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Original Article

CRITICAL SHOULDER ANGLE MEASUREMENT ACCURACY IN MAGNETIC RESONANCE IMAGING VERSUS RADIOGRAPHS: A RETROSPECTIVE CROSS-SECTIONAL STUDY.

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ABSTRACT

Background: The Critical Shoulder Angle (CSA) is a radiographic measurement that has proven valuable in assessing shoulder pathologies such as osteoarthritis and rotator cuff tears. Despite its clinical utility, the consistency of CSA measurements across different imaging modalities, particularly magnetic resonance imaging (MRI) versus radiographs, remains debated.

Objective: This retrospective cross-sectional study aims to assess the accuracy and reliability of CSA measurements obtained from routine shoulder MRI compared to standard radiography.

Methods: A total of 210 patients with both coronal oblique MRI images and true anteroposterior (AP) radiographs of the shoulder were included in the study. CSA measurements were independently performed y two observers using a standardized method, and interand intraobserver agreement was evaluated. Statistical analyses were conducted to determine differences in CSA measurements between the two modalities and assess agreement levels.

Results: The mean CSA measured on radiographs (33.7 ± 4.4) was significantly higher than that on MRI (32.8 ± 4.06, p=0.04). Inter- and intra-observer agreements were higher for radiographic measurements (ICC > 0.95) compared to MRI, where variability was noted, particularly concerning gender differences. CSA values showed no significant differences based on shoulder side (right vs. left) in either modality.

Conclusion: CSA measurements were more accurate and consistent on radiographs than MRI, suggesting that radiography remains the preferred modality for assessing CSA in clinical settings. The study highlights the need for standardized imaging techniques to improve measurement consistency across modalities.

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الملخص

الخلفية: زاوية الكتف الحرجة هي قياس شعاعي أثبت فعاليته في تقييم أمراض الكتف، مثل هشاشة العظام وتمزقات الكفة المدورة. على الرغم من فائدتها السريرية، لا يزال اتساق قياسات زاوية الكتف الحرجة عبر مختلف وسائل التصوير، وخاصةً التصوير بالرنين المغناطيسي مقارنةً بالأشعة السينية، موضع جدل.

الهدف: تهدف هذه الدراسة المقطعية إلى تقييم دقة وموثوقية قياسات زاوية الكتف الحرجة المُستقاة من تصوير الكتف بالرنين المغناطيسي الروتيني مقارنةً بالتصوير الشعاعي القياسي.

المنهجية: شملت الدراسة ٢١٠ مرضى، خضعوا لتصوير بالرنين المغناطيسي الإكليلي المائل، وصور شعاعية أمامية خلفية حقيقية للكتف. أُجريت قياسات زاوية الكتف الحرجة بشكل مستقل من قِبل مراقبَين باستخدام طريقة موحدة، وتم تقييم التوافق بين المراقبَين. أُجريت تحليلات إحصائية لتحديد الاختلافات في قياسات زاوية الكتف الحرجة بين الوسيلتَين، وتقييم مستويات التوافق. النتائج: كان متوسط مساحة المقطع العرضي المُقاس بالأشعة السينية (٣٣.٧ ± ٤.٤) أعلى بكثير منه في التصوير بالرنين المغناطيسي (٣٢.٨ ± ٤.٠٦، قيمة p=٠.٠٠٤). وكانت التوافقات بين المراقبين وداخلهم أعلى في القياسات بالأشعة السينية (ICC > ٠.٩٥) مقارنةً بالتصوير بالرنين المغناطيسي، حيث لوحظ تباين، لا سيما فيما يتعلق بالجنسين. ولم تُظهر قيم مساحة المقطع العرضي أي فروق ذات دلالة إحصائية بناءً على جانب الكتف (الأيمن مقابل الأيسر) في أيٍّ من الطريقتين.

الخلاصة: كانت قياسات مساحة المقطع العرضي أكثر دقة وثباتًا في الصور الشعاعية مقارنةً بالرنين المغناطيسي، مما يشير إلى أن التصوير الشعاعي لا يزال الطريقة المُفضلة لتقييم مساحة المقطع العرضي في البيئات السريرية. وتُسلّط الدراسة الضوء على الحاجة إلى تقنيات تصوير مُوحّدة لتحسين اتساق القياسات بين الطرق.

Keywords: Critical Shoulder Angle; Shoulder; Magnetic Resonance Imaging; Radiograph.

1. INTRODUCTION

Critical shoulder angle (CSA) is a radiographic measuring tool that is crucial in assessing shoulder pathology. [1] Formed by the most inferolateral point of the acromion and the angle extending to the glenoid fossa as seen in anteroposterior (AP) radiographs, the CSA provides valuable insights into various shoulder conditions, including osteoarthritis, rotator cuff tears, and impingement syndrome. Its ability to predict shoulder joint degeneration makes it a crucial tool for the assessment and prediction of shoulder diseases. [2–4]. These shoulder pathologies are significant causes of disability and pain, particularly among older adults. [5] Osteoarthritis and rotator cuff tears are associated with multiple radiographic parameters in the context of CSA. [6] The reported prevalence rates were 16.1% for glenohumeral osteoarthritis and 20.7% for rotator cuff tear. [7, 8]

The normal range of CSA is 30°–35°. [9] CSA >35° is highly correlated to degenerative rotator cuff tears, whereas CSA <30° is correlated to glenohumeral joint osteoarthritis, measured on AP radiographs. [10]

Despite its clinical utility, there is ongoing debate regarding the consistency of CSA measurements across different imaging modalities. Some studies have reported no significant differences between CSA measurements obtained from radiographs and those from MRI. [11,25] However, other research suggests that adjustments in technique could potentially improve the accuracy of CSA assessments through MRI. [14] The true AP radiographic view has been expanded to clinically improve the reliability of CSA and facilitate accurate CSA measurement. [14,15,16] Yet, obtaining such a view in a clinical setting can be challenging due to factors like scapular orientation and patient posture, which can impact the spatial relationships between the scapula and the radiograph beam. [15–30] Some authors have compared CSA measurement and other measuring tools in radiographs, such as the acromial index, in predicting shoulder pathologies; CSA provided more accurate patient assessment values and significant diagnostic reliability than other parameters. [15, 26–29] Moreover, CSA measurements on cross-sectional modalities such as MRI have shown congruence with radiographic measurements, while also being practical for detecting internal derangements of the shoulder. [19] However, the evaluation of clinically significant features of shoulder joint using MRI and radiographs demonstrated a quality comparable to that of a standard radiograph, while also offering additional diagnostic insights into osseous structures assessment of the shoulder joint [32]. Accurate identification of joint malalignment on either MRI or radiograph can support a more aggressive treatment approach in ambiguous cases, such as partial ligament tears.

The primary objective of this retrospective study is to evaluate the agreement between MRI and radiographic CSA measurements and their diagnostic efficacy for shoulder pathologies.

2. MATERIALS AND METHODS

2.1 Study design

This retrospective cross-sectional study was approved by our institutional ethics research committee (IRB number: xxx). We reviewed all shoulder MRI studies conducted between January 2019 and August 2021, resulting in a total of 676 MRI studies. Imaging data were retrieved using the Picture Archiving and Communication System (PACS), and corresponding clinical information was extracted from our center's EPIC system (healthcare American software company). The shoulder MRIs were initially reviewed by a musculoskeletal radiologist (observer1) to apply the study's inclusion criteria.

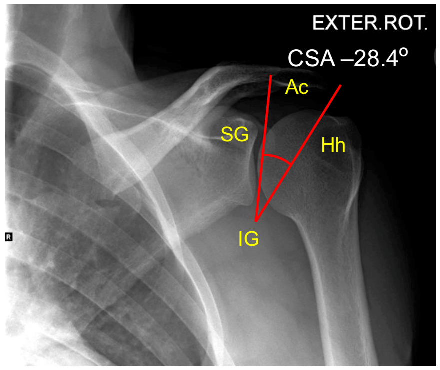
2.2 Study population and inclusion criteria:

Patients aged 26 years and older were included to ensure closure of acromial bone synchondrosis or secondary ossification centers. A total of 466 MRI studies were excluded due to the absence of corresponding radiographic images, post-traumatic osteoarthritis, full-thickness rotator cuff tears, or a history of previous shoulder surgery. The sample size lacked formal power calculation, and strict criteria were used to ensure homogeneity but may limit generalizability. Patient positioning was standardized to reduce variability through potential effect of positioning errors and imaging artefacts on CSA measurements. Sample size was calculated based on the formula $ss=Z^2 x (p) X (1-p) / d^2$, where ss is the sample size, Z is the 95% confidence level, p is the percentage of population and d is the confidence level at 80% power. The final study population comprised 210 cases with both coronal oblique MRI images and true AP radiographs of the same shoulder comprised the study population. Demographic data for these patients were collected.

2.3 Images acquisition

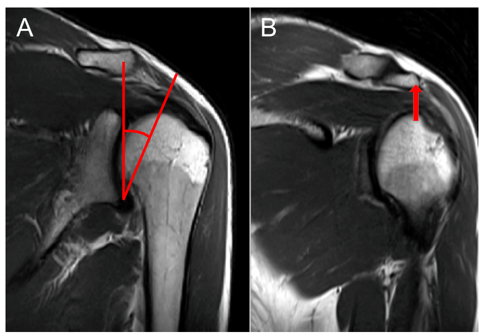
MRI acquisitions were performed on a 3.0-T system (Siemens Magnetom Spectra, Germany). Our center's routine shoulder MRI protocol included oblique axial and coronal PDFS, oblique coronal PD, oblique sagittal T2FS, and T1 sequences, using a slice thickness of 3-4 mm and spacing of 0.5-1 mm.

Shoulder radiographs were obtained using a standardized true AP view with the patient in a standing position and the shoulder in neutral rotation, employing a Siemens Healthineers digital X-ray machine (Germany) (Figure 1a)



CSA measurement on standard true AP radiograph (CSA= 28.4°). The concept of the critical shoulder angle, introduced by Moor et al in 2013. Acromion (Ac), humeral head (Hh), inferior margin of the glenoid (IG), superior margin of the glenoid (SG) and critical shoulder angle (CSA).

Figure 1a



Coronal- oblique PD MRI weighted images demonstrating the critical shoulder angle measurement value (CSA= 33°) of a 32-year-old male patient presenting with on and off shoulder pain.

Figure 1 b & c

2.4 Image Evaluation and Critical Shoulder Angles Calculation

CSA measurements were performed by two independent observers: a senior musculoskeletal (MSK) radiologist with 7 years of experience (observer 1) and an MSK radiology fellow (observer 2). The angle measuring tool provided in the PACS system was used for both modalities. The observers had an initial practical discussion to ensure consensus on the CSA measurement method before evaluating the MRI images.

Each observer took two readings of the CSA, blinded from each other, with a 2-week interval to assess inter- and intra-observer agreement. For radiographs, the CSA was measured from true AP radiographs that clearly showed the glenohumeral joint space with overlapping posterior and anterior rims of the glenoid bone. The measurement method followed the protocol described by Moor et al. [6]

For the purpose of this study, only images of the coronal oblique PD were reviewed for the MRI measurements. MRI slices showing the most lateral acromion border were selected. The lateral border of the acromion was marked, followed by the selection of the MRI slice running through the center of the glenoid bone to calculate the CSA (Fig. 1b and Fig. 1c).

2.5 Statistical analysis

Data analysis was performed using the statistical package for social sciences (SPSS) version 28.0 (IBM-SPSS, Armonk, New York, USA). Data are presented as mean and standard deviation (SD) for continuous variables and frequencies as percentages (%) for categorical variables. The Kolmogorov–Smirnov test was used to determine the normality of the distribution of CSA values in the radiographs and MRI. Differences in the mean CSA according to gender were determined using the independent samples t-test. Differences over time were measured using paired t-tests. Associations between the two measurements were assessed using Pearson correlations. Intra-observer agreement was assessed using the two-way mixed single-measure intraclass correlation coefficient (ICC) with 95% confidence interval and Cohen's Kappa values. All analyses were performed using two-tailed significance and a p-value of <0.05 was considered statistically significant.

3. RESULTS

3.1 General findings

The study analyzed radiographic and MRI images of 210 patients, consisting of 76 males (36.2%) and 134 females (63.8%). The average age of the patients was 49.1 ± 11.5 years, with ages ranging from 28 to 83 years. Out of these, 127 cases (60.5%) involved the right shoulder, and 83 cases (39.5%) involved the left shoulder (Figure 2).

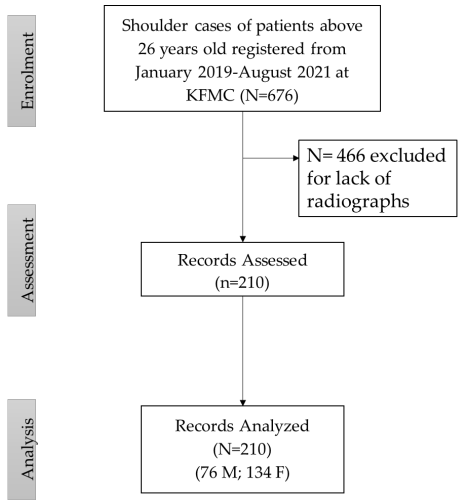


Figure 2 Flowchart of participant selection

3.2 Mean CSA Measurements

The mean CSA for all patients was significantly higher on AP radiographs compared to MRI (33.7 ± 4.4 vs. 32.8 ± 4.06, p=0.04). There was no significant difference in the mean CSA between males and females on radiographs. However, on MRI, the mean CSA was significantly higher in females than in males (33.3 ± 3.9 vs. 32.0 ± 4.1, p=0.02) (Figure 3). Additionally, there were no differences in the mean CSA measurements between the right and left shoulders on either radiographs or MRI (Figure 4).

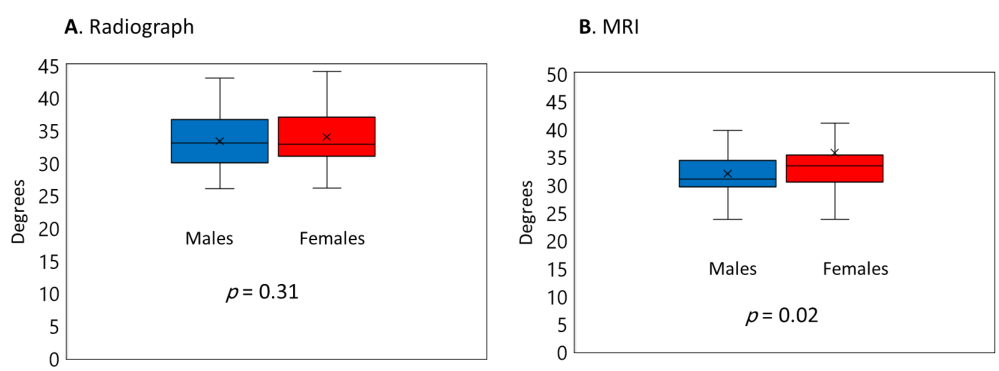


Figure 3 Mean CSA measurements on radiographs and MRI according to gender.

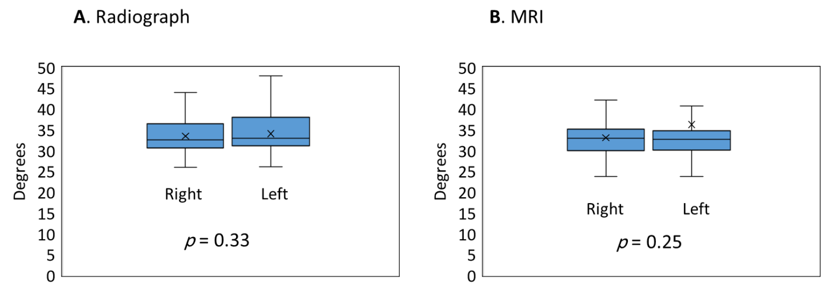


Figure 4 CSA measurements on radiographs and MRI according to the side of the shoulder.

3.3 Intra-observer Agreement

Observer 1's radiographic CSA measurements for both readings had an ICC of 0.985 with an accuracy of 90.5% and a Kappa value of 0.841 across three-binned angle measures, indicating a strong agreement. Observer 2's radiographic CSA measurements showed an ICC of 0.987 with an accuracy of 92.3% and a Kappa value of 0.877, also indicating a strong agreement (Table 1).

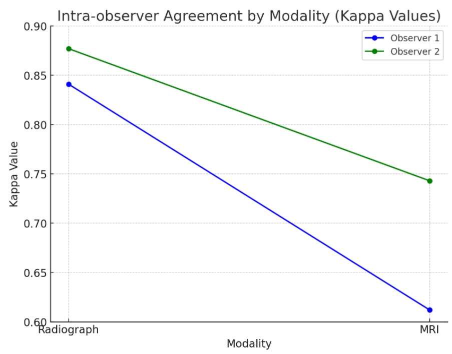
For MRI, Observer 1's measurements of CSA for both readings had an ICC of 0.957 and an absolute mean difference of 0.04, which was not statistically significant (p=0.692). The accuracy across three-binned angle measures was 76.7%, with a Kappa value of 0.612, denoting moderate agreement. Observer 2's CSA measurements for both readings recorded an ICC of 0.968 and an absolute mean difference of 0.30 (p=0.002). The accuracy across three-binned angle measures was 85.2%, with a Kappa value of 0.743, indicating moderate to strong agreement (Table 1).

Table 1 Intra-observer agreement between the CSA measurements for radiographs and MRI, collect observers

Readings	Observer 1	Observer 2	AMD	*p*-value	ICC	Concordance	Kappa
			Radiograph				
1	33.8±4.4	33.5±4.1	0.25	0.001	0.985	190 (90.5)	0.841
2	33.7±4.4	33.6±4.2	0.16	0.018	0.987	193 (92.3)	0.877
			MRI				
1	33.6±4.0	33.6±3.8	0.04	0.692	0.957	161 (76.7)	0.612
2	33.4±3.9	33.7±3.8	0.30	0.002	0.968	178 (85.2)	0.743

Note: AMD, absolute mean difference; ICC, intraclass correlation coefficient; p-value significant at <0.05.

Both observers show high agreement (ICC > 0.95) for both radiographs and MRIs. Observer 1 has slightly lower Kappa and accuracy for MRI compared to radiographs (Fig 5). Observer 2 shows strong agreement across both modalities.



Graph showing Kappa statistics values is interpreted as demonstrating an excellent intra-observer agreement with radiographic modality compared to MRI, emphasizing the superior utility of radiography for assessment.

Figure 5

3.4 Intra-observer Agreement

The first radiographic CSA measurements by both observers showed an intraclass correlation coefficient (ICC) of 0.978, with an absolute mean difference of 0.10, which was not statistically significant (p=0.42). The accuracy across three-binned angle measures was 90.5%, with a Kappa value of 0.82, indicating strong agreement. The second radiographic measurements by both observers had an ICC of 0.983, with an absolute mean difference of 0.10, which was also not statistically significant (p=0.30). The accuracy across three-binned angle measures was 92.3%, with a Kappa value of 0.86, again indicating strong agreement (Table 2).

Table 2 Inter-observer agreement of the CSA measurements for radiographs and MRI, collected by observers

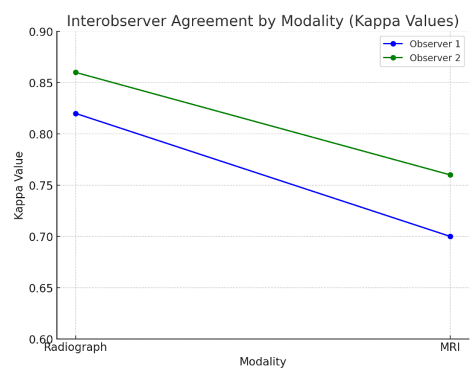
Readings	Observer 1	Observer 2	AMD	*p*-value	ICC	Concordance	Kappa
Radiograph							
1	33.8±4.4	33.5±4.1	0.10	0.42	0.978	190 (90.5)	0.82
2	33.7±4.4	33.6±4.2	0.10	0.30	0.983	193 (92.3)	0.86

			MRI				
1	33.6±4.0	33.6±3.8	0.20	0.25	0.967	161 (76.7)	0.70
2	33.4±3.9	33.7±3.8	0.10	0.37	0.971	178 (85.2)	0.76

Note: AMD, absolute mean difference; ICC, intraclass correlation coefficient; p-value significant at <0.05.

For the MRI CSA measurements, the first readings by both observers had an ICC of 0.967, with an absolute mean difference of 0.20 (p=0.25). The accuracy across three-binned angle measures was 76.7%, with a Kappa value of 0.7, indicating moderate agreement. The second MRI readings had an ICC of 0.971, with an absolute mean difference of 0.10, which was not statistically significant (p=0.37). The accuracy across three-binned angle measures was 85.2%, with a Kappa value of 0.76, showing a substantial level of agreement (Table 2).

The agreement between observers is strong, with high ICC values for both radiographs and MRIs. The Kappa values are slightly lower for MRI compared to radiographs, indicating moderate to strong agreement (Fig 6).



Graph displaying kappa statistic values, revealing lower inter-observer agreement for MRI compared to the radiographic modality, suggesting that the MRI does not support its utility in accessing the accuracy of the critical shoulder angle.

Figure 6

4. DISCUSSION

We evaluated the agreement between MRI and radiographic CSA measurements and their diagnostic efficacy for shoulder pathologies considering both inter and intra-observer agreements. The most significant finding of our study is the marked difference in the CSA measurement between the radiograph and MRI. The radiograph measurements had an accuracy percentage reaching 92.3% and a Kappa value of 0.88, which was higher than that of MRI. This study corroborates with several published works regarding the angle measurement accuracy and the absence of variance based on side or gender. [6, 9, 12, 15] Other studies that have measured CSA values in patients with glenohumeral osteoarthritis and rotator cuff tears further validate our findings. [6, 9, 10, 12] Contrary to their methodologies, we established a consensus before measuring CSA, which standardized the inter and intra-observer agreement method and eliminated the errors of measurement arising from inconsistency among different investigators. Spiegl et al. analyzed the correlation between MRI and standard AP radiographs to measure CSA. They discovered that the CSA value on MRI was substantially lower than that on AP radiographs, and had lower MRI-measured intra-observer (ICC = 0.68) and inter-observer (ICC = 0.62) agreements which suggested that MRI is less suitable for accurate CSA measurements. [12] In the present study, we found discordancein the CSA measurements obtained from the MRI and s AP radiographs. However, on radiographic imaging alone, there was a strong agreement between and within observers suggesting that radiography to be a more precise and reliable technique for measuring CSA. A similar conclusion was reached by Shibayama et al., who compared 88 pairs of three-dimensional computed tomography (3D-CT) and standard AP radiographs and demonstrated that the radiography-based approach is a good substitute for measuring CSA. [17]

Additionally, two periods of analysis demonstrated no significant differences between the observers' readings. Considering the findings of our study, the intra- and inter-observer assessments of radiographs and MRI have no significant differences. Other studies showed that intra- and inter-observer reliabilities on CSA measurements by radiograph and true AP views were high with an average deviation of 2.1° to 2.2°. [16] Another study showed near-perfect inter- and intra-observer reliabilities (>0.96 and 0.97) for CSA measurements between standard AP radiographs and 3D CT scans. [17] A recent study indicated a strong inter- and intra-observer agreement in measuring the CSA by two observers, similar to our results. [13] This consistency was evident from the perspectives of intra- and inter-observer agreements. Additionally, initial variations were observed with the agreement's values of Kappa, about their experience; thereafter, a high level of agreement was noted among the examiners, as reflected by the ICC. [18] While radiographs demonstrated strong intra- and inter-observer agreement, MRI measurements showed significant variability through the obtained values from the selected patients, regardless of the importance of MRI in assessing CSA accurately. [4, 15, 17] In some studies, the measurement of certain morphometric parameters, such as the acromion index, using radiographs is comparable to that using MRI, further highlighting the possibility of using MRI to measure CSA. [18, 16, 20] However, a study reported that radiographs are sufficient to assess CSA whereas CT scans, despite having the same diagnostic performance, are limited by the increased radiation dose and MRI should not be used to measure CSA. [21] Conversely, the variability of MRI measurement values in assessing CSA has been discriminated, raising concerns about clinical interpretations based on the modality of MRI CSA values. [22] In studies related to reverse total shoulder arthroplasty, the CSA predictive value has been demonstrated in analyzing postoperative interventions, further highlighting the clinical reliability of accurate radiographic CSA measurements. [23]

One of the unexpected findings of our study was the significant discrepancy of the MRI mean CSA measurements according to gender contrary to several studies which reported no significant association / differences in the CSA according to gender. [1, 11, 15] This discrepancy may be associated with the morphological appearance of the acromion where the acromial index was found to be higher in females than males. [31] However, this discrepancy in MRI-measured CSA according to gender needs further analysis on the underlying cause/s. Additionally, the existing body of literature giving valuable insights into CSA remains unchanged at a mean follow-up of 10 years interval. These results show that the CSA value is likely to be congenital, unchanged with time, and responsible for shoulder conditions. rather than an outcome of an acquired deformity from the degeneration. [24] Eventually, the claim that radiographs are inherently mor reliable may not apply universally, as their reliability depends on factors like patient characteristics, clinical conditions and the context in which they are used.

However, the study did have some limitations, including potential issues with radiographic imaging due to patient positioning and technique; for example, the reliability of radiographic CSA measurements is influenced by scapular positioning and beam alignments making the term "gold standard" debatable. These limitations highlight the need for carful interpretation and consideration of alternative imaging methods or standardized protocol to ensure accuracy. The steeper learning curve required for MRI assessment, and the single-centre design. While the study demonstrates statistical differences between radiographs and MRI, the claim that radiographs are inherently more reliable may not universally apply without considering context, patient characteristics, and clinical conditions. Despite these limitations, the study’s strengths lie in its large sample size, rigorous statistical analysis, and the thorough testing of inter- and intra-observer agreements. The longitudinal study design and the strategic inclusion of specific patient groups add to the validity of the results.

This research offers new insights into the accuracy and reliability of CSA measurements across radiographs and MRI. Future studies should investigate whether different imaging protocols can further improve measurement consistency, thereby making a significant contribution to shoulder condition assessments and enhancing clinical practices.

5. CONCLUSION

CSA measurement was found greater on radiographs compared to MRI, suggesting that radiographs may be a more reliable measurement for diagnosing shoulder pain and predicting related pathologies. The high level of inter and intra agreement with less variability when using radiographs supports the use of radiographs as a preferred method for CSA assessment.

CONFLICT OF INTEREST

None

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None

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