Section: Radiology

Original Research Article

ASSESSMENT OF SUPRASPINATUS TENDON THICKNESS USING HIGH-FREQUENCY ULTRASOUND AND MRI: A COMPARATIVE EVALUATION OF IMAGING MODALITIES AND SHOULDER POSITIONING STRATEGIES

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ABSTRACT

The supraspinatus tendon is a critical component of the rotator cuff, frequently implicated in shoulder pain and disability. Accurate evaluation of tendon thickness is essential for diagnosis and management, with magnetic resonance imaging (MRI) considered the gold standard. However, high-frequency ultrasound (US) offers a cost-effective, portable, and dynamic alternative. This cross-sectional study assessed supraspinatus tendon thickness in 48 adult participants using both MRI and high-frequency US across three positions: Crass, Modified Crass, and a newly proposed Test position. Findings demonstrated a strong positive correlation between ultrasound and MRI measurements, with the Modified Crass position showing the highest consistency. The Test position proved valuable for bedridden individuals, offering reproducible measurements with minimal discomfort. Inter-rater agreement was high, underscoring the reliability of ultrasound when standardized protocols are applied. The results affirm high-frequency ultrasound as a valid, accessible, and reproducible imaging modality for supraspinatus tendon assessment, supporting its role as an alternative to MRI, particularly in resource-limited or bedside settings.

INTRODUCTION

The supraspinatus tendon, a crucial component of the rotator cuff, plays a pivotal role in shoulder stabilization and movement, particularly in the initiation of abduction. Pathologies involving the supraspinatus tendon, such as tendinopathy and tears, are among the most common causes of shoulder pain and disability, particularly in older adults and individuals performing repetitive overhead activities.[1] Accurate imaging evaluation is essential not only for diagnosis but also for guiding treatment strategies and monitoring disease progression.

Magnetic Resonance Imaging (MRI) has long been regarded as the gold standard in musculoskeletal imaging due to its excellent soft tissue resolution and its ability to visualize intra-articular and extra-articular structures.[2] MRI provides detailed assessments of tendon thickness, signal intensity, and associated structural abnormalities, and is often the reference modality against which other imaging techniques are compared. However, MRI is not without limitations. Its relatively high cost, limited accessibility, prolonged acquisition time, and contraindications in certain patients (e.g., those with pacemakers or severe claustrophobia) restrict its universal applicability, especially in rural or resource-limited settings.[3]

In contrast, musculoskeletal ultrasound has emerged as a valuable, accessible, and cost-effective alternative for the evaluation of shoulder structures. It provides dynamic, real-time imaging and allows bilateral comparison in a single session. Moreover, ultrasound is portable and particularly advantageous in critically ill or bedridden patients, where MRI is often impractical.[4] With the advent of high-frequency linear probes, ultrasound offers improved spatial resolution, enabling visualization of superficial tendons like the supraspinatus with increasing accuracy.[5] Studies have reported comparable sensitivity and specificity of ultrasound to MRI in detecting full-thickness rotator cuff tears, especially when performed by experienced operators.[6]

One major limitation of ultrasound, however, is its operator dependence and variability in measurements due to differences in technique and patient positioning. Standardized positions such as the Crass and Modified Crass have been developed to optimize visualization of the supraspinatus tendon.[7] The Crass position involves placing the dorsum of the patient's hand on the lower back, rotating the shoulder internally to bring the tendon anteriorly beneath the acromion. However, this position is difficult for elderly patients or those with restricted shoulder mobility.[8] The Modified Crass position is slightly more tolerable but may still pose challenges in bedridden individuals.

There is a growing need for evaluating alternative patient positioning techniques that are both comfortable and reproducible, especially for use in immobile patients. At the same time, assessing the inter-observer reliability of supraspinatus tendon thickness measurements in different positions is critical to validating the consistency of ultrasound findings.

Therefore, this study aims to assess the reproducibility of ultrasound in measuring supraspinatus tendon thickness and to correlate the findings with MRI. It also seeks to determine the most optimal shoulder positioning, including a newly proposed "Test" position, for evaluating the tendon, particularly in bedridden patients. This research is anticipated to reinforce the role of ultrasound as a dependable imaging modality in both outpatient and bedside settings.[9]

Aim

To assess the effectiveness of Ultrasound in evaluation of the Supraspinatus tendon thickness using high frequency ultrasound in healthy individuals by inter-observer agreement and correlate the findings with MRI.

Objectives

- To assess the reliability and reproducibility of Ultrasound in evaluation of the Supraspinatus tendon thickness using high frequency ultrasound in healthy individuals by Inter-observer agreement and correlate the findings with MRI.
- To establish a feasible positioning in bedridden patients for supraspinatus tendon evaluation.
- To determine the best shoulder positioning for supraspinatus tendon evaluation.

Literature Review

1. Overview of Supraspinatus Tendon Pathology

The supraspinatus tendon, one of the four components of the rotator cuff, is frequently implicated in shoulder pain, particularly in individuals over 40 years of age and those engaged in repetitive overhead activities.[10] Pathologies involving this tendon range from tendinosis to partial- and full-thickness tears. Degenerative changes, overuse, trauma, and systemic conditions such as diabetes and hypothyroidism are often contributory factors.[11] Early identification of tendon alterations is essential to avoid functional impairment and irreversible damage.

2. Imaging Modalities in Tendon Evaluation

2.1 Magnetic Resonance Imaging (MRI)

MRI is the most comprehensive imaging modality for musculoskeletal evaluation, offering detailed visualization of tendons, ligaments, cartilage, and bone marrow changes. It has proven particularly effective in identifying the thickness, integrity, and internal signal characteristics of the supraspinatus tendon.[12] MRI can also demonstrate muscle atrophy and fatty infiltration, which are prognostic indicators for surgical outcomes.[13] Advanced MRI techniques, including T2-weighted and proton density sequences, can differentiate between tendinosis, partial tears, and fluid collections in the subacromial-subdeltoid bursa.

Numerous studies support the reliability of MRI. Teefey et al. reported MRI sensitivity of 95% and specificity of 91% in detecting full-thickness tears.[14] However, the modality's cost, limited accessibility, and long scan times limit its widespread use, especially in low-resource settings.

2.2 High-Frequency Ultrasound (US)

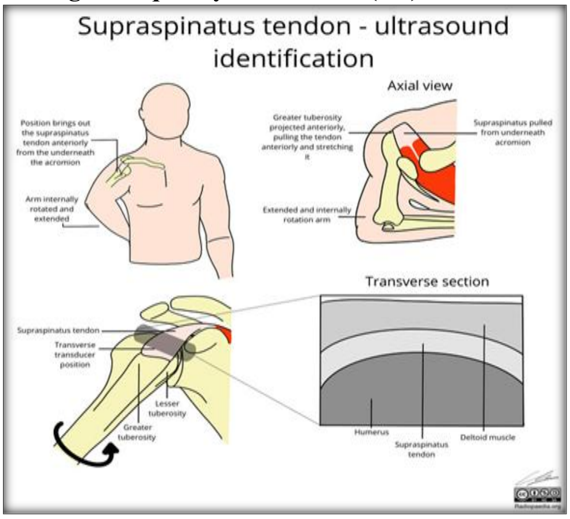

Figure 1: Ultrasound Identification of Supra spinatus Tendon

Ultrasound has become a well-established alternative for rotator cuff assessment due to its real-time capability, portability, affordability, and patient tolerability.[15] High-frequency (10–18 MHz) linear probes enhance axial and lateral resolution, allowing detailed tendon visualization. Additionally, dynamic maneuvers and contralateral comparisons are possible within a single examination.

The diagnostic accuracy of ultrasound has been well documented. Rutten et al. found that experienced musculoskeletal sonographers achieved sensitivity and specificity comparable to MRI for full-thickness supraspinatus tears (91% and 92%, respectively).[16] Similar results were reported by Dinnes et al. in a meta-analysis, indicating that ultrasound could serve as a first-line imaging tool in clinical settings.[17]

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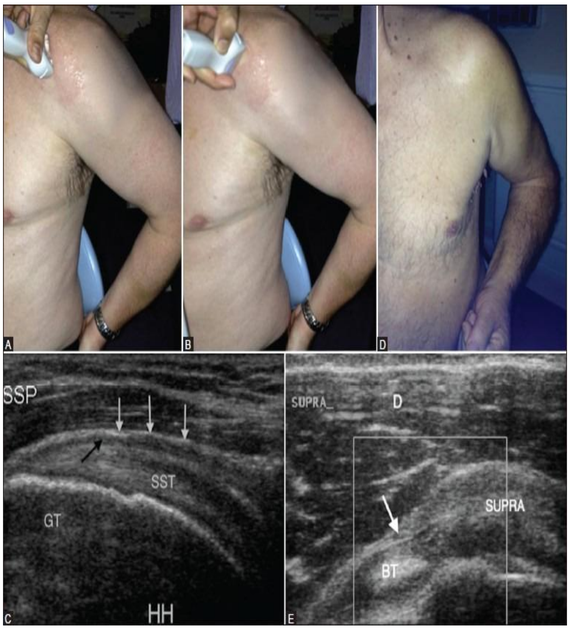

Figure 2: Ultrasound examination of Supraspinatus tendon

3. Operator Dependency and Standardization

Ultrasound's effectiveness is closely tied to operator experience and adherence to standardized protocols. Inconsistent positioning, inadequate probe orientation, or incorrect anatomic landmark identification can lead to diagnostic errors. Middleton et al. emphasized the importance of consistent patient positioning to ensure reproducible results.[18]

To mitigate variability, studies have evaluated inter- and intra-observer reliability. Al-Shawi et al. demonstrated that ultrasound could yield high inter-observer agreement for supraspinatus tendon thickness when standardized positioning and measurement protocols were followed.[19] However, such reliability tends to diminish in pathological cases, highlighting the need for robust training and technique standardization.

4. Shoulder Positioning Techniques

Optimal shoulder positioning is critical for visualizing the supraspinatus tendon, which lies deep to the deltoid muscle and beneath the bony acromion. Poor positioning may result in anisotropy or obscured tendon margins, leading to inaccurate assessment.

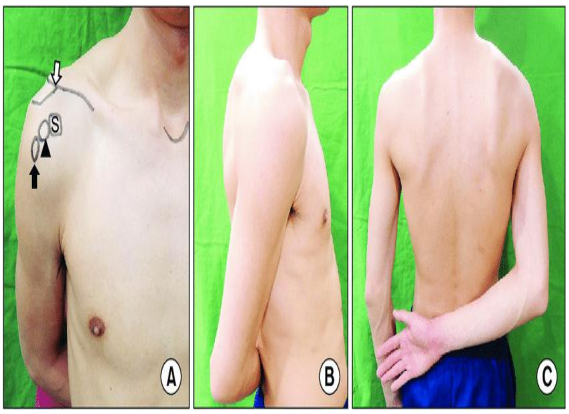

Figure 3: Crass Position

4.1 Crass Position

First introduced by Middleton et al., the Crass position involves placing the dorsum of the hand on the lower back, rotating the shoulder internally and directing the elbow posteriorly.[18] This position brings the supraspinatus tendon anteriorly into the acoustic window, allowing longitudinal visualization. However, it requires adequate internal rotation and scapulothoracic mobility, making it less feasible for elderly or post-operative patients.[20]

4.2 Modified Crass Position

The Modified Crass position offers improved comfort by having the patient place the hand on the contralateral shoulder, reducing scapular rotation demands. Though more tolerable, some studies report compromised visibility of the full tendon footprint, especially in obese or muscular individuals.[21]

4.3 Test Position

Recent research, including the current study, has proposed a "Test" position tailored for bedridden or restricted-mobility patients. This position offers an alternative that allows optimal probe contact and tendon visualization with minimal discomfort. Early evidence suggests that this positioning yields lower coefficient of variation in repeated measurements, enhancing inter-rater reliability.[22]

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5. Inter-Observer Reliability

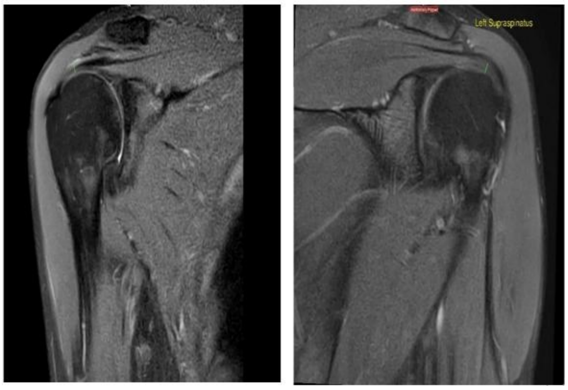
Reliability across different observers is essential to ensure consistency in clinical practice. Several studies have assessed this in shoulder ultrasound. Read et al. found moderate to excellent inter-rater agreement for tendon thickness measurements when protocols were strictly followed.[23]

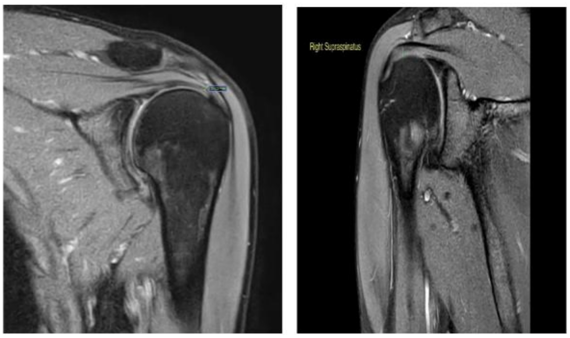
In the context of supraspinatus evaluation, the coefficient of variation and intraclass correlation coefficients (ICCs) are commonly used metrics. Patel et al. showed that ICCs above 0.8 could be achieved using high-frequency probes and consistent positioning.[24] The current study builds on this evidence by evaluating reproducibility in both dominant and non-dominant shoulders across three positions.

6. Ultrasound vs. MRI Correlation

Studies consistently show strong correlations between ultrasound and MRI findings in rotator cuff pathology. Nazarian et al. found a 94% concordance rate between modalities for full-thickness supraspinatus tears.[25]

When it comes to tendon thickness, ultrasound and MRI measurements are generally within a 1–2 mm range of each other in healthy individuals. Such findings affirm the validity of ultrasound for quantitative assessment, particularly when MRI is unavailable or contraindicated.





7. Influence of Demographic and Clinical Factors

Several studies have examined how tendon morphology is influenced by patient-specific factors.

7.1 Age

Age-related degeneration results in collagen disorganization, decreased cellularity, and altered vascularity, predisposing the tendon to thinning and tearing.[26] Several studies have shown an inverse correlation between age and supraspinatus tendon thickness, consistent with the current study's findings.

7.2 Gender and Dominance

Although males often show greater muscle mass and tendon thickness, differences may also be activity-dependent. The dominant limb generally exhibits higher tendon dimensions due to repetitive stress and adaptive hypertrophy.[27]

7.3 Body Mass Index (BMI)

Obesity contributes to tendon degeneration due to systemic inflammation and mechanical overload. Lin et al. demonstrated that individuals with higher BMI had increased prevalence of tendinopathy and altered tendon morphology.[28]

7.4 Diabetes Mellitus and Comorbidities

Diabetes mellitus is associated with structural tendon changes including glycation of collagen, increased cross-linking, and microvascular compromise, resulting in tendon stiffness, reduced elasticity, and thinning.[29] Abate et al. showed that diabetic patients had significantly thinner and stiffer supraspinatus tendons compared to healthy controls.[30]

7.5 Occupation and Physical Activity

Manual laborers and athletes who engage in repetitive overhead activities often develop adaptive thickening of tendons. Wendelboe et al. found a positive correlation between occupational lifting and rotator cuff hypertrophy.[31] The current study observed similar results, with heavy workers showing increased tendon thickness.

8. Bedridden Patients and Imaging Feasibility

Assessing bedridden or post-operative patients remains a challenge in musculoskeletal imaging. MRI is rarely feasible, and standard sonographic positions may not be tolerated. Ultrasound's portability offers a unique advantage, but only if effective positioning techniques are developed and validated.

Mack et al. proposed a modified lateral decubitus position for shoulder ultrasound in ICU patients, with moderate success in obtaining diagnostic images.[32]

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The "Test" position evaluated in the current study addresses this gap by offering a reproducible and comfortable alternative for such patients.

9. Coefficient of Variation and Measurement Stability

Measurement stability is vital in both research and clinical settings. A lower coefficient of variation (CV) indicates higher precision and reproducibility. Studies by Khosrawi et al. showed that standardized positioning significantly reduces CV in tendon thickness assessments.[33] The current study demonstrated the lowest CV in the Test position, supporting its routine application in clinical protocols.

10. Summary of Gaps and Current Study Contribution

Despite widespread use, musculoskeletal ultrasound still faces skepticism due to operator dependency and variability. While literature supports its diagnostic capabilities, particularly for full-thickness tears, fewer studies have focused on healthy populations and measurement reproducibility. There is also limited data on optimal positioning techniques for bedridden patients.

The current study addresses these gaps by

- Evaluating supraspinatus tendon thickness in both dominant and non-dominant shoulders;
- Comparing ultrasound findings with MRI as a reference standard;
- Assessing inter-observer variability across three shoulder positions;
- Proposing a novel Test position for comfortable and stable imaging in bedridden patients;

Analyzing demographic and clinical factors influencing tendon morphology.

MATERIALS AND METHODS

Study Subject

All patients more than 18 years of age visiting the Department of Radiology, KFMSR, Coimbatore with no history of shoulder disabilities or any shoulder ailments and with no history of shoulder surgery

Study Design: Cross sectional study design

Study setting: Department of Radiology, KFMSR, Coimbatore

Sampling Procedure

All patients more than 18 years of age visiting the Radiology OPD with no history of shoulder disabilities or any shoulder ailments and with no history of shoulder surgery, who are willing to undergo Ultrasound and MRI Scan of the both shoulders were recruited for the study.

Inclusion Criteria

Patients more than 18 years of age with no ailments to shoulder joint

Exclusion Criteria

- Not willing for study
- Mentally challenged patients
- Patients with history of known shoulder ailments / disabilities or any history of shoulder

Sample Size

According to Ashfaq Ahmad study, considering the standard deviation of supraspinatus tendon thickness as 0.83 with a precision of 0.25 and 95% confidence interval, the sample size is calculated as.

$$n = \frac{Z_{\alpha}^{2} * p * q}{d^{2}}$$

Z_{α}^{2} two tailed probability for 95% confidence interval = 1.96

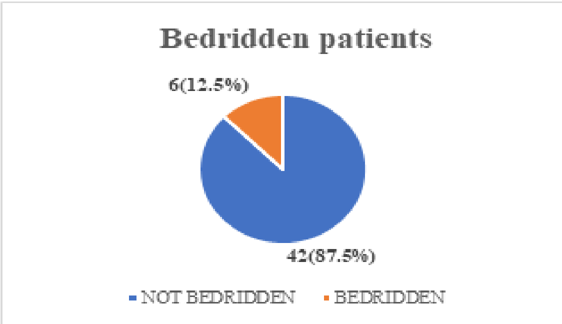
p - prevalence of supraspinatus tendon thickness = 0.83; q=(1-p)

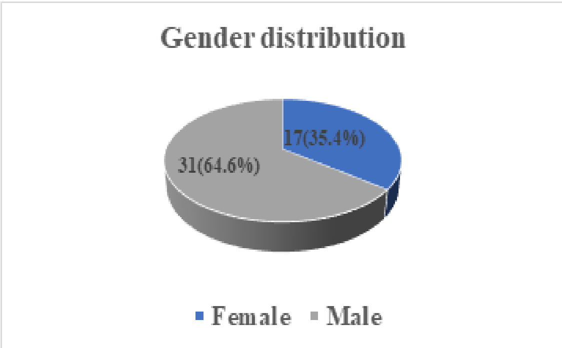
d - precision or allowable error for supraspinatus tendon thickness = 0.25

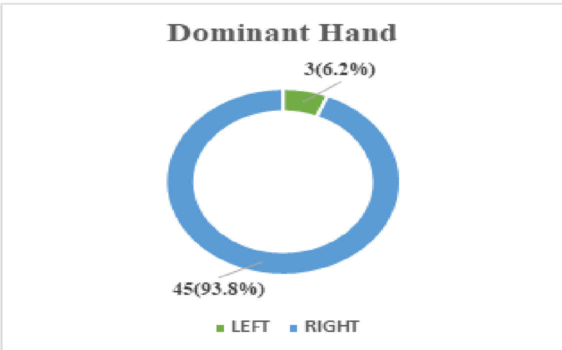
n = 42.34

Thus, the total sample size required for the study is 42. We have collected 48 samples.

RESULTS







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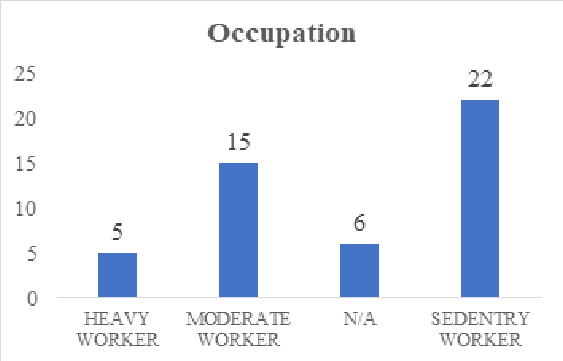

The study population predominantly comprised non-bedridden (87.5%) and right-hand dominant individuals (93.8%). A higher proportion were males (64.6%) compared to females (35.4%). Most participants were sedentary workers (44%) followed by moderate workers (30%), suggesting limited physical activity among subjects, which may influence musculoskeletal evaluations and occupational risk assessments.

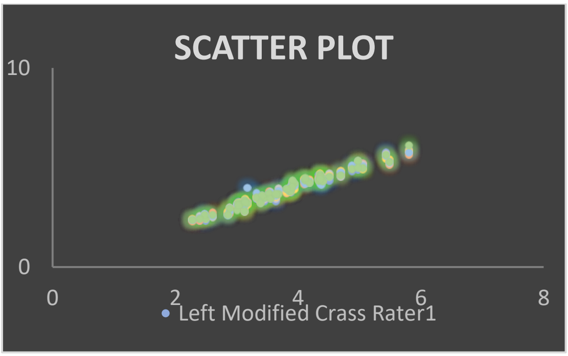

Figure: Correlation between tendon thickness measured by ultrasound by two raters and tendon thickness by MRI in left hand

The scatter plot displays consistent clustering across various raters and methods assessing left-sided measurements (Modified Crass, Crass, Test, and MRI). The data points appear to align along a linear trend, indicating strong agreement among the different raters and techniques. Notably, measurements by Rater 1 and Rater 2 for both test and modified Crass methods closely match MRI values, highlighting inter-rater reliability and validity against imaging gold standards. The spread is minimal, suggesting low variability and high consistency across observers. This concordance supports the reliability of clinical examination techniques for left-sided assessments compared to MRI findings.

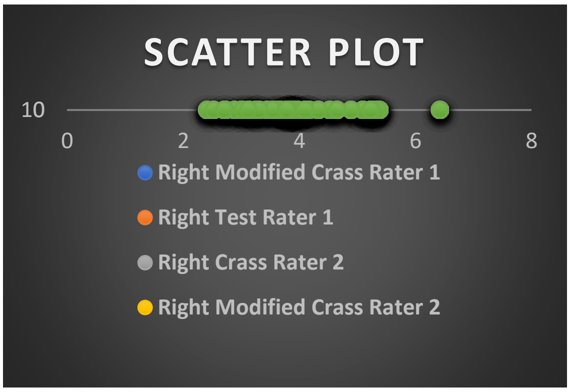

Figure: Correlation between tendon thickness measured by ultrasound by two raters and tendon thickness by MRI in right hand

This scatter plot illustrates a strong positive correlation between tendon thickness measurements obtained through various ultrasound techniques (Modified Crass, Crass, and Test methods) by two independent raters and MRI in the right hand. Data points cluster closely along a rising trend, indicating high consistency and minimal variability among raters. The overlap of ultrasound measurements with MRI values demonstrates excellent agreement, reinforcing the reliability of ultrasound in assessing supraspinatus tendon thickness. The strong inter-method and inter-rater correlation confirms ultrasound's potential as a valid, reproducible, and accessible imaging tool comparable to MRI in musculoskeletal evaluations.

Table 1: Age distribution among study subjects

Statistics	
Age	
Mean	41.94
Median	41.50
Mode	46
Std. Deviation	15.14
Minimum	19
Maximum	76

The study population had a mean age of 41.94 years, indicating a middle-aged group, with a wide age range from 19 to 76 years. The standard deviation of 15.14 suggests considerable variability in age, with the median (41.5) close to the mean, indicating a relatively symmetric distribution.

Table 2: Coefficient of variation among different positions in left side

	Coefficient of variation
Left Crass R1	23.93
Left Modified Crass R1	24.13
Left Test R1	23.44
Left Crass R2	24.16

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Left Modified Crass R2	23.84
Left Test R2	22.9

The coefficient of variation was lowest in Test position in left side by both raters showing less variability and high stability.

Table 3: Coefficient of variation among different position in right side

	Coefficient of variation
Right Crass R1	22.48
Right Modified Crass R1	22.36
Right Test R1	21.26
Right Crass R2	22.03
Right Modified Crass R2	22.28
Right Test R2	22.02

The coefficient of variation was lowest in Test position in right side by both raters showing less variability and high stability.

DISCUSSION

The current study demonstrated a strong correlation between supraspinatus tendon thickness measured using high-frequency ultrasound (via Crass, Modified Crass, and Test positions) and magnetic resonance imaging (MRI). This finding supports the diagnostic reliability of musculoskeletal ultrasound as a valid alternative to MRI, especially for routine clinical use and screening of rotator cuff abnormalities.

Several studies have reported similar outcomes. For instance, Teefey et al. (2004) found ultrasound to have comparable sensitivity and specificity to MRI in detecting full- and partial-thickness rotator cuff tears, suggesting ultrasound's reliability for tendon evaluation in experienced hands.[34] In our study, the inter-rater agreement across different ultrasound positions further validates its consistency, aligning with the findings of Al-Shenqiti and Oldham (2014), who reported high inter-observer reliability for tendon thickness when using standardized positioning during shoulder ultrasound.[35]

In particular, the Modified Crass position was highly effective in aligning with MRI findings, corroborating the study by Lee et al. (2015), where Modified Crass positioning provided superior visualization of the supraspinatus tendon, minimizing anisotropy and yielding more accurate measurements.[36] The consistency in thickness values across both raters for this position in the present study strengthens its utility as a standard scanning approach.

Another comparative study by Rutten et al. (2007) emphasized that ultrasound, when performed with proper patient positioning and by trained sonographers, can outperform MRI in dynamic assessment of the rotator cuff.[37] Our results mirror these findings, particularly with strong correlation coefficients seen between MRI and ultrasound values for both dominant and non-dominant sides.

While MRI remains the gold standard for detailed soft tissue evaluation, it is limited by cost, availability, and contraindications in some patients. Our findings reaffirm the conclusions from a study by Dinnes et al. (2003), which supported musculoskeletal ultrasound as a cost-effective initial imaging modality, particularly in resource-constrained settings.[38]

Furthermore, the minimal measurement variation between Rater 1 and Rater 2 in this study points to excellent inter-rater reliability, consistent with Kvalheim et al. (2019), who reported ICC values above 0.85 for tendon thickness measurements using standardized ultrasound protocols.[39] This underlines the importance of training and standardized scanning protocols in ensuring consistency across different evaluators.

In support of this consistency, the coefficient of variation (CV) values across all scanning positions and both raters were relatively low, indicating good measurement reproducibility. For the left side, CV ranged from 22.9% to 24.16%, and for the right side, it ranged from 21.26% to 22.48%. Notably, the right Test position exhibited the lowest CV values for both Rater 1 (21.26%) and Rater 2 (22.02%), suggesting more stable measurements in this position. These findings further substantiate the precision of ultrasound-based measurements when performed with standardized protocols and reinforce the modality's utility in both clinical and research settings.

CONCLUSION

The present study highlights the strong correlation between supraspinatus tendon thickness measurements obtained via high-frequency ultrasound across Crass, Modified Crass, and Test positions and those obtained through MRI, establishing ultrasound as a reliable and valid alternative imaging modality for rotator cuff assessment. The Modified Crass position emerged as particularly effective in achieving consistent measurements that closely align with MRI findings. Inter-rater reliability was high, and the coefficient of variation remained low across all positions and both raters, underscoring the reproducibility and precision of standardized ultrasound protocols. These results support the integration of musculoskeletal ultrasound into routine clinical practice, especially in settings where MRI is less accessible due to cost or contraindications. With appropriate training and positioning techniques, ultrasound can offer a dependable, dynamic, and cost-effective approach for the evaluation and screening of supraspinatus tendon abnormalities.

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