Research paper

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# Measures of acromiohumeral distance with wireless ultrasound machine in subacromial impingement syndrome: an inter-machine reliability study

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acromiohumeral distance; inter-machine reliability; wireless ultrasound

**Abstract**

**Aim:** Shoulder pain is the third most prevalent musculoskeletal condition that impairs function. Subacromial impingement syndrome is among the most typical causes of shoulder pain. The aim of this study was to evaluate inter-machine reliability of acromiohumeral distance measurements performed with standard ultrasound and wireless ultrasound devices in patients with subacromial impingement syndrome. **Material and methods:** A total of 61 participants diagnosed with subacromial impingement syndrome were included. Acromiohumeral distance was measured with wireless and standard ultrasound devices in a neutral position and at 60-degree abduction, respectively. The inter-machine intraclass correlation coefficient, standard error of measurements, and minimum detectable changes were calculated. **Results:** Inter-machine reliability measured in the neutral position was excellent (ICC = 0.97, 95% CI = 0.95–0.98); the standard error of measurement was 0.23 mm, and the minimum detectable change was 0.63 mm. Inter-machine reliability measured at 60 degrees abduction was excellent as well (ICC = 0.96; 95% CI; 0.93–0.97). The standard error of measurements was 0.20 mm, and the minimum detectable change was 0.55 mm. The mean difference between the two machines was 0.04 mm for the neutral position and 0.02 mm for the 60-degree abduction position. **Conclusions:** The study showed that wireless ultrasound devices were similar to standard ultrasound devices in measuring the acromiohumeral distance in patients with subacromial impingement syndrome. The findings could contribute to a significant improvement in the clinical use of wireless ultrasound devices.

## Introduction

Shoulder pain is the third most common musculoskeletal cause of admissions for treatment[1]. Subacromial impingement syndrome (SIS) is among the most typical causes of shoulder pain. SIS occurs when the rotator cuff tendons, especially the supraspinatus tendon (SST), are compressed between the acromion and the humerus[2]. Many factors are thought to lead to the development of SIS. Extrinsic processes compressing the subacromial space and intrinsic changes in the supraspinatus tendon have both been shown to be contributing factors[3,4]. Different imaging modalities have measured the acromiohumeral distance (AHD) in the literature to assess the subacromial space[5–7]. However, the advantage of ultrasonography (US) among these imaging modalities is that it is fast, inexpensive, real-time, provides easy access, and causes no radiation exposure. In SIS, symptoms occur especially during arm lifting, and the US, which allows dynamic imaging, can reveal changes in the subacromial space during the activity of lifting[6,8].

McCreesh *et al*. reported that AHD measured by US was reliable when compared with other imaging modalities[9]. Previously, the intraobserver and interobserver reliability of AHD measured with US was evaluated with ultrasound studies[10–12]. However, there is no inter-machine reliability study for AHD in the available literature. Wireless US (WUS) devices have been developed with advances in technology and have applications in many fields. WUS have been shown to provide excellent compatibility and reproducibility in the examination of the abdomen and chest in emergencies[13], in the field of urology[14], and in comparisons with standard US (SUS) devices in cardiology[15].

The use of WUS devices is gradually increasing; however, it is necessary to compare these devices with SUS and investigate their reliability. This study was undertaken to evaluate the inter-machine reliability of AHD measurements in patients with SIS.

## Material and method

This study had a cross-sectional design. The study protocol was approved by the Istanbul Training and Research Hospital Ethics Committee (approval no: 2011-KAEK-50, Decision No. 61). A written informed consent was obtained from each patient. The study was conducted following the principles of the Declaration of Helsinki.

### Study population

Patients presenting to our clinic with shoulder pain were screened for eligibility. The diagnosis of SIS was made by EA, a specialist with a 15-year interest in musculoskeletal disorders, in the presence of at least three of the five positive clinical tests (Neer, Hawkins-Kennedy, painful arch, Jobe, and external rotation resistance) on physical examination[16]. The inclusion criteria were patients aged 18–55 years with unilateral shoulder pain lasting longer than six weeks. Patients were excluded from the study if they presented with bilateral shoulder pain, history of rheumatological diseases, diabetes mellitus, chronic liver or kidney failure, cervical pathologies, previous upper extremity/shoulder fracture or surgery, positive apprehension test, adhesive capsulitis (<90° of passive abduction and external rotation)[17], hook-shaped acromion and severe glenohumeral osteoarthritis evident, or a full-thickness tear on Magnetic Resonance Imaging (MRI). The study also excluded patients who had received steroid injections or physiotherapy in the shoulder area in the last six months, and those who had received anti-inflammatory-analgesic treatment over the past week.

Demographic data (age, gender, body mass index, dominant extremity) of the patients included in the study were recorded at the beginning of the study.

### US examination

Two different linear probes at a frequency of 5–10 MHz were used on a mode B standard ultrasound device (Philips Affiniti 50, Medical International Co., Ltd., Amsterdam, The Netherlands) and a wireless ultrasound device (Clarius™ ultrasound scanner linear, L7, Clarius, Burnbaby, BC, Canada). FB, a specialist with at least five years of expertise in musculoskeletal ultrasonography, assessed the acromiohumeral distance. Before the start of the study, FB performed a pilot ultrasound examination with SUS and WUS in the neutral and 60° abduction positions on 10 patients (fulfilling the study criteria) until he was confident that reproducible measurements would be obtained. Patients who participated in the pilot examination were excluded from the study. In the ultrasound scanner, preset ultrasonographic settings were selected for musculoskeletal imaging, including depth, focal point, and gain. These settings were adjusted according to the ultrasound image and the person being scanned to ensure optimal visualization of the anatomical landmarks. To obtain images with the wireless probe, the Wireless USG application was downloaded from the app store of the tablet or mobile device. In our study, we used an iPad (screen size 20 cm ×15 cm) and provided a WI-FI connection to the iPad with the wireless probe's password. The device became usable with a WI-FI connection, and real-time images were instantly transferred to the iPad. Each measurement was kept in the SUS database and on the iPad. After all scans of all study participants were completed, AHD measurements were performed three times at weekly intervals by FB, using two different devices for each patient. The measurements made by FB were recorded by BTD, and FB was prevented from accessing the measurement results again. The mean of the recorded measurements was calculated by BTD.

#### *AHD measurement in shoulder neutral position (AHD_0)*

AHD measurements in the neutral position were performed with the patients seated in an upright posture in a chair, at rest, with their elbows in a 90° flexion position and their forearms resting on a pillow in their laps in the shoulder neutral position[18]. The ultrasound transducer was placed longitudinally on the anterior surface of the anterior acromial border to visualize the humeral head and the acromion. The acromiohumeral distance was defined as the linear perpendicular distance between the upper surface of the humeral head and the lower surface of the acromion[12,19] (Fig. 1 A).

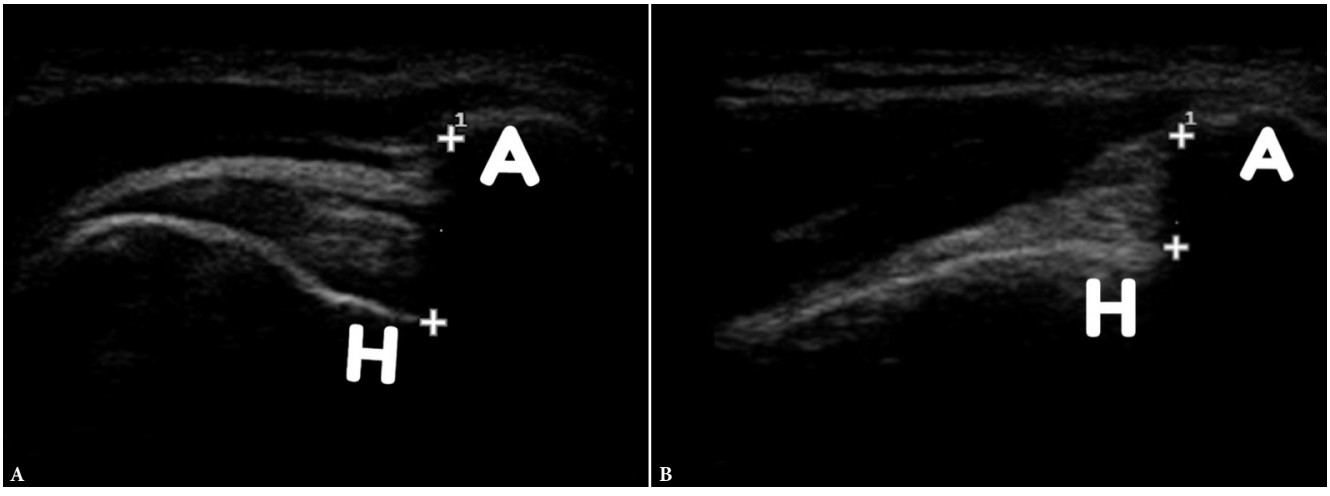


**Fig. 1. A.** *Acromiohumeral distance measurement in shoulder neutral position.* **B.** *Acromiohumeral distance measurement in shoulder 60° abduction position. Acromion (A), humeral head (H)*

### *AHD measurement in shoulder 60° abduction (AHD_60)*

The shoulder was passively abducted to 60° with the help of the Orthoservice SAW 60° shoulder abduction brace. The patient was held in an upright position in a chair, and the elbow was flexed to 90°. The measurement was confirmed with a goniometer. The ultrasound transducer was placed longitudinally on the anterior surface of the anterior acromial border to visualize the humeral head and the acromion. The acromiohumeral distance was defined as the linear perpendicular distance between the upper surface of the humeral head and the lower surface of the acromion[19] (Fig. 1 B).

### Sample size

The sample size was determined using Power Analysis and Sample Size Software 15 (2017) (NCSS, LLC., Kaysville, UT, USA; www.ncss.com/software/pass). A one-way random-effects analysis of variance model with an estimated intraclass correlation of 0.700 was found to provide a two-sided 95% confidence interval (CI) of 0.200 for a random sample of 61 participants, each measured twice.

### Statistical analysis

Statistical analysis was performed using IBM SPSS version 22.0 software (IBM Corp., Armonk, IL, USA). The normal distribution was evaluated by the Kolmogorov-Smirnov/Shapiro-Wilk test, kurtosis and skewness values, and histogram plots. Mean ± standard deviation and median (minimum–maximum) values were given when presenting descriptive analyses. Bland-Altman analysis was used to detect systematic bias by comparing the differences between machines according to their means with 95% limits of agreement (LOA)[20]. Standard error of the measurement (SEM) and minimal detectable change (MDC) values were determined. The SEM value provides an estimate of how much samples differ within a population. MDC is the smallest difference detected that is clinically significant for the measurement to be considered reliable, i.e. the value at which differences are most likely not due to measurement error[10]. SEM = (SD) × √(1-ICC) and MDC = (SEM) × (√2) × (1.96). Here, 1.96 represents a 95% confidence level. The inter-machine reliability of US measurements was assessed by calculating intraclass correlation coefficients (ICC) with 95% CI and absolute agreement for a single measurement. Statistical significance was determined as $p$ <0.05. When evaluating the reliability of ICC, values of 0.5–0.75 indicated moderate reliability, 0.75–0.90 indicated good reliability, and >0.90 indicated excellent reliability[10,21].

## Results

A total of 61 participants with SIS, 30 (49.2%) males and 31 (50.2%) females, were included in our study. Demographic data of the participants are shown in Tab. 1. AHD_0 was measured as 11.59 ± 1.38 mm and 11.63 ± 1.34 mm for SUS and WUS, respectively. AHD_60 was found to be 6.34 ± 1.01 mm and 6.32 ± 1.02 mm for SUS and WUS, respectively. AHD_0 and AHD_60 were not significantly different between the two machines ($p$ >0.05) (Tab. 2). Inter-machine reliability was excellent for both AHD_0 (ICC = 0.97; 95% CI; 0.95–0.98) and AHD_60 (ICC = 0.96; 95% CI; 0.93–0.97). SEM values were low, in the range of 0.20–0.23 mm. MDC values were also low, in the range of 0.55–0.63 mm. The inter-machine reliability coefficients of ICC, SEM, and MDC values are presented in Tab. 3. The mean difference between the two machines was 0.04 mm for AHD_0 with a 95% agreement limit of -0.821 to 0.899 mm, and 0.02 mm for AHD_60 with a 95% agreement limit of -0.605 to 0.565 mm (Fig. 2).

**Tab. 1**. Patients characteristics

| | Mean ± SD | Median (min-max) |
|---|---|---|
| Height (cm) | 163.84 ± 7.96 | 165 (149–180) |
| Weight (kg) | 69.98 ± 12.43 | 70 (35–102) |
| BMI (kg/cm$^2$) | 25.7 ± 4.95 | 25 (15–37) |
| Age (years) | 45.25 ± 8.63 | 48 (26–59) |

BMI – body mass index

**Tab. 2**. Comparison of patients' AHDs measured with different devices and at different angles

| AHD | Standard US ($n$ = 61) | Wireless US ($n$ = 61) | *P* |
|---|---|---|---|
| AHD_0 | 11.5 ± 1.38 | 11.6 ± 1.3 | 0.398 |
| | 11.7 (8.8–16.3) | 11.5 (9–16.2) | |
| AHD_60 | 6.3 ± 1.0 | 6.3 ± 1.0 | 0.609 |
| | 6.4 (3.3–8.9) | 6.5 (3.3–8.9) | |

P* Paired Sample T-Test. Values are means ± standard deviation (SD) and median (minimum-maximum).
AHD – acromiohumeral distance; US – ultrasound; $p$ >0.05

**Tab. 3.** Inter-machine reliability analysis

| | ICC | %95 CI | SEM (mm) | MDC (mm) |
|---|---|---|---|---|
| AHD_0 | 0.97 | 0.95–0.98 | 0.23 | 0.63 |
| AHD_60 | 0.96 | 0.94–0.97 | 0.20 | 0.55 |

ICC – intraclass correlation coefficients, CI – confidence interval; SEM – standard error of measurement; MDC – minimal detectable change

## Discussion

In this study, we analyzed the inter-machine reliability for both the neutral position and the 60° abduction position. In both positions, the results were excellent in terms of inter-machine reliability. In the US-based evaluation of SIS, the passage of the tendon and subacromial bursa under the acromion is observed. Compression is suspected if fluid in the subacromial bursa collects laterally, the large tubercle does not pass under the acromion, and pain is present during dynamic evaluation[22]. However, these findings are usually not observed on the US in individuals clinically diagnosed with SIS[19]. Therefore, AHD measurements were performed to evaluate the subacromial space in patients with SIS. In US-based studies reported in the literature, patients with SIS and healthy control groups were compared in terms of AHD, and differences were found[6,7,17]. Desmeules *et al.*[6] measured AHD in patients with SIS as 12.0 ± 1.9 mm and 9.6 ± 2.3 mm in the neutral position and at 60° abduction, respectively. Hunter *et al.*[7] found AHD to be 11.9 ± 2.2 mm in patients with SIS in their study. Pijls *et al.*[23] measured AHD in the neutral position as 9.3 ± 1.7 mm by an experienced observer and 9.0 ± 1.4 mm by a novice observer. In 60° abduction, both experi-

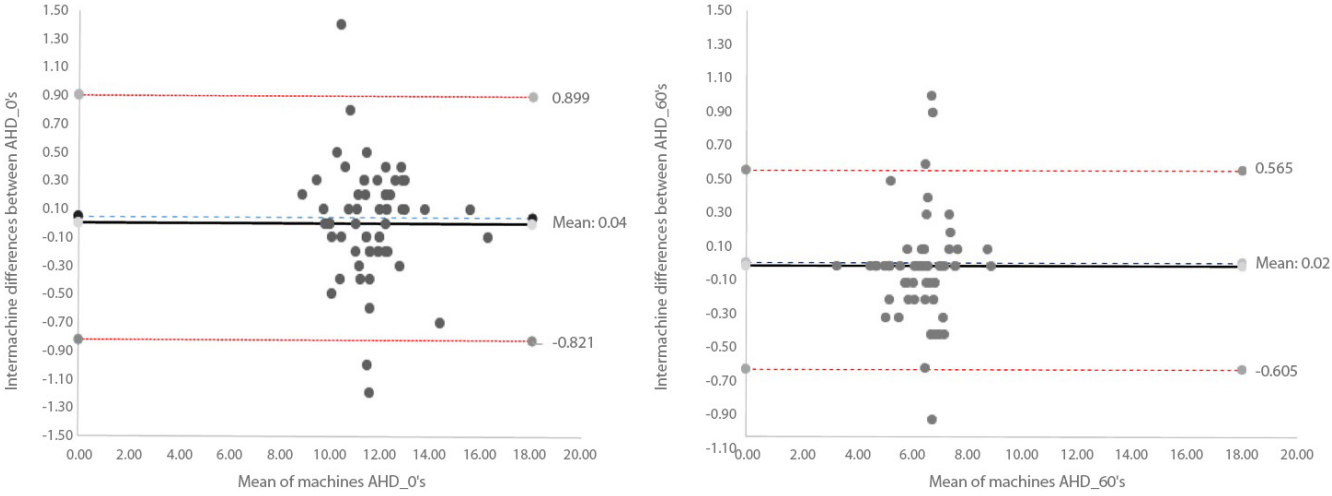


**Fig. 2.** *The Bland-Altman plot shows the mean difference between the two machines and the amount of dispersion around the mean, demonstrating inter-machine reliability when measuring the acromiohumeral distance at 0° and 60°*

enced and novice observers obtained the results of 6.7 ± 1.7 mm and 6.7 ± 1.4 mm, respectively. Although the measurements are similar, there are differences. The AHD range reported in the literature is approximately 2–17 mm. It has been reported that some of the reasons for this wide range in AHD measurement may be related to age, race, gender, shoulder position, shoulder pathologies, and different imaging methods and measurement techniques[24]. On the other hand, the consistency of measurements performed by different physicians, using different ultrasound devices, and at different times is also important. Therefore, standardization of the relevant parameters may yield more effective results in the diagnosis and follow-up process. Measurement of the acromiohumeral space is clinically important in patients with SIS. However, there is conflicting information in the literature regarding the correlation between the acromiohumeral space and pain, range of motion, activities of daily living, and functionality parameters in patients with SIS[25–28]. On the other hand, changes in AHD as a result of treatment have been reported[18]. In the literature, there are many studies evaluating the inter-rater and intra-rater reliability of image interpretation of AHD measurements performed with the US[9–11,23]. In these studies, the AHD measurement in the US is reliable. However, the common aspect of these studies is that the devices used were exclusively SUS devices.

A study on device consistency found excellent inter-machine reliability for patellar tendon length and cross-sectional area[29]. Another study found that patellar, Achilles, and plantar fascia thickness could be measured reliably with different US devices[30]. However, only SUS devices were used in these studies. An ultrasound-based inter-machine reliability study has recently been published. To measure the cross-sectional area of the median nerve and the thickness of the tendons, SUS and WUS devices were used. Correlation analysis, not intraclass correlation coefficients, was used here to assess the measurement relationship. The measurements had a moderate correlation between 0.43–0.77[31]. This study evaluated the application of WUS devices in the musculoskeletal system for the first time, bringing a new perspective to the literature. Future studies may investigate the reliability of WUS in different musculoskeletal regions.

## Limitations

The limitations of our study are the following: 1) intra- and inter-rater reliability of supraspinatus tendon thickness with the WUS device was not evaluated, and 2) inter-rater reliability of image interpretation was not evaluated.

## Conclusion

The findings of our study show that WUS devices are reliable in comparison to SUS devices in the measurement of the acromiohumeral distance in patients with shoulder impingement syndrome. The results of the study could contribute to a significant improvement in the clinical use of WUS devices.

### Conflict of interest

*The authors declare no conflict of interest in relation to the writing and/or publication of this article.*

### Author contributions

*Original concept of study: BTD. Writing of manuscript: BTD, FB. Analysis and interpretation of data: BTD. Final approval of manuscript: EA, FB. Collection, recording and/or compilation of data: EA. Critical review of manuscript: EA, FB.*

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