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Role of Critical Shoulder Angle in Degenerative Type Rotator Cuff Tears: A Turkish Cohort Study

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Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: This retrospective study investigated the association between the critical shoulder angle (CSA) and the development of full-thickness rotator cuff tears (FTRCTs) in the Turkish population. The CSA is an imaging parameter that quantifies the relationship between the inclination of the glenoid and the lateral extension of the acromion in the coronal plane. The CSA is an anatomical measurement, and higher CSA values have been associated with an increased incidence of FTRCTs. However, there is a lack of data on CSA regarding the Turkish population.

Material/Methods: In this study, CSA measurements were recorded in 2 groups: 50 patients with FTRCT who had arthroscopic repair (group 1) and 50 age- and sex-matched individuals with no FTRCT detected by magnetic resonance imaging (group 2). Sex, age, affected side, dominant side, and smoking status were recorded for each patient. The CSA measurements of the affected sides were performed on true anterior-posterior view radiographs.

Results: The results showed a statistically significant difference between the mean CSA values of group 1 (37.48°) and group 2 (33.53°), $P < 0.001$. CSA values of 36 and above had a sensitivity of 73.58%, specificity of 74.47%, positive predictive value of 75%, and negative predictive value of 74.47% for detecting FTRCT.

Conclusions: CSA measurement on radiographs is a useful diagnostic tool in the Turkish population, and an above-average CSA value is associated with a significantly increased incidence of degenerative-type FTRCT.

Keywords: Rotator Cuff Tear Arthropathy • Shoulder Joint • Shoulder Pain • Scapula

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Introduction

Full thickness rotator cuff tears (FTRCTs) are among the most common shoulder pathologies, with a reported frequency of 7% to 40% [1]. Determining the exact underlying etiology of an FTRCT is quite challenging, as it is multifactorial in nature. While age and trauma have been suggested as the most common causes, there is still debate surrounding this topic [2].

Etiological factors that induce rupture are divided into 2 groups: intrinsic and extrinsic. Intrinsic factors include hypovascularity within the tendon, degeneration due to aging, and inflammation, while extrinsic factors affect the tendon from outside, such as bony or soft tissue surrounding the tendon, impingement syndromes, and differences in scapular morphology [2].

Differences in scapular morphology have been extensively studied to better understand FTRCT etiology. Various concepts, such as acromion type, acromion slope, and acromial index, have been introduced [3-5]. Moreover, the vertical slope of the glenoid has been reported to be associated with the formation of rotator cuff tears [5].

In 2013, Moor et al [6] studied the acromial index and glenoid slope in 298 cases and defined the critical shoulder angle (CSA) as the strongest radiological parameter in predicting rotator cuff tears. In their article, the measurement of the CSA is reported as follows. A line connecting the most lateral points of the superior and inferior borders of the glenoid is drawn. Then, a second line extending from the inferior glenoid to the most lateral point of the acromion is drawn. The angle formed between the 2 lines is defined as the CSA. It has been stated that above-average CSA measurements are associated with degenerative-type rotator cuff tears.

Shinagawa et al [7] investigated the Japanese population and reported that the CSA was higher in patients with FTRCTs and lower in patients with primary shoulder osteoarthritis, compared with CSA values in healthy individuals. Gerber et al [8] conducted a biomechanical study and found that in shoulders with a high CSA, compressive forces should be augmented to meet the increased deltoid shear force during abduction and to preserve joint stabilization. Therefore, the force required for the supraspinatus to compensate for the shear forces increases, leading to degeneration and, eventually, tears.

Previous research has shown that individuals with higher CSA values had a significantly increased prevalence of FTRCTs than the normal population [6]. However, the average CSA values for healthy individuals and patients with rotator cuff tears can differ according to racial/ethnic groups [1,6,7]. Therefore, this study aims to investigate the role of CSA – an anatomical variance that can be measured radiologically – in the development

of FTRCTs at average and high angles. The study compares measurements in groups with and without FTRCTs in the Turkish population. The results can serve as baseline values for future studies involving the Turkish population.

Material and Methods

Patient Selection

Following the approval of the local ethics committee (05/02/2019-A58) in accordance with international agreements (Helsinki Declaration), 100 patients were included in the study: 50 patients who presented to the outpatient clinic with shoulder pain and underwent arthroscopic repair after being both clinically and radiologically diagnosed with FTRCT and 50 age- and sex-matched controls who presented to the outpatient clinic with shoulder pain but did not have FTRCT detected by magnetic resonance imaging (MRI). Informed consent was obtained from each patient.

Each patient case was assessed retrospectively based on the available radiological data and discharge report. Patients who were ≥ 45 years old, had true shoulder anterior-posterior (AP) view X-rays in compliance with specific criteria, and had arthroscopic repair due to FTRCT were included. Age-matched patients who presented to the outpatient clinic with shoulder pain but did not have a clinical or radiological (MRI) FTRCT diagnosis with available true shoulder AP-view X-rays were recruited as controls.

Exclusion criteria were as follows: history of major trauma, previous shoulder surgery, incompatible true shoulder AP-view X-rays, history of previous glenoid or acromion fractures, severe deformities, avascular necrosis, and infectious or inflammatory arthritis.

Patients who participated in the study were all operated on by the same surgeon (NA), who had 15 years of experience in shoulder surgery. Demographic data regarding sex, age, upper extremity dominance, and smoking status were recorded.

Radiological Assessment

A Toshiba Rotanode X-ray tube was used to obtain radiographs; a Philips Ingenia 1.5T MRI system was used for MRI examination. The radiological data of each participant were evaluated by the authors.

Two CSA measurements were performed by 2 different orthopedic surgeons (NA, MNT) for each patient, and the average value was recorded. Preoperative radiographs of the surgical group were taken into consideration. Techniques regarding CSA

measurement and true shoulder AP-view X-rays were determined based on criteria established by Moor et al [6].

Theoretically, if the rotation of the scapula changes during imaging, the CSA value can also change. In the present study, radiographs with visible joint space and minimal overlap of the superior and inferior edges of the glenoid were included. In their study, Moor et al [6] reported that flexion/extension or internal/external rotations of up to 20° created a CSA change of a maximum of 2°. They also stated that during scapular rotations above the abovementioned degrees, the measurement could not be made accurately, because the superior and inferior edges of the glenoid were not clear. Therefore, radiographs that were not within the recommended values were not included in our study. If a participant had multiple radiographs, the radiograph with minimal overlap of the superior and inferior glenoid edge was preferred (Figure 1).

Statistical Analysis

The Number Cruncher Statistical System 2007 (Kaysville, Utah, USA) program was used for statistical analysis. Descriptive statistical methods (mean, standard deviation, frequency, percentage, minimum, maximum) were used to evaluate the data. The intrarater and interrater reliability of CSA measurements were assessed with intraclass correlation (ICC). The Shapiro-Wilk test and graphical models were used to test the normality of quantitative data. For quantitative variables that showed a normal distribution, an independent sample *t* test was used to compare 2 unrelated groups. The Pearson chi-square test was used to compare qualitative data. Pearson correlation analysis was used to assess the relationship between quantitative variables. Receiver operating characteristic (ROC) analysis and diagnostic screening tests were used to determine the cutoff value for CSA measurement in differentiating the patient groups. *P* values below 0.05 were accepted as statistically significant.

Power analysis performed based on previous studies in the literature determined that the minimum sample size for each group should be 43, calculated with a power of 80%. Therefore, the sample size for each group was set as 50 ($\alpha=0.05$, $\beta=0.9$)

Results

The study involved 100 patients, with ages ranging from 45 to 74, and a mean age of 58.44 ± 7.43 years; 43% ($n=43$) of patients were women and 57% ($n=57$) were men. In group 1, the mean age was 58.54 ± 7.37 , while in group 2, it was 58.34 ± 7.57 . In group 1, 44% ($n=22$) of patients were women and 56% ($n=28$) were men. In group 2, 42% ($n=21$) of patients were women and 58% ($n=29$) were men.

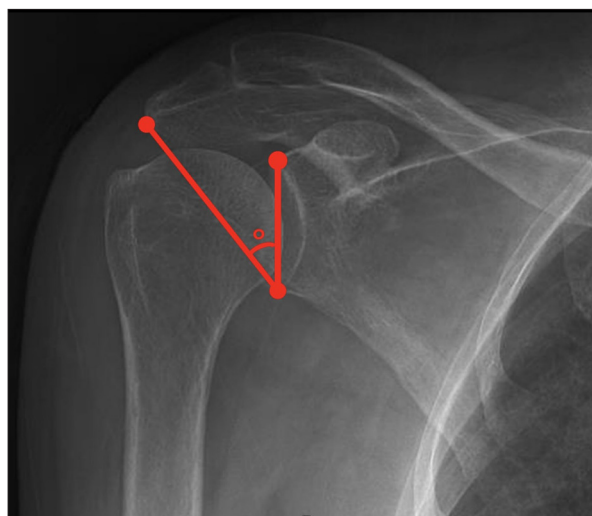


Figure 1. Critical shoulder angle (CSA) measurement technique. A line connecting the most lateral points of the superior and inferior borders of the glenoid is drawn. Then, a second line extending from the inferior glenoid to the most lateral point of the acromion is drawn. The angle formed between the 2 lines is defined as the CSA (Powerpoint, Office for Mac, 2023 version: 16.74; Redmond, Washington, USA).

In both groups, the right extremity involvement rate was higher than the left, with a total right extremity involvement rate of 57% ($n=57$) and a left extremity involvement rate of 43% ($n=43$). In group 1 62% ($n=31$) of patients smoked, while 38% ($n=19$) did not. In group 2, 66% ($n=33$) of patients smoked, while 34% ($n=17$) did not.

The CSA values of the patients ranged between 27.7° and 42.2°, with a mean value of $35.51^\circ \pm 3.42^\circ$. The mean CSA value in group 1 was $37.48^\circ \pm 2.47^\circ$, while in group 2, it was $33.53^\circ \pm 3.10^\circ$. Excellent intraobserver and interobserver reliabilities were obtained, with an ICC for intrarater reliability of 0.95 (95% CI: 0.92-0.97) and ICC for interrater reliability of 0.94 (95% CI: 0.91-0.96).

There was no statistically significant difference between the 2 groups in terms of age, sex, affected side, upper extremity dominance, and smoking status ($P>0.05$). However, a statistically significant difference was detected between the 2 groups regarding CSA values ($P<0.001$). Group 1 had higher CSA values than did group 2 (Table 1).

A cutoff point for CSA was calculated, and patients with CSA values of 36 and above had a sensitivity of 73.58%, specificity of 74.47%, positive predictive value of 75%, and negative predictive value of 74.47% for detecting FTRCTs (Table 2). The area under the ROC curve was 77.4%, with a standard error of 4.6 (Figure 2). There was no statistically significant relationship

Table 1. Distribution of descriptive properties.

		Total	Group 1	Group 2	P
Age	Min-Max	45-74	45-74	45-73	^a 0.894
	Mean±SD	58.44±7.43	58.54±7.37	58.34±7.57	
Sex, n (%)	Female	43 (43)	22 (44)	21 (42)	^b 0.840
	Male	57 (57)	28 (56)	29 (58)	
Dominance, n (%)	Right	85 (85)	41 (82)	44 (88)	^b 0.401
	Left	15 (15)	9 (18)	6 (12)	
Smoking status, n (%)	Yes	36 (36)	19 (38)	17 (34)	^b 0.677
	No	64 (64)	31 (62)	33 (66)	
Affected side, n (%)	Right	57 (57)	31 (62)	26 (52)	^b 0.313
	Left	43 (43)	19 (38)	24 (48)	
CSA	Min-Max	27.7-42.2	30.6-42.2	27.7-41.1	^a <0.001*
	Mean±SD	35.51±3.42	37.48±2.47	33.53±3.10	

^a Independent sample *t* test; ^b Pearson chi-square test; * *P*<0.01. min – minimum; max – maximum; CSA – critical shoulder angle; SD – standard deviation.

Table 2. Diagnostic screening test results for critical shoulder angle.

Diagnostic scan					ROC curve		<i>P</i>
	Cut off	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Area	
CSA	≥36	73.58	74.47	75.0	74.40	0.774	0.001*

* *P*<0.01. CSA – critical shoulder angle; ROC – receiver operating characteristic.

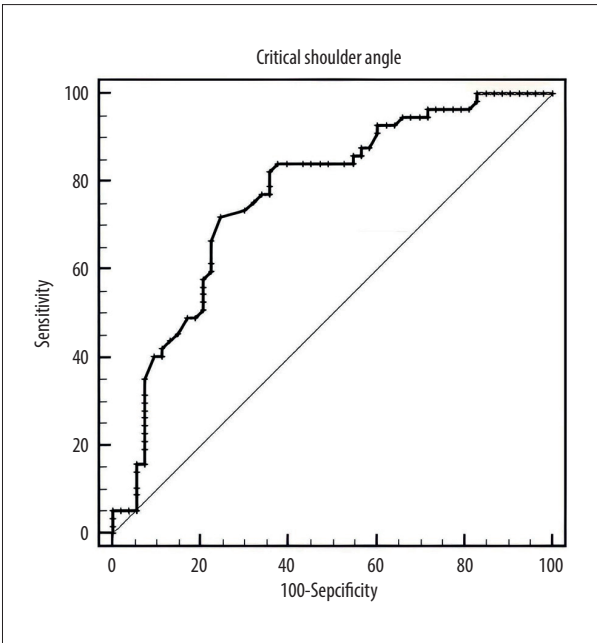


Figure 2. Receiver operating characteristic (ROC) curve for critical shoulder angle (CSA). A cutoff point for CSA was calculated, and patients with CSA values of 36 and above had a sensitivity of 73.58%, specificity of 74.47%, positive predictive value of 75%, and negative predictive value of 74.47% for detecting full thickness rotator cuff tear. The area under the ROC curve was 77.4%, with a standard error of 4.6 (*Number Cruncher Statistical System 2007; Kaysville, Utah, USA*).

between age, sex, dominant extremity, smoking status, affected side, and CSA values of the patients (*P*>0.05; Table 3).

Discussion

According to our data, there was a statistically significant difference between the group with FTRCTs (group 1) and group without FTRCTs (group 2) in terms of CSA values (*P*<0.001). In group 1, the mean CSA value was 37.48°, while in group 2, it was 33.53°. These measurements are compatible with the case and control group values reported by Moor et al [6] and

Table 3. Comparison of critical shoulder angle values according to age, sex, dominance, smoking status and affected side.

		Critical shoulder angle	
		r	P
Age		-0.189	0.060
		Mean±SD	P
Sex, n (%)	Female	34.99±3.42	ª0.189
	Male	35.90±2.41	
Dominance, n (%)	Right	35.41±3.47	ª0.493
	Left	36.07±3.21	
Smoking status, n (%)	Yes	35.23±3.35	ª0.554
	No	35.66±3.48	
Affected side, n (%)	Right	36.06±3.31	ª0.063
	Left	34.77±3.47	

r – Pearson correlation coefficient; ª independent sample *t* test. CSA – critical shoulder angle; SD – standard deviation.

other research groups [7,9]. As a result, we consider CSA measurement a useful diagnostic tool in Turkish society and assert the notion that above-average CSA values increase the incidence of full-thickness degenerative-type FTRCT development.

The study group was compared with the age- and sex-matched controls, and age and sex were not significant in terms of FTRCT development. However, it is well established that age is one of the most important risk factors for the development of degenerative FTRCT [6-8]. Several studies have found that rotator cuff tears are more common among men, while others have argued that female sex is also a potential risk factor [10,11]. Abate et al [12], for example, observed that postmenopausal women have an increased risk of developing rotator cuff tears.

In the present study, there was no statistically significant difference between the groups regarding the dominant side. The ratio of the dominant side being the affected side was higher in the study group than in the control group; however, the difference was not statistically significant. While some studies reported a higher incidence of rotator cuff tears on the dominant upper extremity, others have reported the opposite; a consensus has not been reached on this issue [13-15].

Although the rate of smoking was higher in the control group, the difference between the 2 groups was not statistically significant. Numerous studies have demonstrated that the amount and duration of smoking increase the risk of rotator cuff tear development. Baumgarten et al [16] investigated 586 patients with unilateral shoulder pain, 375 of whom were diagnosed with rotator cuff tears. It was also demonstrated that 61.9% of the individuals diagnosed with rotator cuff tears smoked, with an average use of 30.1 packs/year. Consistent with the literature, 64% of the patients who participated in our study

smoked. Bishop et al [17] demonstrated an increased incidence of rotator cuff tear development, larger tears, and a higher number of surgical interventions in individuals who smoked. Carbone et al [18] reported that the prevalence of type II tears (34.8%) was higher than that of type I tears (23.2%) in smokers. This finding promotes the notion that smoking could lead to tendon hypovascularity.

Different CSA values have been reported in the literature due to possible anatomical differences between diverse societies and ethnicities. Our goal was to determine the mean CSA value in Turkish society and to assess its role in FTRCT development. This study is one of few Turkish studies investigating the relationship between bone morphology and FTRCT development. The findings will provide baseline values for future studies regarding CSA values involving the Turkish population. The mean CSA value was 33.53° in the group without FTRCTs and 37.48° in the group with FTRCTs. In a similar study conducted in East Asia, the mean CSA value was reported as 32.3° in the group without FTRCTs and 33.9° in the group with FTRCTs [7]. In another study, performed in Japan, the mean CSA value was 33.7° in the group without FTRCTs and 36.3° in the group with FTRCTs. Moreover, it has been suggested that CSA values are not affected by height and weight [7,9,19]. Furthermore, the mean CSA value was reported as 33.59° in the group without FTRCTs and 39.75° in the group with FTRCTs in a study performed in Brazil [1]. In light of this information, we consider the morphological differences between races to affect CSA values.

There have been many other radiological parameters previously defined in the literature. Balke et al [20] reported that acromial slope, type 3 acromion, high acromial index, CSA, short acromiohumeral distance, and lateral acromial angle were associated with rotator cuff tear development. Moor et al [21],

on the other hand, reported that among the acromial index, CSA, and lateral acromial angle, CSA has the strongest predictive value for rotator cuff tear development. Pandey et al [22] studied several factors, such as acromial index, subacromial index, lateral acromial angle, CSA, and presence of subacromial osteophytes, and concluded that above-average CSA values and subacromial osteophyte presence have the strongest predictive value for the development of rotator cuff tears.

In the present study, CSA measurements were performed on the radiographs. Several studies have compared CSA measurements on radiographs, MRI, and computerized tomography scans and have concluded that plain radiography had similar reliability to computed tomography and was more reliable than MRI [23,24].

Bjarnison et al [25] conducted a study with 979 patients and concluded that high CSA values did not significantly increase rotator cuff tear; however, low CSA values were associated with primary glenohumeral osteoarthritis. Chalmers et al [26] also reported that high CSA values were not associated with rotator cuff tear development, initial extent, or progression of tears. Moreover, it was pointed out that CSA values did not change over the 4-year follow-up period. However, the authors stated that only 20% of the radiographs met the Suter-Henninger criteria, emphasizing the practical difficulty of using suitable true AP-view X-rays for CSA measurement.

According to our data, in patients with CSA values of 36 and above, the sensitivity of detecting FTRCTs was 73.58%, specificity was 74.47%, positive predictive value was 75%, and negative predictive value was 74.47%. A meta-analysis encompassing 8 studies concluded that CSA measurement is a useful diagnostic tool and that CSA values of 35° and above increase the incidence of FTRCT development [9]. In this respect, our results seem to be compatible with the previous literature.

Since our study had a retrospective design, one of the limitations is that it was not known whether there were existing rotator cuff tears in the contralateral shoulders of the patients

selected for the group without rotator cuff tears. If this information was made available, statistical results could be affected. The second limitation, a lack of standardization for true shoulder AP-view X-ray and lack of specifically trained technicians, could be avoided if the study was performed prospectively. A prospective design would result in an increased number of patients with appropriate radiographs and thus increased statistical power. A prospective design would also allow us question the patient's occupation and shoulder involvement during work, to investigate these factors as separate variables. One of the study's constraints is that it involved patients with shoulder pain who were part of the control group, and there was no arthroscopic verification of rotator cuff tears in these patients. Finally, our study with 50 control patients and 50 patients with FTRCT in a single center cannot be generalized to the entire population. Although our sample size is compatible with previous studies, multicenter studies with a higher number of participants should be conducted to obtain better data. However, our results could still be important and beneficial in terms of future studies.

Conclusions

Based on the findings of this study, we support the notion that above-average CSA values can be predictive of full-thickness degenerative-type rotator cuff tears. Moreover, the CSA measurement can be regarded as a practical and useful diagnostic tool that can be successfully used in the Turkish population.

Ethical Statement

This study was conducted after the approval of the local institutional review board (Istanbul University-Cerrahpaşa, Cerrahpaşa Medical Faculty Ethical Committee).

Declaration of Figures' Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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