Medical Research Archives

ESMED European Society of Medicine

OPEN ACCESS

Published: April 30, 2022

Citation: José CSV, Anna LAV, et al. 2022. Critical Shoulder Angle Assessment in Radiographies and Magnetic Resonance Imaging (MRI): Measurement of Intra and Inter-Observer Agreement, [online] 10(4). https://doi.org/10.18103/mra.v10i4.2750

DOI: https://doi.org/10.18103/mra.v10i4.2750

ISSN: 2375-1924

RESEARCH ARTICLE

Critical Shoulder Angle Assessment in Radiographies and Magnetic Resonance Imaging (MRI): Measurement of Intra and Inter-Observer Agreement

José Carlos Souza Vilela, MD, PHD [1,2]; Anna Luiza Amancio Vidal [1]; Mabelly Andrade Corrêa [1]; Luciene Mota de Andrade [3]; Paulo Henrique Sampaio Ribeiro [1]; Bruno Biller Teixeira Fernandes de Araújo [3]; Tadeu Fonseca Barbosa [1,4]; Thalles Leandro Abreu Machado [1,4]

[1] Unimed BH hospital
[2] Mater dei Hospital
[3] ECOAR Diagnosis clinic
[4] IPSEMG

*mabellycorrea@yahoo.com.br

ABSTRACT

Objective: to evaluate the critical shoulder angle by comparing the results of measurements performed by radiography and magnetic resonance imaging, considering the intra and interobserver perspectives.

Methods: we evaluated radiographic and magnetic resonance images of 74 shoulders (71 patients) submitted to these exams between 2017 and 2020, regardless of the acquired pathology. We ran a statistical analysis comparing the mean values of the data obtained by the student's t-test, and the analysis of intra and interobserver agreement used the Interclass Correlation Coefficient (ICC), with bidirectional mixed models and a confidence interval of 95%.

Results: the patients had a mean age of 51.7 years, with a predominance of men (51.9%) and the most affected shoulder was the right-sided one (57.9%). There were no significant differences between the measurements made by radiography and those by magnetic resonance, both by intra and interobserver views, and the ICC showed a satisfactory level of agreement in relation to these aspects. Conclusion: there was an excellent degree of agreement between the examiners, in all the situations compared (intra and interobserver, radiography and MRI), considering the two periods of analysis.

Keywords: Critical Shoulder Angle. X-ray. Magnetic Resonance Imaging.

INTRODUCTION

Shoulder injuries are not uncommon and can affect people of both sexes, different age groups, social classes and professions, representing the third most frequent musculoskeletal complaint by patients seeking orthopedic medical services. The incidence of shoulder problems is estimated to vary between seven and 25 of every 1,000 consultations with physicians in general, with a projected prevalence between 6.9% and 34%[1,2]. Its annual occurrence in the general population is estimated at 7%, with an annual prevalence between 5% and 47%; and about 40% of cases tend to become chronic. The prevalence of shoulder pain, associated with pain-related range of motion restriction, with inability to perform daily activities can affect up to 20% of the population[3,4].

Shoulder pathologies, which include glenohumeral osteoarthrosis and rotator cuff disorders, have multifactorial causes[5]. Intrinsic (physiological) and extrinsic (morphological) factors have been proposed as risks for shoulder pathologies and, therefore, are of great interest in defining the best prognosis and management for each patient. When analyzing quantitative scapular anatomy, there are direct associations between specific radiographic parameters and cuff injuries. It is also clear that increased glenoid retroversion is associated with anterior cuff tears, while anteversion expansion is associated with posterior cuff injuries[5,6]. In addition, there are reports on the relationship between lateral extension of the acromion and progression to rotator cuff injuries and osteoarthrosis[7].

Nyffeler et al. published that a high index results in a more vertical orientation of the force vector amidst deltoid fibers, which tend to pull the humeral head upwards, requiring the supraspinatus tendon to exert a greater horizontal force to stabilize the center of rotation during active abduction.[7-9] However, in shoulders with a shorter acromion, the compressive component of the deltoid would become dominant and synergistic with the supraspinatus's vector. This should cause a load increase on the surface of the glenohumeral joint, favoring degenerative wear and causing osteoarthrosis, while reducing tension on the rotator cuff.[8,9]

More recently, this critical shoulder angle definition, proposed by Moore et al., has been advocated to quantify the combination of glenoid tilt and lateral acromion.[10,11] This parameter was obtained by the angle formed between a line that connects the superior and inferior margins of the glenoid and drawn from the inferior margin of the glenoid to the inferolateral border of the acromion. Considerably, some studies have shown that the critical shoulder angle could be a predictor of primary osteoarthrosis and rotator cuff tear. A greater critical shoulder angle (greater than 35°) would be associated with rotator cuff injuries and a lower critical shoulder angle (less than 30°) with osteoarthrosis.[12-14]

Many studies indicate that critical shoulder angles and larger acromial indices are associated with larger, full-thickness rotator cuff injuries.[8,11,15-18] When analyzing the shoulder radiographs of 46 patients in 2017, Gomide et al. concluded that there is a correlation between the increase in the critical shoulder angle value and the increase in the occurrence of rotator cuff injuries, a hypothesis already confirmed and advocated by Moor et al., in 2013.[10,19] The study also reinforces the importance of prior knowledge about the possible causes of rotator cuff injuries, considering that among them is the shoulder critical angle, quantifying the extension of the acromial coverage without being influenced by a flattening of the humeral head or excessive bone erosion of the posterior glenoid cavity - both of which are typically found in glenohumeral osteoarthritis. Additionally, the critical shoulder angle does not only reflect acromial coverage, but also the glenoid tilt, and integrates both risk factors into a biomechanical parameter.[19]

These analyzes are compatible with the concept that a healthy shoulder has a balanced mechanical load. Previous studies have reported a negative correlation between rotator cuff tears and the prevalence of osteoarthrosis.[20] In their study, Moor et al. reported that 93% of patients with a critical shoulder angle lower than 30° had osteoarthritis. The measurement of the critical shoulder angle is often performed on anteroposterior radiographs of the shoulder to determine the angle between the glenoid and the glenoacromial planes.[10,21] Despite the proven reliability of critical shoulder angle measurements in radiographs and computed tomography in the current literature, there is still little information about its measurement in magnetic resonance images.

This is a retrospective study, which goal is to evaluate the critical shoulder angle from values measured by radiographs and magnetic resonance imaging, under the intra and interobserver viewpoints.

METHODS

We started this study after we got approval by the Ethics Committee of Governador Magalhães Pinto hospital. We searched the database of the radiologic service for all patients over 18 years of age who underwent imaging tests as a request from the two senior examiners between 2017 and 2020, regardless of the pathology that motivated the exam. From all the patients found, we searched for those who underwent radiographs and MRI of the same shoulder. After we selected the patients, the two senior examiners, both orthopaedic surgeons, assessed patients' medical records and radiographs, and were excluded those individuals who presented radiological signs of previous fractures that compromised the measurement of the critical shoulder angle, those with a previous history of shoulder surgeries, those with radiographs with any sign of glenohumeral osteoarthrosis and those with exams performed at different times, exceeding the maximum period of one year. We found that 74 shoulders (71 patients) met the inclusion and exclusion criteria. After the two radiologists primarily examined the radiological images, additional 17 shoulders (17 patients) were excluded from the study, due to a technical error in radiological positioning, leaving 57 shoulders (54 patients) in the study.

All images were collected in a single database in Digital Imaging and Communications in Medicine (DICOM) format and were analyzed by two radiologists from the same service. Digital radiographs were evaluated in the true anteroposterior view of the shoulder and magnetic resonance imaging using a coronal oblique section on T(1). The two radiologists performed the measurements individually at the same time and repeated the same procedure one week after the first measurement. All data were collected to one decimal point using the OsiriX v.5.8.2 32-bit software.

On radiographs, the critical shoulder angle was measured as described by Moor et al., using anteroposterior radiographs of the shoulder (true AP)[10]. A vertical line was drawn connecting the upper edge of the glenoid (point 1a) to the lower edge (point 2a). Then, another line was drawn from the lower border of the glenoid (point 2a) to the lateral border of the acromion (point 3a). As an exclusion criterion for exams with positioning errors, the Suter-Henninger (SH) classification system was adopted and, as proposed by Suter et al., the radiographs classified by both radiologists as belonging to the B1, B2, B3 or D1, D2, D3 standards were excluded from the study[22].

In magnetic resonance imaging, the critical shoulder angle was measured using the coronal oblique-derived cross-section T(1) at different levels. Initially, we established the magnetic resonance slice that would cross the center of the glenoid, in order to mark its upper and lower edges (1b and 2b respectively); and the line connecting the two points was drawn. Then, we identified the extreme lateral point of the acromial border (3b); and we drew the line connecting the inferior border of the glenoid (point 2b) to the lateral border of the acromion (point 3b). By superimposing the captured images, the critical angle of the shoulder was calculated.

The statistical analysis of the data was carried out together with a statistician, comparing the means using the Student's t test, which consists of a hypothesis test, using statistical concepts to reject or not a null hypothesis when the test statistic (t) follows the *student* distribution[23].

First, we ran an exploratory analysis to determine the normality of the collected data, when the D'Agostino-Pearson and Shapiro-Wilk tests were used, which enabled the calculation of the difference between their values and the value expected by the parametric distribution. Then, we obtained the mean, standard deviation and minimum and maximum values from each examiner. The comparative analysis between the techniques (radiography/magnetic resonance) and between the examiners (A1, A2 / B1, B2) was performed using the unpaired Student's t-test, with the results presented in tables and graphs.

The intra- and inter-observer agreement analyzes used the Intraclass Correlation Coefficient (ICC), using bidirectional mixed models, or two-way mixed models, with a confidence interval of 95% (CI = 95%). In all analyzes performed, the differences found were considered statistically significant when the p value was lower than 0.05, i.e., $p < 0.05$. For statistical analyses, we used the GraphpadPrism® software, version 5.0 for Windows, and the Stata® program, version 14.0.

RESULTS

The results obtained revealed that the patients included in the study had a mean age of 51.7 years, ranging from 18 to 85 years of age; with a slight predominance of males (51.9%), compared to females (48.1%). Regarding the affected shoulder, the right side had a higher occurrence, with 57.9%, and the left side represented 42.1% of the total (Table 1).

Table 1: Age, sex and affected side distribution.

Age range n = 54		Sex (n / %) n = 54				Affected side (n / %) n = 57			
Mean age	**Years**	**Males**		**Females**		**Right**		**Left**	
51.7	18 – 85	28	51.9%	26	48.1%	33	57.9%	24	42.1%

Source: Prepared by the author.

Measurement of the critical shoulder angle was performed by two radiologists (A and B), who used radiographs and magnetic resonance imaging at two different times, with a one-week interval between measurements. Therefore, initially, we calculated the mean, standard deviation and minimum and maximum values from each examiner, enabling the comparative analysis between the evaluators' critical shoulder angle measurements, according to radiography and magnetic resonance techniques.

Table 2: Comparative analysis between critical shoulder angle measurements – radiography technique.

Radiography	Mean	SD	Min – Max
A1	34.54	± 4.84	21.80 – 44.50
A2	34.36	± 4.65	22.20 – 44.30
B1	33.39	± 4.83	22.40 – 47.20
B2	34.38	± 4.81	24.00 – 47.70
Intraobserver analysis			
Examiners		***p*-value**	
A1 x A2		0.8454[T]	
B1 x B2		0.2761[T]	
nterobserver analysis			
Examiners		***p*-value**	
A1 x B1		0.2081 [T]	
A2 x B2		0.9830 [T]	

Legend: SD – Standard Deviation; A1 – first radiologist in the first evaluation; A2 – first radiologist in the second evaluation; B1 – second radiologist in the first evaluation; B2 – second radiologist in the second evaluation; T – Student's t-test.

According to Table 2, the comparison between the measurements of the critical shoulder angle, based on the radiographic technique used by examiners A and B, does not show significant differences both among intra and interobservers, indicating a $p > 0.05$. Therefore, the means and standard deviations obtained between the two examiners, in both evaluation periods, are considered statistically equal.

Table 3: Comparative analysis between critical shoulder angle measurements – magnetic resonance (MRI) technique.

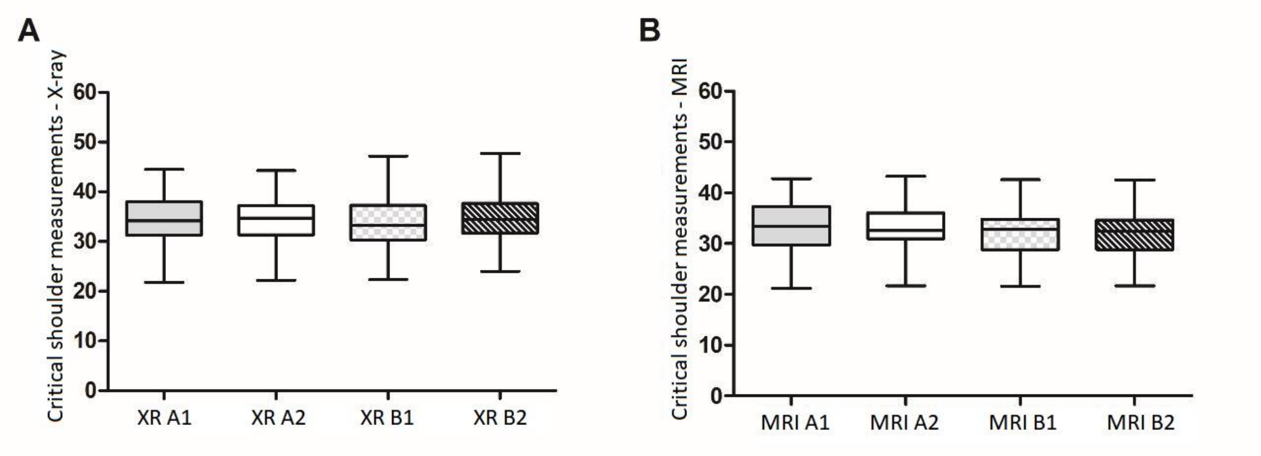
MRI	Mean	SD	Min – Max
A1	33.23	± 4,53	21,19 – 42,80
A2	32.98	± 4,50	21,70 – 43,30
B1	31.89	± 4,72	21,60 – 42,60
B2	32.10	± 4,60	21,70 – 42,50
Intraobserver analysis			
Examiners		***p*-value**	
A1 x A2		0.7691^{T}	
B1 x B2		0.8128^{T}	
nterobserver analysis			
Examiners		***p*-value**	
A1 x B1		0.1267^{T}	
A2 x B2		0.3054^{T}	

Legend: SD – Standard Deviation; A1 – first radiologist in the first evaluation; A2 – first radiologist in the second evaluation; B1 – second radiologist in the first evaluation; B2 – second radiologist in the second evaluation; T – Student's t-test.

The comparative data shown in Table 3 reveal that there were no significant intra- and inter-observer differences in the measurements of the critical shoulder angle by the magnetic resonance technique, with a $p > 0.05$. Such results indicate that the means and standard deviations obtained by each of the examiners in the two analyzed periods were statistically equal.

In order to facilitate the visual interpretation of the comparison of data related to measurements of the critical shoulder angle, performed through radiographs and magnetic resonance imaging, by the two examiners, these results are graphically demonstrated in Figure 1, containing Figures 1A and 1B.

Figure 1: Comparison of critical shoulder angle measurements – radiography (A) and magnetic resonance (B) techniques.



The horizontal line in each box represents the mean value from each examiner; the box, the standard deviation; and the bars, the minimum and maximum values. A1 and A2: first examiner in the first and second evaluations, respectively. B1 and B2: second rater in the first and second assessment, respectively.

Table 4 depicts the comparative analysis of the critical shoulder angle measurements from each examiner radiologist, performed in the two evaluated periods, which considered the mean, standard deviation and p-value, according to radiography and MRI.

Table 4: Comparative analysis of the measurements of the critical shoulder angle from each examiner in the periods evaluated – radiography and magnetic resonance imaging (MRI) techniques.

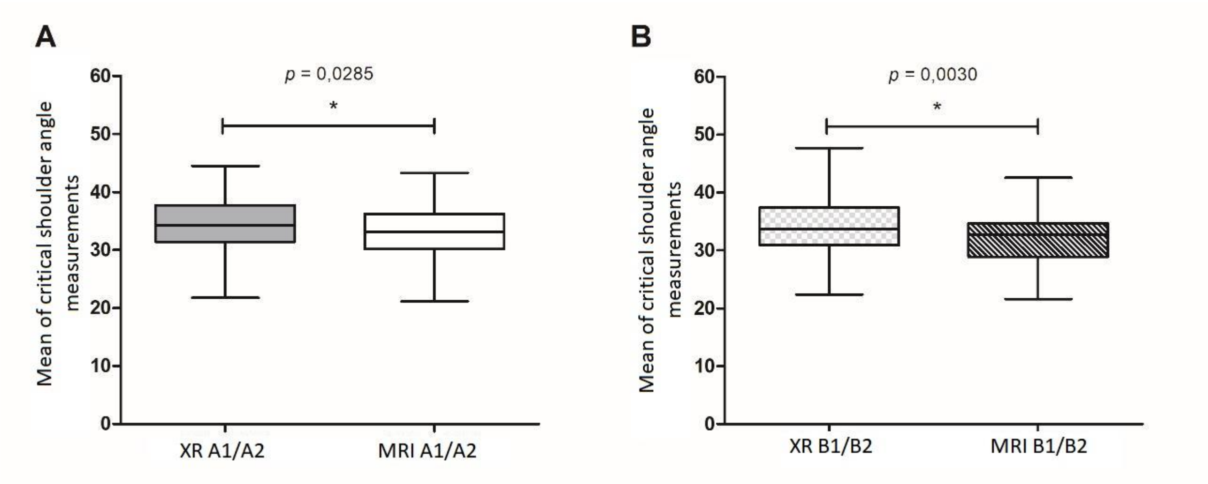
	Radiography	MRI	*p*-value
General Mean Examiner A			
Mean	34.45	33.10	0.0285*
SD	± 4.73	± 4.49	
General Mean Examiner B			
Mean	33.88	32.00	0.0030*
SD	± 4.82	± 4.64	

SD – Standard Deviation; * p-value considered statistically significant ($p < 0.05$), according to the Student's t-test.

As shown in Table 4, the analysis of the general mean from each examiner radiologist, in the two periods included, for both examiners, indicated that the measurements of the critical shoulder angle obtained by radiography are statistically higher than those obtained by MRI, were p = 0.0285 and p = 0.0030, respectively.

To facilitate the interpretative visualization of the comparative analysis, the data related to the general average from each examiner in the measurements of the critical shoulder angle, in the two periods evaluated, by radiography and magnetic resonance imaging, are presented in Figure 2, containing Figures 2 A and 2B.

Figure 2: Comparison of the overall mean of critical shoulder angle measurements – radiography (XR) and magnetic resonance imaging (MRI) techniques in A (overall mean from examiner A) and B (overall mean from examiner B).



The horizontal line in each box represents the mean from each examiner, in each technique; the box, the standard deviation; and the bars, the minimum and maximum values. (*): $p < 0.05$, according to Student's t test.

The agreement analysis, Intraclass Correlation Coefficient (ICC), includes the comparison of the measurements results of the critical shoulder angle from the two evaluating radiologists, intra and interobserver, according to radiography and magnetic resonance imaging, as shown in Table 5.

The Intraclass Correlation Coefficient (ICC) has the ability to inform how much the observers or examiners agree with each other, comparatively considering the results obtained by each one of them. The interpretation of the ICC is considered simple, because the closer to 1 (one), the more the evaluators agree, and the closer to 0 (zero), the more they disagree in their measurements. The most used classification considers the following ranges: ICC < 0.40 = poor agreement; ICC between 0.41 and 0.60 = reasonable agreement; ICC between 0.61 and 0.75 = good agreement; and ICC > 0.76 to 1.00 = excellent agreement.

Table 5: Analysis of intra and interobserver ICC, according to examiners A and B – radiography and magnetic resonance imaging (MRI) techniques.

Intraobserver analysis			
	ICC	**95% IC**	
Radiography – A1 x A2	0.9636	0.9384	0.9786
Radiography – B1 x B2	0.9527	0.8867	0.9767
RM – A1 x A2	0.9609	0.9338	0.9769
RM – B1 x B2	0.9645	0.9400	0.9791
Interobserver analysis			

	ICC	95% IC	
Radiography – A1 x B1	0.9339	0.8502	0.9666
Radiography – A2 x B2	0.9674	0.9444	0.9809
RM – A1 x B1	0.9075	0.7852	0.9538
RM – A2 x B2	0.9321	0.8705	0.9625

ICC – Intraclass Correlation Test; 95% ICC – 95% confidence interval; A1 – first radiologist in the first evaluation; A2 – first radiologist in the second evaluation; B1 – second radiologist in the first evaluation; B2 – second radiologist in the second evaluation.

Based on the ICC values found, Table 5 shows an excellent agreement between the examiners, depicting that their first and second assessments had high degree of agreement, both in radiography and in the MRI.

Furthermore, according to this classification, the interobserver agreement was excellent, indicating that the results obtained by the two examiners (A and B) were very much similar, regardless of how the results from their first or second evaluation compared, according to Table 5.

DISCUSSION

The critical shoulder angle has been widely used to assess patients with inflammatory and degenerative processes, since it can be used as a predictor of several injuries, especially primary osteoarthrosis, supraspinal rupture and rotator cuff tears;[9,11,14, 18,19,24,25] Critical shoulder angle have been described as a good parameter to predict and distinguish between different pathologies. Typically, patients with higher critical angle were diagnosed with rotator cuff tears, and patients with osteoarthritis had lower critical shoulder angle. Evaluation of intra and interobserver agreement is an import parameter to evaluate reproducibility of a parameter or score. Therefore the importance of measuring the critical shoulder angle, through effective imaging tests and compare them, as is the case with radiography and magnetic resonance imaging, in order to look for differences, level of intra and interobserver agreement and, thus, make evidence from its accuracy in the assessment and diagnosis of these patients.

Among the findings of this study, we stress that, for both radiography and magnetic resonance images, there were no significant intra and interobserver differences in the two periods analyzed by the two examiners, making the results obtained statistically equal. Such findings, obtained through the mean and standard deviation of the measurements, indicate that the assessment of the critical shoulder angle is highly effective when performed using both exams and through the two perspectives used in the study, that is, intra and interobserver, regardless of the period of its realization and/or repetition.

In this sense, it is worth noting that there is a scarcity of studies on the comparison of critical shoulder angle assessment between radiographic and magnetic resonance images, in order to obtain intra and interobserver agreement between these two techniques. Even so, it is relevant to mention a recent study carried out by Garcia et al. which aimed to assess the degree of reliability of the critical shoulder angle measurement made by magnetic resonance compared to radiography. Among its results, the study found the absence of a statistically significant difference between these two techniques, indicating only that, regardless of the examiner's experience, there was less variation in data in the evaluations performed by magnetic resonance imaging[25]. This aspect corroborates our findings from the present study.

Likewise, a study carried out by Spiegl et al., in 2016, aiming to establish the association between the critical shoulder angle, rotator cuff injuries and osteoarthritis, by comparing radiography and MRI measurements, found no significant difference between the data obtained by these two techniques. In addition to finding an association between the critical shoulder angle and the two types of injuries mentioned, the study concluded that the use of both magnetic resonance imaging and radiography in measurements is extremely effective and highly reliable for the evaluation of patients with these shoulder injuries.[18]

In our study, we found that the general average values found by each examiner, in the two periods considered, indicated that the measurements of the critical shoulder angle resulting from the radiographic technique are statistically higher than those obtained by MRI, with a *p* value lower than 0.05 in both cases, being considered statistically significant. However, the statistically significant interobserver general mean value in measurements of the critical shoulder angle, comparing radiography and magnetic resonance imaging, was also found in studies that, in the end, showed relevant aspects, such as great efficacy and high degree of confidence in the results obtained with the measurements performed by these two techniques and the absence of significant inter and intra-observer differences (mean; standard deviation; p-value), indicating a high level of agreement between observers/examiners.[11,14,18,24,25]

In this regard, this study detected a high degree of agreement between the examiners, both from an intra and interobserver perspective, considering both techniques used, that is, radiography and MRI, and such general agreement was classified as excellent according to the interpretive standards of the Intraclass Correlation Coefficient. This result indicates that the measurement of the critical shoulder angle can provide excellent results, in terms of accuracy, reliability and precision, both through radiographic imaging and through magnetic resonance imaging, provided that it is performed by a trained and experienced radiology professional, and one must consider incongruities or insignificant differences between these techniques.

Corroborating these results, the study by Spiegl et al., for instance, concluded that the measurements of the critical shoulder angle obtained from radiographs showed a satisfactory level of statistical agreement with results from the analysis of magnetic resonance imaging[18]. Likewise, the study by Garcia et al. showed conclusively that, in addition to the absence of statistically significant differences, the results from the measurements of the critical shoulder angle, from the comparison between radiographic and magnetic resonance data, showed excellent agreement, with minor caveats in the intraobserver comparison of the resonance magnetic.

It should be noted that, in the study carried out by Spiegl et al., there was a statistically significant difference between the measurements performed by radiography and magnetic resonance imaging in cases of glenohumeral osteoarthrosis, indicating low intraobserver reproducibility and moderate interobserver correlation. This result was attributed to the osteophytosis present at the lower border of the glenoid, which could have compromised the accuracy of measuring the critical shoulder angle. In the present study, radiographs of patients with osteoarthrosis were excluded from the evaluation and, therefore, we cannot state that for this group of patients there is the same precision in the evaluation of the critical shoulder angle performed by magnetic resonance imaging. This aspect proves to be a limiting factor in the results of this study compared to others that included this criterion in the assessment of the critical shoulder angle.

Critical shoulder angle has been described as a good parameter to predict and distinguish between different pathologies. However, this angular assessment only takes in account two parameters, the glenoid angulation and the acromion, ignoring the forces of other muscles. The evaluated parameters influence only at the extremes of movement on the shoulder. We must also consider limitations of imaging methods, as the MRI assessment requires a larger learning curve. Therefore, we believe that the critical angle is a good parameter, but it should not be examined in isolation.

CONCLUSION

There was no statistically significant difference between measurements of the critical shoulder angle, performed using radiography compared to those performed using magnetic resonance imaging, considering the intra and interobserver perspectives, regardless of the assessment periods included in the study.

An excellent degree of agreement was found between the examiners, in all the situations compared (intra and interobserver in radiography and magnetic resonance) in the context of the Intraclass Correlation Coefficient.

REFERENCES

1. Souza MC, Jorge RT, Jones A, Lombardi Júnior I, Natour J. *Progressive resistance training in patients with shoulder impingement syndrome: literature review*. Reumatismo, 2009;61(2):84-9.
2. Brennan GP, Prent EC, Cleland JA. *Description of clinical outcomes and postoperative utilization of physical therapy services within 4 categories of shoulder surgery*. J Orthop Sports Phys Ther. 2010;40(1):20-9.
3. Watson J, Helliwell P, Morton V, Adebajo A, Dickson J, Russel I, Torgerson D. *Shoulder acute pain in primary healthcare: is retraining effective for GP principals? SAPPHIRE: a randomized controlled trial*. Rheumatology (Oxford), 2008;47(12):1795-1802.
4. Feitosa ALM, Silva CC. *Prevalência das síndromes dolorosas do ombro em pacientes atendidos em uma clínica privada de fisioterapia em Teresina – PI*. Rev. Saúde em Foco, 2015;2(1):12-24.
5. Matthews TJW, Hand GC, Rees JL, Athanasou NA, Carr AJ. *Pathology of the torn rotator cuff tendon. Reduction in potential for repair as tear size increases*. J Bone Joint Surg Br. 2006;88(4):489-95.
6. Tétreault P, Krueger A, Zurakowski D, Gerber C. *Glenoid version and rotator cuff tears*. J Orthop Res Off Publ Orthop Res Soc. 2004;22(1):202-7.
7. Bhatia DN, Debeer JF, Toit DF du. *Association of a large lateral extension of the acromion with rotator cuff tears*. J Bone Joint Surg Am. 2006;88(8):1889-90.
8. Nyffeler RW, Werner CML, Sukthankar A, Schmid MR, Geber C. *Association of a large lateral extension of the acromion with rotator cuff tears*. J Bone Joint Surg Am. 2006;88(4):800-5.
9. Gerber C, Snedeker JG, Baumgartner D, Viehöfer AF. *Supraspinatus tendon load during abduction is dependent on the size of the critical shoulder angle: a biomechanical analysis*. J Orthop Res Off Publ Orthop Res Soc. 2014;32(7):952-7.
10. Moor BK, Bouaicha S, Rothenfluh DA, Sukthankar 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(7):935-41.
11. Li H, Chen Y, Chen J, Hua Y, Chen S. *Large critical shoulder angle has higher risk of tendon retear after arthroscopic rotator cuff repair*. Am J Sports Med. 2018;46(8):1892-1900.
12. Balke M, Liem D, Greshake O, Hoeher J, Bouillon B, Banerjee M. *Differences in acromial morphology of shoulders in patients with degenerative and traumatic supraspinatus tendon tears*. Knee Surg Sports Traumatol Arthrosc Off J ESSKA. 2016;24(7):2200-5.
13. Daggett M, Werner B, Collin P, Gauci M-O, Chaoui J, Walch G. *Correlation between glenoid inclination and critical shoulder angle: a radiographic and computed tomography study*. J Shoulder Elbow Surg. 2015;24(12):1948-53.
14. Heuberer PR, Plachel F, Willinger L, Moroder P, Laky B, Pauzenberger L, Lomoschitz F, Ander W. *Critical shoulder angle combined with age predict five shoulder pathologies: a retrospective analysis of 1000 cases*. BMC Musculoskelet Disord. 2017;18(259):1-9.
15. Kim JR, Ryu KJ, Hong IT, Kim BK, Kim JH. *Can a high acromion index predict rotator cuff tears?* Int Orthop. 2012;36(5):1019-24.
16. 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(4):536-41.
17. Pandey V, Vijayan D, Tapashetti S, Agarwal L, Kamath A, Acharya K, Maddukuri S, Willems WJ. *Does scapular morphology affect the integrity of the rotator cuff?* J Shoulder Elbow Surg. 2016;25(3):413-21.
18. Spiegl UJ, Horan MP, Smith SW, Ho CP, Millett PJ. *The critical shoulder angle is associated with rotator cuff tears and shoulder osteoarthritis and is better assessed with radiographs over MRI*. Knee Surg Sports Traumatol Arthrosc. 2016;24(7):2244-51.
19. Gomide LC, Carmo TC, Bergo GHM, Oliveira GA, Macedo IS. *Associação entre o ângulo crítico do ombro e lesão do manguito rotador: um estudo epidemiológico retrospectivo*. Rev Bras Ortop. 2017;52(4):423-7.
20. Bjarnison AO, Sorensen TJ, Kallemose T, Barfod KW. *The critical shoulder angle is associated with osteoarthritis in the shoulder but not rotator cuff tears: a retrospective case-control study*. J Shoulder Elbow Surg. 2017;26(12):2097-102.

21. Bishop JL, Kline SK, Aalderink KJ, Zauel R, Bey MJ. *Glenoid inclination: in vivo measures in rotator cuff tear patients and associations with superior glenohumeral joint translation*. J Shoulder Elbow Surg. 2009;18(2):231–6.
22. Suter T, Popp AG, Zhang Y, Zhang C, Tashjian RZ, Henninger HB. *The influence of radiographic viewing perspective and demographics on the critical shoulder angle*. J Shoulder Elbow Surg. 2015;24(6):149-58.
23. Lopes ACB, Leinioski AC, Ceccon L. *Testes t para comparação de médias de dois grupos independentes*. Curitiba: UFPR; 2015.
24. Li X, Olszewski N, Abdul-Rassoul H, Curry EJ, Galvin JW, Eichinger JK. *Relationship between the critical shoulder angle and shoulder disease*. JBJS Reviews, 2018;6(8):1-8.
25. Garcia JC, Altoe LS, Amaral RFM, Aihaea AY, Lutfi HV, Mello MBD. *Estudo duplo-cego randomizado da correlação entre radiografia simples e ressonância magnética na avaliação do ângulo crítico do ombro: reprodutibilidade e curva de aprendizado*. Rev Bras Ortop. [online]. 2020. DOI: 10.1055/s-0040-1701288.