recently, the critical shoulder angle (CSA), defined by the angle between a line connecting the superior to the inferior margins of the glenoid and a line connecting the inferior margin of the glenoid to the inferolateral edge of the acromion, has been advocated to quantify the combination of glenoid inclination and lateral extension of the acromion.[18] Notably, some studies demonstrated the CSA could be a powerful predictor of rotator cuff tears and primary OA by revealing their characteristic CSA patterns: a larger CSA with rotator cuff tears and a smaller CSA with OA.[2,9,14,20] In contrast, other studies suggested the effect of this congenital factor on shoulder pathologies could be not significant.[8] Moreover, whether CSA could be standardized among the whole populations is still unclear after a recent study reported the CSA was significantly different between North American and East Asian populations.[7] Most studies to date supporting the use of CSA have been conducted in North American or European countries; therefore, an investigation for other populations would be required.[2,9,14,20]

We hypothesized that the CSA in the East Asian population could be associated with the prevalence of shoulder disorders, including rotator cuff tears or shoulder OA. In addition, increased or decreased CSAs in East Asian population could show significant risks for these shoulder disorders. Therefore, the purposes of this study were (1) to investigate whether increased or decreased CSAs would have similar relationships with rotator cuff tears and OA findings in Japanese patients and (2) to clarify the potential risk of CSA for the occurrence of these pathologies by using multivariate analysis.

## Materials and methods

Our study cohort included patients aged >50 years who were seen in our institution due to shoulder pain from January 2013 to December 2014. Patients with avascular necrosis or severe deformity of the glenoid and the humerus were excluded.

Information obtained from patients at the initial visit included age, sex, height, weight, and smoking history. All patients underwent a shoulder x-ray examination, including standardized anteroposterior, axial, and scapular Y views. Of these, we included patients who underwent diagnostic assessments for the rotator cuff tear, including ultrasonography or magnetic resonance imaging (MRI), or both. Rotator cuff conditions were interpreted by 1 of 3 orthopedic surgeons (E.I., N.Y., M.M.) using ultrasonography or by a radiologist using MRI. Rotator cuff tears were were categorized into full-thickness or partial-thickness tears.

## Measurement of the CSA

The CSA was measured on the anteroposterior radiograph for each patient, according to the established method by Moor et al,[18] and assessed for its correlation to the prevalence of shoulder pathologies. Zio Term 2009 software (Ziosoft, Tokyo, Japan) was used to construct a line that connected the superior and inferior osseous margins of the glenoid cavity and another line from inferolateral border of the acromion were drawn. Thus, both lines intersected at the inferior glenoid margin, and the angle between the lines was measured as the CSA (Fig. 1).

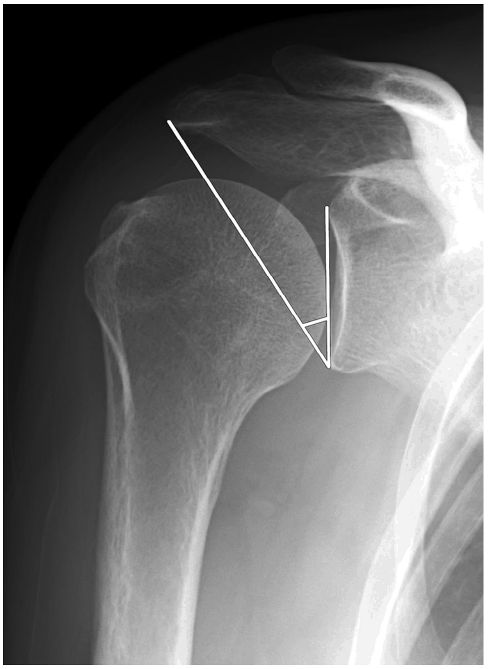

**Figure 1** The angles between a line connecting the superior and inferior osseous margins of the glenoid cavity and another line from the inferolateral border of the acromion were measured as the critical shoulder angle.

For this study, 2 orthopedic surgeons (K.S., T.H.) independently measured the CSA for all patients, and the mean values were calculated to obtain the CSA for the subsequent analyses. In addition, 1 surgeon (K.S.) repeated the measurement twice within a 2-week interval to assess intraobserver reproducibility. Thus, intraobserver and interobserver reliabilities for the CSA measurement were also evaluated.

## CSA assessment in association with shoulder pathologies

Patients in this study were classified according to the presence of absence of rotator cuff tears as the cuff tear group (RCT) and intact cuff group (non-RCT). The non-RCT patients were further classified by OA findings. The anteroposterior radiographs were used to stratify the extent of OA findings into 4 grades according to the Samilson-Prieto classification[23]: grade 0, none; grade 1, mild OA with osteophytes <3 mm on the humeral head; grade 2, moderate with osteophytes between 3 and 7 mm on the humeral head or glenoid rim; and grade 3, severe with osteophytes >7 mm, with or without articular incongruity.

## Statistical analyses

Statistical analyses were performed using SPSS 18.0 (IBM, Armonk, NY, USA), GraphPad Prism 5.0 (GraphPad Software, La Jolla, CA,

**Table I** Characteristics of the study population

| Group | Patients | Age | Sex | | Height | Weight | Smoker |
|---|---|---|---|---|---|---|---|
| | | (yr) | F | M | (cm) | (kg) | (%) |
| RCT | 112 | 70 ± 8.7 | 49 | 63 | 159 ± 8.9 | 62 ± 12 | 24.1 |
| Non-RCT | 183 | 64 ± 9.3 | 106 | 77 | 159 ± 8.9 | 59 ± 13 | 21.9 |
| OA | 50 | 68 ± 9.4 | 26 | 24 | 159 ± 9.0 | 59 ± 13 | 30.0 |
| Non-OA | 133 | 63 ± 8.8 | 80 | 53 | 160 ± 8.8 | 59 ± 13 | 18.7 |

*F*, female; *M*, male; *RCT*, rotator cuff tear; *OA*, osteoarthritis.
Continuous data are shown as mean ± standard deviation and categoric data as number of patients or as indicated otherwise.

USA), and JMP Pro 13.0 (SAS Institute Inc., Cary, NC, USA) software. Intraobserver and interobserver reliability was examined using intraclass correlation coefficient (ICC[2,1]). The Kruskal-Wallis test with the post hoc Dunn test were used to assess differences of CSAs among shoulder pathologies. Multivariable-adjusted analysis for the occurrence of rotator cuff tear or OA was examined using logistic regression analysis. Variables assessed in association with tear or OA included age (per each 10-year increment), sex, height, weight, and the presence of smoking history. The level of significance was set at $P < .05$.

## Results

Among 347 patients aged >50 years with shoulder symptoms, the study included 295 (155 women and 140 men) with a diagnosis on MRI or ultrasonography (Table I). Patients were a mean age was 67 years (range, 50-89 years). There were 112 patients in the RCT group and 183 patients in the non-RCT group. OA findings in the 183 patients in the non-RCT group included bony spur formation in the glenohumeral joint in 50 patients (OA group). Radiologic assessment based on the Samilson-Prieto classification showed 38 patients in grade 1, 8 in grade 2, and 4 in grade 3.

Intraobserver and interobserver reliabilities for CSA measurement were 0.97 (95% confidence interval [CI], 0.96-0.98) and 0.94 (95% CI, 0.90-0.96) for ICC(2,1). The mean CSA was 33.9° ± 4.1° in the RCT group, and 32.3° ± 4.5° in the non-RCT group. The CSA was significantly greater in the RCT group than in the non-RCT group ($P = .002$). Regarding the tear types, the mean CSA was 34.3° ± 4.2°) in patients with full-thickness tears and 32.6° ± 3.2° in those with partial-thickness tears ($P = .08$). Among non-RCT patients, the mean CSA was 32.1° ± 4.3° for group 0 OA patients (non-OA group), 32.9° ± 4.9° for grade 1 OA patients, and 33.0° ± 5.3° for grade 2 or 3 OA patients (Table II).

Multivariable analysis also showed that greater CSAs significantly increased the risk of rotator cuff tears, with an odds ratio of 1.08 per degree (Table III). Risk factors for rotator cuff tears were ex (odds ratio, 2.40 for female to male; $P = .036$ and increased age (odds ratio, 1.95 per 10 years; $P < .001$). Multivariable analyses of OA findings showed no significant correlation with any variables except increased age (odds ratio, 1.87 per 10 years; $P < .001$).

**Table II** Critical shoulder angles in patients with rotator cuff tear and osteoarthritis

| Variable | Patients | CSA |
|---|---|---|
| | (No.) | (Mean ± SD°) |
| RCT | 112 | 33.9 ± 4.1* |
| Non-RCT | 183 | 32.3 ± 4.5* |
| Tear type in RCT | | |
| Complete tear | 85 | 34.3 ± 4.2 |
| Partial tear | 27 | 32.6 ± 3.2 |
| OA grade in non-RCT | | |
| 0 | 133 | 32.1 ± 4.3 |
| 1 | 38 | 32.9 ± 4.9 |
| >2 | 12 | 33.0 ± 5.3 |

*CSA*, critical shoulder angle; *SD*, standard deviation; *RCT*, rotator cuff tear; *OA*, osteoarthrosis.
* $P = .002$ for RCT vs non-RCT groups.

**Table III** Multivariable analysis for factors associated with rotator cuff tear

| Factor | Odds ratio (95% CI) | *P* values* |
|---|---|---|
| Age, per 10 years | 1.95 (1.37-2.78) | **<.001** |
| Sex, female to male | 2.40 (1.06-5.49) | **.036** |
| Height, per cm | 0.97 (0.92-1.02) | .202 |
| Weight, per kg | 1.03 (0.99-1.06) | .103 |
| Nonsmoker to smoker | 1.07 (0.56-2.01) | .858 |
| CSA, per ° | 1.08 (1.02-1.15) | **.014** |

*CI*, confidence interval; *CSA*, critical shoulder angle.
* Bold values are statistically significant ($P < .05$).

## Discussion

This study demonstrated that the CSA was positively associated with the occurrence of rotator cuff tears. An increased CSA had an independent risk of rotator cuff tears, with the odds ratio of 1.08 per degree. Previous studies have reported that greater CSAs are observed in patients with rotator cuff tears than in those with an intact rotator cuff or those with primary OA.[2,9,20] Moor et al[18] reported 84% of patients with a CSA >35° had rotator cuff tears, whereas 70% of those with a CSA between 30° and 35° had no pathologies in their shoulders.

Biomechanical studies also reported higher shear joint reaction forces on the glenohumeral joint in shoulders with a greater CSA.[11,19] Under this condition, increased compensatory activity of the rotator cuff muscles might be required to maintain the center of the humeral head, which might result in degenerative rotator cuff tears.[11] These reports may support our results that the CSA was an independent risk factor of rotator cuff tears, with an odds ratio of 1.08 per degree.

Previous studies have reported a negative correlation between the CSA and the prevalence of OA findings.[4,18] Moor et al[18] showed 93% of patients with a CSA <30° had OA changes. Bjarnison et al[4] also showed that the risk of developing OA was increased in shoulders with a CSA <30°, with the odds ratio of 2.25. That these studies included European populations is notable.

Cabezas et al[7] recently compared the CSA between North American and East Asian populations and revealed that the CSA was significantly smaller in the North Americans than in the East Asians (mean 27.7° ± 4.8° vs. 32.8° ± 4.4°, respectively). This report seems to indicate that the risk of OA is higher in North Americans than in East Asians.

An epidemiologic report[5] revealed racial differences in the prevalence of OA: compared with the Caucasians, the Asians had an odds ratio of 0.42 (95% CI, 0.35-0.50) and were significantly less likely to have OA. This lower prevalence of OA in the Asian population is applicable to all of the joints, including the shoulder. In addition to or partly due to genetic factors, morphologic variations, such as CSA, seem to play a role in the occurrence of OA. According to our results and the evidence, we speculate that the very small percentage of people with a small CSA in the Asian population may explain the lower prevalence of primary OA of the shoulder in Asia.

In addition to greater CSA, the current multivariable analysis demonstrated that increased age and male sex were risk factors of rotator cuff tears. Our results regarding patient age were supported by the studies demonstrating that the prevalence of rotator cuff tears positively correlated with patient age.[27] In contrast, the effect of sex on cuff tear remains controversial. Braune et al[6] reported that traumatic rotator cuff tear is likely to occur in men; however, several studies failed to clarify gender differences to cause rotator cuff tears.[17,27]

Our study has several limitations. First, this study consisted of a case-control design with retrospective collection of data; therefore, bias is inherent to the study design. In addition, our study cohort included symptomatic patients that required diagnostic assessment using ultrasonography or MRI, or both. Further epidemiologic studies including individuals with normal shoulders need to be undertaken.

Second, we used anteroposterior radiographs taken routinely. Recent studies cautioned that factors such as patient positioning, gantry and plate positioning, and scapular positioning influenced the reliability of measuring CSA.[20,25] Moreover, Chalmers et al[8] suggested that approximately 20% of radiographs were acceptable for the CSA measurement according to the radiologic scale. As in the previous studies showing the usefulness of CSA,[10,14,15,24] we used standard x-ray images, which should be considered as a limitation.

Third, the difference of CSA with and without rotator cuff tears was approximately 2°; whereas, the SD was >3°. Although statistically significant, these results should be carefully interpreted for determining clinical application of CSA.

Fourth, RCT and OA groups in our study contained 112 and 50 patients, respectively; therefore, the difference would be also noted as a limitation of the study.

## Conclusion

CSA was greater in patients with rotator cuff tears than in those without rotator cuff tears in the Japanese population. Increased CSA seems to be an independent risk factor of rotator cuff tears.

## Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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