

Evaluation of the Relationship between Critical Shoulder Angle and Acromial Index Measurements with Rotator Cuff Rupture on Three-dimensional Models

Abstract

Objective: The relationship between rotator cuff tears (RCTs) and morphological features of the shoulder joint has yet to be fully explained. The earlier studies were usually done with two-dimensional radiography images, but joint positions and bone formations could not be thoroughly evaluated in two-dimensional images. This study aims to assess the relationship between RCTs and critical shoulder angle (CSA) and acromial index (AI) values in three dimensions. **Methods:** In our study, computerized tomography of 24 RCTs (RCT group) and 20 Bankart lesions, and no RCTs (control group) were examined. CSA and AI were measured on three-dimensional (3D) glenohumeral joint models obtained by 3D reconstructions of computed tomography examinations. **Results:** The RCT group's CSA was significantly higher than the control group ($P = 0.002$). AI values did not differ significantly ($P = 0.151$) between the groups. In addition, there was a moderate positive correlation between the AI and CSA values and the age of patients with RCTs ($r = 0.309$, $r = 0.367$). **Conclusion:** This study differs from earlier studies in some significant respects, such as AI values were not found to be associated with RCTs. CSA values were associated with RCTs in parallel with earlier studies. This difference may be because we performed our study on 3D models. We anticipate that our results will guide clinicians in revealing the etiology of rotator cuff degeneration and determining the surgical method for treatment.

Keywords: Anatomy, morphology, rotator cuff tears, shoulder, three-dimensional imaging

Introduction

Critical shoulder angle (CSA) and acromial index (AI) are variables of rotator cuff tears (RCT) have been examined the most. In two-dimensional images, most lateral part of the acromion reflected in the image is used when surgical planning is made to treat pathologies caused by morphological changes. However, this image can increase the error rate when performing a surgical procedure. To perform examination and surgery with greater accuracy, three-dimensional (3D) pictures are necessary. The study aims to determine any relationship between RCT and CSA, and AI values in 3D and how CSA and AI values impact formation of RCT.^[1-16]

Methods

In this study, computed tomography scans of applicants to the Orthopedics and Traumatology Department at Gazi

University Faculty of Medicine between 2016 and 2019 were retrospectively evaluated. The research comprised a total of 44 individuals, including 20 patients with verified Bankart lesions and no RCTs and 24 patients with proved RCTs by arthroscopic surgery (RCT group). The study excluded those with inflammatory diseases and a history of trauma. Because it is not morally acceptable to do computed tomography on healthy persons in our nation, the control group was selected from individuals with Bankart lesions rather than healthy individuals. According to our research, evaluating a control group made up of individuals with Bankart lesions is not problematic. Since Rhee *et al.* discovered that patients with RCT had significantly different CSA and AI values than those with Bankart lesions.^[17]

In this study, images were captured by General Electric 14 Detector Computed Tomography. The images obtained were transferred to MIMICS software (Mimics

Merve Sevgi Ince^{1,2},
Rabet Gözil³,
Ulunay Kanatli⁴,
Meltem
Bahçelioglu^{2,5,6,7}

¹Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Yüksek İhtisas University, ²Department of Anatomy, Institute of Health Sciences, Gazi University, ³Department of Anatomy, Faculty of Medicine, Yüksek İhtisas University, Departments of ⁴Orthopedics and Traumatology and ⁵Anatomy, Faculty of Medicine, Gazi University, ⁶Neuropsychiatry Education, Research and Application Center, Gazi University, ⁷Neuroscience and Neurotechnology Center of Excellence (NÖROM), Ankara, Turkey

Article Info

Received: 27 February 2023

Revised: 05 May 2023

Accepted: 14 August 2023

Available online: 28 September 2023

Address for correspondence:

Dr. Merve Sevgi Ince,
Oğuzlar Mahallesi, 1375, Sokak,
No: 8, Çankaya, Ankara 06420,
Turkey.
E-mail: msevgi94@gmail.com

Access this article online

Website: <https://journals.lww.com/joai>

DOI:
10.4103/jasi.jasi_20_23

Quick Response Code:



How to cite this article: Ince MS, Gözil R, Kanatli U, Bahçelioglu M. Evaluation of the relationship between critical shoulder angle and acromial index measurements with rotator cuff rupture on three-dimensional models. J Anat Soc India 2023;72:246-51.

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

Innovation Suite, Materialize, Leuven, Belgium), and their 3D reconstructions were obtained.^[18,19]

Image analysis and measurements

In our investigation, computed tomography scans from the RCT and the control groups were 3D reconstructed to build models of the glenohumeral joint. CSA and AI measurements were made on these. Two observers measured the CSA and AI in each patient. To verify interobserver reproducibility, the results acquired by these two observers were compared. To assess intra observer repeatability, one of the observers repeated the measurements after a 3-week gap. The same researcher took three measurements, and their average was calculated and assessed.

Critical shoulder angle measurement

The glenoid cavity's upper and lower edges are connected by a line. Following that, a line is produced by connecting the lower border of the glenoid cavity with the acromion's outermost point (which is thought to be the extreme point where the acromion's medial and lateral borders meet). The CSA is situated between these two lines [Figure 1].^[9]

Acromial index measurement

A line connecting the top and bottom borders of the glenoid cavity (Glenoid plane [GP]). The distance between the GP and the acromion's most lateral point was recorded (a) The width between the GP and the most lateral point of the proximal epiphysis of the humerus was then measured, (b) The gleno-acromial distance (a) is compared to the gleno-humeral distance (b) to determine the AI [Figure 2].^[13]

Ethical statement

This study received ethics committee approval with the decision of the Yüksek İhtisas University Non-Invasive Research Ethics Committee numbered 2019/05/02 and September 13, 2019 dated. This research on humans was carried out by the "Helsinki Declaration."

Statistical analysis

Data from the research were statistically analyzed using the software program Statistical Package for Social Sciences (SPSS) 22.0 (SPSS Inc. Chicago, IL, USA). Although continuous variables are displayed using the mean, standard deviation, and median, categorical variables are presented in the descriptive statistics section using numbers and percentages (minimum–maximum). Using both analytical (Kolmogorov–Smirnov/Shapiro–Wilk tests) and visual (histogram and probability charts) techniques, the conformity of continuous variables to the normal distribution was assessed. Separate samples the *t*-test was used to compare the data that fit the normal distribution between the two groups. In order to assess data that didn't conform to the normal distribution, the Mann–Whitney *U*-test was applied. The Pearson correlation test was used to assess the association between a few continuous data. The comparative research employed the Chi-square test. The Chi-square test was used in a comparative study for categorical variables among independent groups. The threshold for statistical significance in this study was established at $P < 0.05$.

Results

In our study, a total of 44 people, 22 women and 22 men, were evaluated. The participants' average age was 41.41, and the age range was 17–78. The study examined 21 right and 23 left shoulders [Table 1].

The control group's mean age was significantly younger than the RCT group's ($P = 0.004$). Compared to the control group, the RCT group had a significantly greater percentage of individuals over the age of 40 ($P = 0.001$) [Table 2].

The CSA in the RCT group was significantly greater than in the control group ($P = 0.002$). The two group's AI values did not significantly differ from one another ($P = 0.151$) [Table 3].

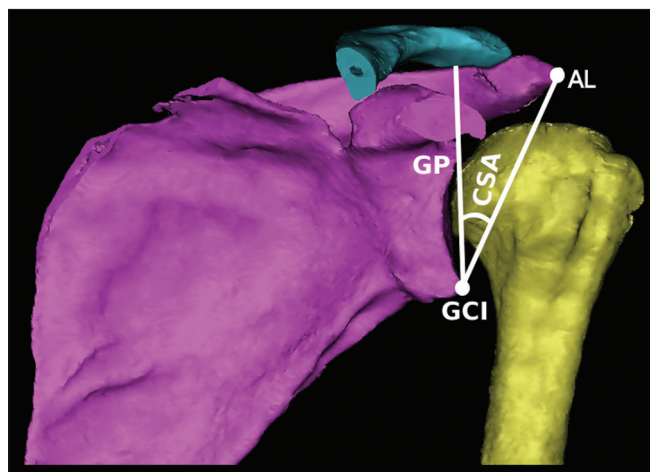


Figure 1: Measurement of critical shoulder angle. GP: Glenoid plane, CSA: critical shoulder angle, GCI: Inferior point of the glenoid cavity, AL: Most lateral point of the acromion

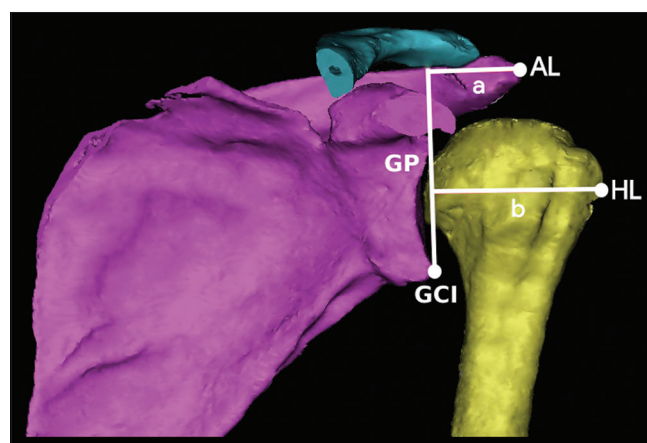


Figure 2: Measurement of the acromial index. (a) distance between AL-GP, (b) distance between HL-GP. GP: Glenoid plane, GCI: Inferior point of glenoid cavity, AL: Most lateral point of acromion, HL: Most lateral point of proximal epiphysis of humerus

There was no correlation between AI and CSA scores in the RCT group ($P = 0.543$). Moreover, there was no statistically significant association between CSA scores and age ($P = 0.142$). No correlation between age and AI levels was found ($P = 0.078$) [Table 4].

In the control group, there was no significant correlation between the CSA and AI scores ($P = 0.913$). Furthermore,

there was no correlation between CSA scores and age that could be considered significant ($P = 0.262$). Moreover, there was no distinct correlation between age and AI scores ($P = 0.168$) [Table 5].

The mean CSA and AI in women in the RCT group were found to be $39.35^\circ \pm 7.82^\circ$ and 0.68 ± 0.10 , respectively. CSA and AI averages in men were $43.70^\circ \pm 8.96^\circ$ and 0.56 ± 0.08 , respectively. Women's AI measures were significantly higher than men's in the RCT group ($P = 0.012$) [Table 6].

The mean CSA and AI in women in the control group were found to be $34.70^\circ \pm 4.00^\circ$ and 0.63 ± 0.05 , respectively. The mean CSA and AI in men were found to be $33.80^\circ \pm 5.34^\circ$ and 0.58 ± 0.14 , respectively. The control group demonstrated no significant correlation between gender, CSA, and AI ($P = 0.827$, $P = 0.238$).

Discussion

Many researchers have studied subjects such as RCT, the etiology of tears, and the biomechanics of rotator cuff muscles. Neer conducted early studies on RCT, subacromial space, and tendon lesions due to reduced subacromial space.^[20] Studies have shown that many biomechanical factors, glenoid cavity, and morphometric properties of the proximal extremity of the humerus play a role in the etiology of RCT. AI and CSA measurements are the most frequently used to define these morphometric properties.

Table 1: Distribution of the rotator cuff tears group's and the control group's demographic features (n=44)

Parameters	n (%)
Gender*	
Female	22 (50.0)
Male	22 (50.0)
Age (years)	
Mean±SD	41.41±16.70
Median (minimum–maximum)	40.0 (17.0–78.0)
Age groups	
Under 40 years	22 (50.0)
40 years and older	22 (50.0)
Group	
RCT group	24 (54.5)
Control group	20 (45.5)
Side	
Right	21 (47.7)
Left	23 (52.3)

*Column percentage. SD: Standard deviation, RCT: Rotator cuff tear

Table 2: Comparison of the rotator cuff tears group's and the control group's demographic features (n=44)

	RCT group (n=24), n (%)	Control group (n=20), n (%)	P
Gender*			
Female	17 (70.8)	5 (25.0)	0.006 ^a
Male	7 (29.2)	15 (75.0)	
Age (years)			
Mean±SD	52.92±12.97	27.60±7.71	0.004 ^b
Median (minimum–maximum)	55.00 (21.00–78.00)	28.50 (17.00–47.00)	
Age groups			
Under 40 years	3 (12.5)	19 (95.0)	0.001 ^a
40 years and older	21 (87.5)	1 (5.0)	
Side			
Right	16 (66.70)	5 (25.0)	0.014 ^a
Left	8 (33.30)	15 (75.0)	

*Column percentage, ^aContinuity correction, ^bIndependent samples *t*-test. SD: Standard deviation, RCT: Rotator cuff tear

Table 3: Comparison of critical shoulder angle and acromial index measurements of rotator cuff tears and control group (n=44)

	RCT group (n=24)	Control group (n=20)	P
CSA			
Mean±SD	40.62±8.22	34.02±4.95	0.002 ^a
Median (minimum–maximum)	41.00 (27.80–53.80)	34.90 (25.90–40.75)	
AI			
Mean±SD	0.65±0.11	0.60±0.13	0.151 ^a
Median (minimum–maximum)	0.64 (0.44–0.88)	0.60 (0.41–0.83)	

^aIndependent samples *t*-test. SD: Standard deviation, AI: Acromial index, CSA: Critical shoulder angle, RCT: Rotator cuff tear

Table 4: Relationship between critical shoulder angle and acromial index and age values in rotator cuff tears group

	<i>r</i> (<i>P</i>)	
	CSA (<i>n</i> =24)	AI (<i>n</i> =24)
AI	-0.130 (0.543)	-
Age	0.309 (0.142)	0.367 (0.078)

r: Pearson correlations coefficient, AI: Acromial index, CSA: Critical shoulder angle

Table 5: Relationship between critical shoulder angle and acromial index and age values in the control group

	<i>r</i> (<i>P</i>)	
	CSA (<i>n</i> =20)	AI (<i>n</i> =20)
AI	0.026 (0.913)	-
Age	-0.263 (0.262)	-0.321 (0.168)

r: Pearson correlations coefficient, AI: Acromial index, CSA: Critical shoulder angle

Table 6: Evaluation of rotator cuff tears group according to gender (*n*=24)

	Female (<i>n</i> =17)	Male (<i>n</i> =7)	<i>P</i>
CSA			
Mean±SD	39.35±7.82	43.70±8.96	0.227 ^a
Median	38.50	45.30	
(minimum–maximum)	(27.80–53.50)	(31.10–53.80)	
AI			
Mean±SD	0.68±0.10	0.56±0.08	0.012 ^a
Median	0.66	0.5	
(minimum–maximum)	(0.55–0.88)	(0.44–0.66)	

^aMann–Whitney *U*-test. SD: Standard deviation, AI: Acromial index, CSA: Critical shoulder angle

Nyffeler *et al.* provided the first description of the AI and claimed that it was connected to RCT.^[13] The CSA was discovered for the first time by Moor *et al.* and has been associated to diseases such shoulder instability, rotator cuff injuries, and osteoarthritis.^[9] The full-thickness RCT patient group in our study had considerably higher CSA scores than the control group. The AI values did not, nevertheless, demonstrate any significant difference.

Ames *et al.* investigated the connection between the AI and full-thickness RCT. They used standard anteroposterior radiographs. The study's findings revealed that the size of the AI and the size of the full-thickness RCT had no correlation.^[21]

Hamid *et al.* prospectively evaluated acromion morphology on 216 patients. As a result of their studies, they could not find a relationship between RCT and AI values.^[22] According to our research, there was no significant difference in the AI scores between the two groups. Using anteroposterior radiographs, Moor *et al.* analysed the AI, lateral acromial angle, and CSA in the patient population having RCT and the comparison group. They discovered a significant

difference between the study group and the control group's mean AI, lateral acromial angle, and CSA values.^[11] In our investigation, there was no significant different in the 3D assessment between the two groups. These current findings result from the use of radiography and 3D imaging techniques.

Moor *et al.* examined the relationship between age, trauma, and CSA with RCT. They evaluated the CSA on standard radiographs of 599 patients. As a result of their studies, the mean age and CSA values of patients with full-thickness RCT were found to be significantly greater than those with intact rotator cuffs.^[10] The full-thickness RCT group in our study had a mean age that was significantly older than the control group.

Cherchi *et al.* in their study, aim to evaluate the relationship between CSA and RCT and measured the CSA using goniometers on standard radiographs. They reported that the CSA was significantly greater in RCT group.^[3]

Gomide *et al.* measured the CSA on the radiographic images of two patient groups with full-thickness RCT and asymptomatic patients. They found that the patient group having RCT had mean CSA scores that were substantially greater than those of the control group.^[23] In our investigation, the full-thickness RCT patient group's CSA values were considerably greater than those of the control group.

Pandey *et al.* studied patients with full-thickness RCT, partial RCT, and the healthy control group. Their research evaluated the CSA and AI using standard radiography and ultrasonography images. As a result of the study, high CSA and AI values were associated with full-thickness RCT. In addition, investigators reported that the CSA and AI values were not associated with partial RCT.^[14] Our study's RCT group consists of patients who underwent full-thickness RCT. According to our research, there is a relationship between CSA scores and full-thickness RCT. In contrast, no correlation was identified between AI scores. This difference is due to our measurements on 3D models.

Heuberger *et al.* evaluated radiographic images of five different shoulder pathologies with several variables in a retrospective study conducted on 1000 patients. The study's findings revealed that the CSA is a more reliable general measure than the AI for predicting and identifying various pathologies. Also, researchers noted that the CSA was highest in RCT participants and lowest in osteoarthritis patients.^[5] In our study, the CSA values in the patient group with RCT and the control group differed significantly. Yet, there was no distinction in the AI values.

When the studies are examined since the CSA and AI parameters were defined, it is seen that the studies were primarily performed using radiographic examinations. Since it is difficult to accurately determine the position of the glenoid cavity of the scapula in two-dimensional

radiographic images, the need for 3D images is increasing. For this reason, recent studies have turned to 3D imaging techniques.

In addition, unlike the CSA, the evaluation of the AI was not significant in the 3D measurements in our study. Therefore, more studies are needed to evaluate the AI measurement on 3D images.

Gerber *et al.* created a model of a shoulder with a supraspinatus tear and a normal shoulder in a biomechanical study they performed by creating a mechanical shoulder simulation. As a result of their research, they found that a high CSA may cause excessive load on the supraspinatus, especially during an active abduction at low degrees.^[24]

Conclusion

As a result, the measurements we made on 3D glenohumeral joint models were compared with the results of two-dimensional radiographic evaluation found in the literature. Unlike most two-dimensional radiographic assessments, AI values were not associated with RCT. In contrast, it was discovered that CSA scores were related to RCT in parallel with two-dimensional radiographic evaluation. We think this difference may be because we performed our study on models obtained by 3D computed tomography reconstruction. However, we recommend that these factors be considered in future studies, as we cannot determine whether the RCT we evaluated within the scope of the study are degenerative or traumatic due to the age difference between the groups. We anticipate our results will guide clinicians in revealing the etiology of rotator cuff degeneration and determining the surgical method for repair.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

- Balke M, Schmidt C, Dedy N, Banerjee M, Bouillon B, Liem D. Correlation of acromial morphology with impingement syndrome and rotator cuff tears. *Acta Orthop* 2013;84:178-83.
- Blonna D, Giani A, Bellato E, Mattei L, Caló M, Rossi R, *et al.* Predominance of the critical shoulder angle in the pathogenesis of degenerative diseases of the shoulder. *J Shoulder Elbow Surg* 2016;25:1328-36.
- Cherchi L, Ciomhac JF, Godet J, Clavert P, Kempf JF. Critical shoulder angle: Measurement reproducibility and correlation with rotator cuff tendon tears. *Orthop Traumatol Surg Res* 2016;102:559-62.
- Hanciau FA, da Silva MA, Martins FS, Ogliari A. Association clinical-radiographic of the acromion index and the lateral acromion angle. *Rev Bras Ortop* 2012;47:730-5.
- Heuberger PR, Plachel F, Willinger L, Moroder P, Laky B, Pauzenberger L, *et al.* Critical shoulder angle combined with age predict five shoulder pathologies: A retrospective analysis of 1000 cases. *BMC Musculoskelet Disord* 2017;18:259.
- Logvinov A, Ilyin D, Kadantsev P, Makar'yeva O, Burtsev M, Riazantsev M, *et al.* Radiographic characteristics of the acromion process as a predictive factor of partial rotator cuff tears. *Genij Ortop* 2019;25:71-8.
- Mantell MT, Nelson R, Lowe JT, Endrizzi DP, Jawa A. Critical shoulder angle is associated with full-thickness rotator cuff tears in patients with glenohumeral osteoarthritis. *J Shoulder Elbow Surg* 2017;26:e376-81.
- Miyazaki AN, Fregoneze M, Santos PD, Silva LA, Martel ÉM, Debom LG, *et al.* Radiographic analysis of the acromion index and its association with rotator cuff tears. *J Rev Bras Ortop* 2010;45:151-4.
- Moor BK, Bouaicha S, Rothenfluh DA, Sukthakar A, Gerber C. Is there an association between the individual anatomy of the scapula and the development of rotator cuff tears or osteoarthritis of the glenohumeral joint? A radiological study of the critical shoulder angle. *Bone Joint J* 2013;95-B: 935-41.
- Moor BK, Röthlisberger M, Müller DA, Zumstein MA, Bouaicha S, Ehlinger M, *et al.* Age, trauma and the critical shoulder angle accurately predict supraspinatus tendon tears. *Orthop Traumatol Surg Res* 2014;100:489-94.
- Moor BK, Wieser K, Slankamenac K, Gerber C, Bouaicha S. Relationship of individual scapular anatomy and degenerative rotator cuff tears. *J Shoulder Elbow Surg* 2014;23:536-41.
- Musil D, Sadovský P, Rost M, Stehlik J, Filip L. Relationship of acromial morphology and rotator cuff tears. *Acta Chir Orthop Traumatol Cech* 2012;79:238-42.
- Nyffeler RW, Werner CM, Sukthakar A, Schmid MR, Gerber C. Association of a large lateral extension of the acromion with rotator cuff tears. *J Bone Joint Surg Am* 2006;88:800-5.
- Pandey V, Vijayan D, Tapashetti S, Agarwal L, Kamath A, Acharya K, *et al.* Does scapular morphology affect the integrity of the rotator cuff? *J Shoulder Elbow Surg* 2016;25:413-21.
- Sukthakar A, Werner C, Brucker P, Nyffeler R, Gerber C. Lateral extension of the acromion and rotator cuff tears – A prospective study. *Orthop Proc Br Ed Soc Bone Joint Surg* 2009;91:123.
- Watanabe A, Ono Q, Nishigami T, Hirooka T, Machida H. Association between the critical shoulder angle and rotator cuff tears in Japan. *Acta Med Okayama* 2018;72:547-51.
- Rhee SM, Kim JY, Kim JY, Cho SJ, Kim JH, Rhee YG. The critical shoulder angle: Can it be sufficient to reflect the shoulder joint without the humeral head? *J Shoulder Elbow Surg* 2019;28:731-41.
- Chen D, Chen CH, Tang L, Wang K, Li YZ, Phan K, *et al.* Three-dimensional reconstructions in spine and screw trajectory simulation on 3D digital images: A step by step approach by using mimics software. *J Spine Surg* 2017;3:650-6.
- Yavuz MS, Buyukkurt MC, Tozoglu S, Dagsuyu IM, Kantarci M. Evaluation of volumetry and density of mandibular symphysis bone grafts by three-dimensional computed tomography. *Dent Traumatol* 2009;25:475-9.
- Neer CS 2nd. Anterior acromioplasty for the chronic impingement syndrome in the shoulder: A preliminary report. *J Bone Joint Surg Am* 1972;54:41-50.
- Ames JB, Horan MP, Van der Meijden OA, Leake MJ, Millett PJ. Association between acromial index and outcomes following arthroscopic repair of full-thickness rotator cuff tears. *J Bone Joint Surg Am* 2012;94:1862-9.

22. Hamid N, Omid R, Yamaguchi K, Steger-May K, Stobbs G, Keener JD. Relationship of radiographic acromial characteristics and rotator cuff disease: A prospective investigation of clinical, radiographic, and sonographic findings. *J Shoulder Elbow Surg* 2012;21:1289-98.
23. Gomide LC, Carmo TC, Bergo GH, Oliveira GA, Macedo IS. Relationship between the critical shoulder angle and the development of rotator cuff lesions: A retrospective epidemiological study. *Rev Bras Ortop* 2017;52:423-7.
24. Gerber C, Snedeker JG, Baumgartner D, Vieh  fer AF. Supraspinatus tendon load during abduction is dependent on the size of the critical shoulder angle: A biomechanical analysis. *J Orthop Res* 2014;32:952-7.