Measuring Ultrasonographic Thickness of the Achilles Tendon Insertion is Less Reliable Than the Midportion in Healthy Tendons and Patients With Tendinopathy

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Abbreviations

AP, Anterior-posterior; AT, Achilles Tendinopathy; ICC, Intraclass correlation coefficient; PAL, Physical Activity Level; SRD, Smallest Real Difference; US, Ultrasound; UTC, Ultrasound Tissue Characterization; VISA-A, Victorian Institute of Sports Assessment-Achilles

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Introduction—Ultrasound is the preferred imaging method in the diagnostic process of Achilles tendinopathy (AT). Ultrasound tissue characterization (UTC) is a frequently used, standardized and valid method to assess tendon geometry in AT patients. It is unknown whether UTC is reliable for measuring Achilles tendon thickness.

The aim of the study was to assess intra- and inter-rater reliability of Achilles tendon thickness measurements using UTC in both asymptomatic individuals and patients with AT, and to evaluate if the reliability of thickness measurements differs between the midportion and insertional area.

Methods—Exactly 50 patients with AT and 50 asymptomatic individuals were included. Using the conventional US and standardized UTC procedure maximum thickness was measured in the midportion and insertion region. To determine inter- and intra-rater reliabilities, the intraclass correlation coefficient (ICC) was used.

Results—The ICC values for inter- and intra-rater reliability were classified as "excellent," for the AT group (0.93 [95% CI: 0.88–0.96] and 0.95 [0.92–0.97]) and asymptomatic participants (0.91 [0.87–0.94] and 0.94 [0.92–0.96]). The reliability of measuring tendon thickness in the midportion region was "excellent," with both inter-rater (0.97 [0.95–0.98]) and intra-rater (0.98 [0.96–0.99]) ICC values indicating high levels of agreement. In the insertional region, ICC values for inter-rater (0.79 [0.69–0.87]) and intra-rater (0.89 [0.84–0.93]) reliability were "moderate to good."

Conclusion—We showed excellent reliability for measuring the US thickness of the midportion and good reliability of measuring the insertional region in patients with AT. Significantly lower ICCs were observed for the reliability of thickness measurements in the insertional region when compared with the midportion.

Key Words—imaging; minimal detectable change; tendon geometry; ultrasound tissue characterization; UTC

Achilles tendon pain related to mechanical loading is commonly referred to as Achilles tendinopathy (AT).[1] Patients with AT are classified by location (midportion vs

insertional AT) as this might affect the choice of treatment.[2,3] Individuals with AT experience a lower quality of life when compared with healthy people and AT has significant socio-economic consequences.[4,5] There is a need to optimize the diagnostic process for this patient group.[6] According to the current guidelines, ultrasound (US) is the preferred imaging method in the diagnostic process of AT.[2,7,8] One of the typical findings of AT on US examination is increased tendon thickening, with a cut-off value of ~7 mm being accepted as reference standard based on several small cross-sectional studies.[7,9–11]

Reliability of Achilles tendon thickness measurements using conventional US ranges from fair to excellent.[12–14] In the majority of the cases, only the reliability of measuring the Achilles tendon midportion area has been assessed.[14,15] No studies have evaluated the reliability of measuring the insertional area in AT patients.[14,15] Most of the reliability studies on ultrasonographic Achilles tendon geometry have a high risk of bias (eg, a very specific selection of participants, inadequate blinding to prior findings/clinical information/reference standards/additional cues and no time interval between measurements), which limits drawing firm conclusions.[14,15] Implementing standardized US procedures is becoming more essential in clinical practice and is a suggested method to improve the reliability of tendon geometry measurements.[14,16,17] Ultrasound tissue characterization (UTC) is a customized tracking and ultrasonographic data-collection device that facilitates these standardized measurements (see online supplemental File 1 for a detailed explanation of UTC).[9] To date, it is unknown whether a standardized US method is reliable for measuring Achilles tendon thickness and whether there is a difference in reliability when measuring the midportion versus the insertional area of the Achilles tendon. It is also unknown whether a standardized procedure improves this reliability when compared with conventional US measurements of geometry.

The primary aim of this study was to evaluate the intra- and inter-rater reliability of Achilles tendon thickness measurements using UTC in both asymptomatic individuals and patients with AT. The secondary aims were to evaluate if the reliability of thickness measurements differs between the midportion and insertional area and to determine whether tendon thickness measurements using UTC can be translated to conventional US.

Materials and Methods

Participants

We recruited a total of 100 participants, comprising 50 patients diagnosed with AT and 50 asymptomatic individuals. We included 25 patients with insertional AT and 25 patients with midportion AT. To be eligible for inclusion, AT patients had to meet the following criteria: 1) age ≥18 years, 2) the clinical diagnosis of AT established by the sports physician and 3) provide informed consent. The patients with AT were consecutively recruited between September 2020 and September 2022 from the outpatient department of Orthopaedic Surgery and Sports Medicine of Erasmus MC University Medical Centre, and the clinical diagnosis was established by a single sports medicine physician with 9 years of clinical experience as a medical specialist (RJDV). The diagnosis was made based on the presence of gradual-onset pain in the Achilles tendon region during tendon-loading activities and recognizable and localized pain upon palpation of the Achilles tendon.[1,2,6,18] Insertional tendinopathy was diagnosed when the pain was located between the Achilles tendon insertion and the upper border of the calcaneus. Midportion tendinopathy was diagnosed when symptoms were located proximal to the upper border of the calcaneus (free tendon region).

Asymptomatic participants were consecutively recruited through informing potential participants via social media platforms (Twitter, Facebook, and LinkedIn). To be eligible for inclusion, asymptomatic participants had to meet the following criteria: 1) age ≥18 years, 2) no current or past history of Achilles tendon pain or stiffness, 3) no localized tendon pain or nodular thickening upon palpation and 4) provide informed consent.

Procedures

The study was designed at the Erasmus MC University Medical Centre (Rotterdam, the Netherlands). The local Medical Ethics Committee (Southwest-Holland, the Netherlands) approved the study protocol (MEC-2020-0585, MEC-2021-0033). We adhered to the minimum reporting standards for reporting participant characteristics in tendinopathy research and to the guidelines for reporting reliability and agreement studies.[19,20] Online supplemental File 2 shows a graphical description of the design of the study.

Patients with Achilles Tendinopathy

Before their appointment at the outpatient department, patients completed a standardized digital questionnaire that encompassed demographic information, health status, and sports activities. Physical Activity Level (PAL) was assessed using a 6-point Likert scale.[21] Additionally, patients completed the Victorian Institute of Sports Assessment-Achilles (VISA-A) questionnaire, ranging from 0 to 100.[22] A single senior sports physician (RJDV) conducted a comprehensive history taking and physical examination for each patient. If the clinical diagnosis of AT was established, conventional US and UTC were performed by the sports physician. Participants were positioned in a standardized manner, prone on an examination table with the ankle placed in maximum passive dorsiflexion and then supported by the examiner's knee (online supplemental File 1). A multifrequency 5–16 MHz linear-array transducer (Terason, Burlington) was used. The depth was set at 3.0 cm. The transducer was placed in a transverse position and perpendicular to the Achilles tendon.

The sports physician has 15 years of experience with US tendon imaging and UTC data collection and analysis. The procedures were conducted on the symptomatic side. Both sides were examined in cases of bilateral symptoms.

The same sports physician simultaneously conducted thickness measurements using conventional US as part of routine care. To minimize recall bias, the thickness measurements on the UTC scans were performed by the sports physician/researcher (RJDV) an average of 16 (standard deviation [SD]: 7) months after the UTC scan and the measurements on conventional US. The conventional US and UTC scan thickness measurements will be described more extensively below.

Asymptomatic Population

If the inclusion criteria were met, participants were asked to complete a standardized questionnaire that included demographic information, health status, and details on their physical activity and participation in sports activities. Subsequently, a brief physical examination was conducted to evaluate the presence or absence of localized pain upon palpation of the Achilles tendon, as well as to assess localized thickening of the tendon using the Arc sign.[18] Finally, the UTC scan was carried out following a standardized protocol on both Achilles tendons by a single trained researcher (TSV). This researcher has 3 years of experience with US tendon imaging and UTC data collection and analysis. To mitigate the potential influence of anatomical variations, we included 25 left Achilles tendons and 25 right Achilles tendons in our study. The UTC thickness measurements on asymptomatic individuals were performed an average of 5 months (SD: 0.3) after the UTC scan.

Outcome Measures

Conventional Ultrasound

The largest anterior-to-posterior (AP) diameter of the Achilles tendon was estimated in the transversal view, in line with current clinical and research practice.[7,15] This section of maximum thickness was frozen and subsequently the thickness was directly measured in millimeter (mm), rounded to one decimal (Figure 1). This procedure was performed for the Achilles tendon midportion, insertional region, or both, based on the location of symptoms (data were only collected from the region(s) in which patients experienced symptoms).

Ultrasound Tissue Characterization

We utilized the UTC Imaging version 2020 (UTC Imaging, Stein, The Netherlands) for the standardized ultrasound assessment. This system involves a tracking device and conventional US equipment. The UTC scan was carried out following a standardized protocol. Participants were positioned in an identical manner to the conventional US procedure, prone on an examination table with a maximum passive dorsiflexion angle of the ankle obtained and then maintained by the researchers knee (online supplemental File 1). The same multifrequency 5–16 MHz linear-array transducer (Terason, Burlington) was used in a transverse and perpendicular position, moving automatically from proximal to distal over a distance of 12 cm to obtain a three-dimensional data block. The UTC tracking and data-collection device facilitated the collection of "raw" digital transverse images at regular intervals of 0.2 mm. The exact working mechanisms of the UTC procedure have been described in detail in previous literature.[9,23,24] All scans were collected in a database and pseudonymized before initiating the measurements.

The maximum AP distance was measured manually by two independent researchers (RJDV and TSV) using a standardized procedure (Figures 2 and 3).

First, the thickest part of both the midportion and insertion region of the tendon were estimated by the researchers in the longitudinal plane. Then, these regions of the tendon were assessed in the transversal plane and subsequently the maximum diameters of the tendon were measured. Measurements were performed using pixel size (rounded to one decimal), with 1 pixel corresponding to 0.062 mm. Both raters were blinded to the conventional US measurements and each other's measurements. Both raters were aware of the disease condition (symptomatic vs asymptomatic) but were blinded to clinical information such as localized tendon thickening and additional cues (eg, age, height, symptom duration, gender, etc). Measurements were performed in a consecutive order as varying the order of subjects was impractical.

Figure 1. Achilles tendon thickness measurements with conventional ultrasound of the insertion (upper image) and midportion (lower image) of the tendon. The largest AP diameter of the Achilles tendon perpendicular to the latero-medial width was measured in the transversal view.[9] This section of maximum thickness was frozen and subsequently the thickness was measured directly (yellow dotted line).

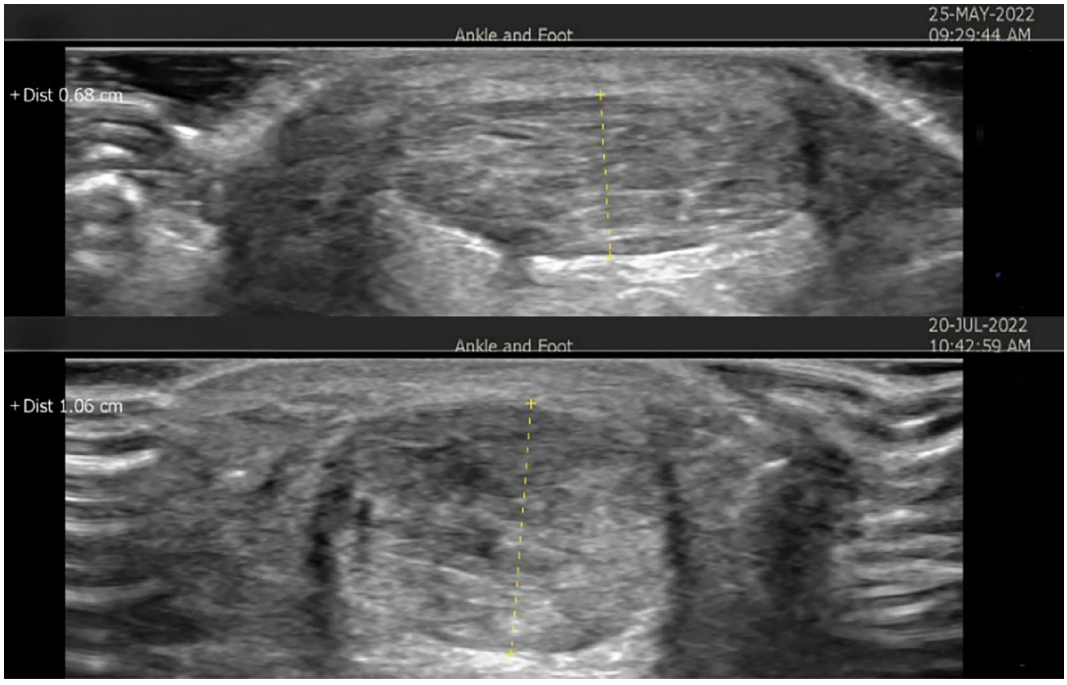
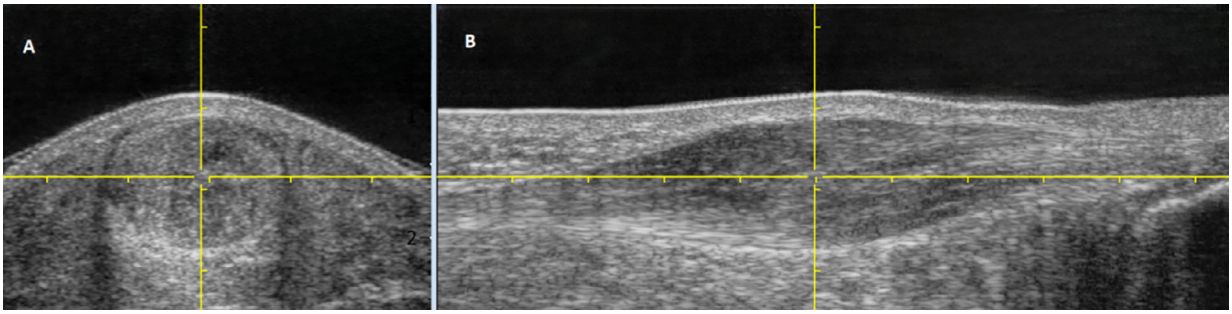


Figure 2. UTC image of the Achilles tendon. In the longitudinal plane (**B**), the thickest part of both the midportion and insertional region of the tendon were estimated. Subsequently, those regions were assessed in the transversal plane (**A**).

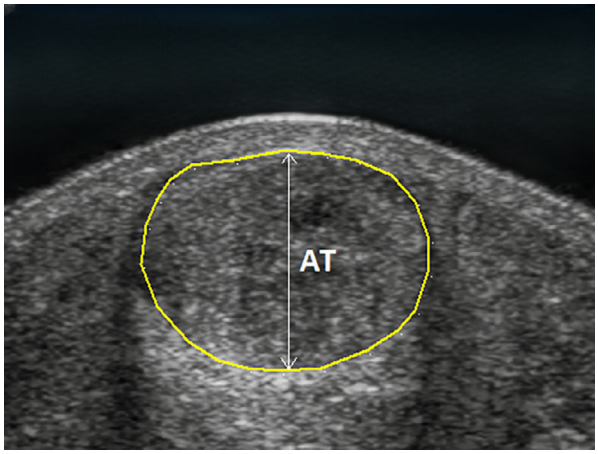


For intra-rater reliability, a single researcher (TSV) performed thickness measurements in a consecutive order on all UTC scans a second time with an average time interval of 43 (SD: 1) days. This researcher was unaware of previous measurements (both his own and of the other rater).

Statistical Analysis

A total of 100 participants were recruited. Descriptive statistics comprising mean and standard deviations were computed for the participants' characteristics and tendon thickness (maximum AP diameter in mm). During the measurement phase, both researchers also assessed whether data collection errors were present which refrained them from properly obtaining the outcome measurement. In case both researchers independently agreed that a UTC scan was not suitable to obtain the outcome measurement, we decided to exclude the scan in the analysis. If only one of both researchers assessed the scan as unsuitable for performing measurements, this was discussed between the two. In case there was no consensus, we decided to ask a third reviewer with experience in US data collection and analysis (SO) to assess the suitability of the UTC images. To determine inter- and intra-rater reliabilities, the intraclass correlation coefficient (ICC) was used. For both asymptomatic participants and those diagnosed with AT, the ICC ± 95% confidence interval (CI) was calculated for the maximum thickness in the midportion area and insertional area, using two-way random, single measurement on UTC scans. The reliability between conventional US and UTC measurements was also calculated for maximum thickness in the midportion and insertional region, using a two-way mixed, single measurement for patients diagnosed with AT. An ICC value of <0.5, ranging from 0.5 to 0.75, ranging from 0.75 to 0.9 and above 0.9 were, respectively, classified as "poor," "moderate," "good," and "excellent."[25] We also calculated the standard error of measurement (SEM = √total mean square within people) and smallest real difference (SRD = 1.96 × SEM × √2).[26] Smallest real difference can also be referred to as minimal detectable change (MDC), which is calculated in the same manner. IBM SPSS Statistics (version 28.0.1.0) was used for statistical analyses.

Figure 3. Achilles tendon thickness measurement with the UTC procedure of the midportion of the tendon. After identifying the thickest part of the tendon in the longitudinal plane the maximum AP diameter perpendicular to the latero-medial width (white solid line) was measured in the transversal plane. The yellow line identifies the periphery of the tendon.



Results

One hundred UTC scans in the database were assessed by the two researchers. One UTC scan of a patient with insertional AT was excluded because of an artifact caused by a large air bubble within the scan gel (both researchers independently agreed on this). Consequently, 99 UTC scans were included in the analyses. The sports physician performed all thickness measurements of the conventional US in the remaining patients with AT (n = 49).

The participants' characteristics are depicted in Table 1. Patients with AT had an average symptom duration of more than 5 years. Maximum tendon thickness using UTC is also displayed in Table 1. Mean ± SD tendon thickness in AT patients was 8.3 ± 2.2 mm (midportion) for patients with midportion AT and 5.4 ± 1.3 mm (insertion) for patients with insertional AT. There were significant differences in age and body mass index (BMI) between the AT and asymptomatic group.

Overall, ICC values for inter- and intra-rater reliability using UTC were classified as "excellent" for both AT patients and asymptomatic participants (Table 2). In symptomatic as well as asymptomatic individuals, reliability of measuring thickness in the midportion and insertional region were respectively

classified as "excellent" and "moderate to good." The 95% CIs of the ICC values did not overlap between the two regions, indicating a statistically significant difference in reliability of measuring Achilles tendon thickness between the midportion and insertional region. The 95% CIs of the ICC values did overlap

Table 1. Participant Characteristics.

	Total Group (n = 99)	Achilles Tendinopathy Patients (n = 49)	Asymptomatic Participants (n = 50)	Mean Difference (95%CI, *P*-value)
Age (years)	44.2 (14.5)	48.0 (13.5)	40.4 (14.5)	7.6 (2.0–13.2, $P = .008$)
Height (cm)	177.3 (8.6)	178.7 (7.8)	175.9 (9.2)	2.8 (−0.6–6.2, $P = .105$)
BMI (kg/m^2)	25.3 (4.2)	26.6 (4.3)	23.9 (3.8)	2.7 (1.1–4.3, $P = .001$)
Gender (female/male)	48/51	21/28	27/23	$P = .267$
Physical activity level (PAL; 1–6)[a]	4.6 (0.9)	4.5 (0.8)	4.8 (1.0)	−0.4 (−0.7 to 0.01, $P = .058$)
Symptom duration (weeks)	—	278 (375)	—	
VISA-A score	—	46.3 (18.0)	—	
Side (Left/Right/Both)	39/41/19	14/16/19	25/25/0	—
Tendon thickness on UTC (mm; midportion)	—	8.3 (2.3)[b]	5.5 (1.2)	2.8 (2.0–3.6, $P < .001$)
Tendon thickness on UTC (mm; insertion)	—	5.4 (1.4)[b]	4.3 (0.69)	1.1 (0.59–1.6, $P < .001$)
Tendon thickness on US (mm; midportion)	—	8.2 (2.5)[b]	—	—
Tendon thickness on US (mm; insertion)	—	5.8 (1.9)[b]	—	—

Note: Values are means with standard deviation (SD) unless otherwise described.
[a]1–6—1 = Hardly any physical activity, 2 = Mostly sitting, sometimes walk, easy tasks/play, 3 = Light physical activity for about 2–4 times a week (eg, fishing, talking, dancing), 4 = Moderate exercise 1–2 hours a week (jogging, swimming, gymnastics), 5 = Moderate exercise at least 3 hours a week (jogging, swimming, gymnastics), 6 = Hard or very hard exercise regularly and several times a week during which the physical exercise is great (jogging, rugby, football).
[b]Midportion thickness included 25 patients with midportion AT. Insertional thickness included 24 patients with insertional AT.
AT, Achilles tendinopathy; BMI, body mass index (kg/m^2); PAL, Physical Activity Likert Scale; VISA-A, Victorian Institute of Sports Assessment-Achilles.

Table 2. ICC Values for Inter-and Intra-Rater Reliability of Tendon Thickness Measurements Using UTC.

	Inter-Rater Reliability			Intra-Rater Reliability		
	ICC (95% CI)	SEM (mm)	SRD (mm)	ICC (95% CI)	SEM (mm)	SRD (mm)
Overall (total, n = 99)	**0.93** (0.91–0.95)	0.521	1.44	**0.96** (0.95–0.97)	0.399	1.11
Midportion (n = 75)	**0.97** (0.95–0.98)	0.396	1.10	**0.98** (0.96–0.99)	0.345	0.96
Insertion (n = 74)	**0.79** (0.69–0.87)	0.581	1.61	**0.89** (0.84–0.93)	0.408	1.33
Achilles tendinopathy patients (total, n = 49)	**0.93** (0.88–0.96)	0.727	2.02	**0.95** (0.92–0.97)	0.492	1.36
Midportion (n = 25)	**0.95** (0.90–0.98)	0.529	1.47	**0.96** (0.92–0.98)	0.439	1.22
Insertion (n = 24)	**0.80** (0.61–0.91)	0.888	2.46	**0.87** (0.74–0.94)	0.543	1.51
Asymptomatic participants (total, n = 50)	**0.91** (0.87–0.94)	0.366	1.01	**0.94** (0.92–0.96)	0.340	0.94
Midportion (n = 50)	**0.94** (0.89–0.96)	0.301	0.84	**0.96** (0.93–0.98)	0.282	0.78
Insertion (n = 50)	**0.71** (0.53–0.82)	0.421	1.17	**0.81** (0.69–0.89)	0.388	1.07

Note: Bold values are considered statistically significant.
CI, confidence interval; ICC, intraclass correlation coefficient; SEM, standard error of measurement; SRD, smallest real difference.

between the AT patient group and the asymptomatic group, indicating that disease status has no significant effect on reliability of measuring Achilles tendon thickness. The SRD for intra-rater reliability ranged between 1.22 mm (midportion) and 1.51 mm (insertion) for AT patients and between 0.78 (midportion) and 1.07 (insertion) for asymptomatic participants. For inter-rater reliability the SRD was 1.47 mm (midportion) and 2.46 mm (insertion) for AT patients and ranged between 0.84 mm (midportion) and 1.17 mm (insertion) for asymptomatic participants.

ICC values for the reliability between UTC and conventional US were classified as "good" (0.81) for the insertional region and "excellent" (0.96) for the midportion (Table 3). The SRDs between these two measurement techniques were 2.27 mm for the insertional area and 1.60 mm for the midportion area.

Discussion

This is the first large-scale study to evaluate the reliability of Achilles tendon thickness measurements using a standardized US procedure for both the midportion and insertional region in AT patients as well as asymptomatic individuals. Overall, our findings indicate a high level of agreement between and within observers with respect to thickness measurements of the Achilles tendon. This observation holds true for both individuals who suffer from AT and those who are asymptomatic. Lower ICC and higher SRD values were observed for the thickness measurements in the insertional region when compared with the midportion. The reliability of thickness measurements between the standardized UTC procedure and conventional US was excellent for the midportion region and good for the insertional region.

Clinical Relevance

These findings are relevant for the clinical setting, as current guidelines advise performing US as the first imaging modality of choice in the diagnostic process of patients with AT. For this reason, it is important to know the reliability of measuring Achilles tendon thickness in specific regions (the midportion and insertional region) where pathology is frequently observed. It is also relevant to have more knowledge of the reliability when using standardized US procedures, such as UTC, since these are gaining popularity in the clinical setting.[16,17] When US is used to monitor change in tendon diameter it is important to verify that changes exceed the SRD to be of relevance. This is illustrated when considering the range of SRD values observed in our study, which lie between 0.8 and 2.5 mm. This range must be interpreted in the context of the absolute mean values of Achilles tendon thickness, which we found to be between 4.3 and 8.3 mm. The SRD values represent a threshold for clinically meaningful changes in tendon thickness. When a change in tendon thickness less than the SRD is observed, it may be considered within the margin of measurement error.

Excellent Reliability for Measuring Achilles Tendon Thickness

Previous systematic reviews on the reliability of Achilles tendon thickness measurements using conventional US reported wide ranges for intra-rater (0.78–0.99 vs 0.96 for the current study) and inter-rater (0.68–0.99 vs 0.93 for the current study) ICC values.[14,15] These studies did not distinguish between the midportion and insertional region, did not use a standardized US procedure, such as the UTC, and did not include both AT patients and asymptomatic individuals, which may account for the discrepant findings. Notably, the SRD values observed in the current study were relatively higher (1.22–1.47 mm for midportion AT and 1.51–2.46 mm for insertional

Table 3. ICC Values for Standardized and Conventional US Procedures.

	Reliability Between Standardized UTC and Conventional US Procedures		
	ICC (95% CI)	**SEM (mm)**	**SRD (mm)**
Achilles tendinopathy patients (total, n = 49)	**0.95** (0.91–0.98)	0.681	1.89
Midportion (n = 25)	**0.96** (0.92–0.98)	0.577	1.60
Insertion (n = 24)	**0.81** (0.62–0.91)	0.819	2.27

Note: Bold values are considered statistically significant.
CI, confidence interval; ICC, intraclass correlation coefficient; SEM, standard error of measurement; SRD, smallest real difference; US, Ultrasound; UTC, ultrasound tissue characterization.

AT) than those reported in previous investigations (ranging between 0.007 and 0.84 mm).[14,15] This may be attributed to the heterogeneity of the study population evaluated as the previously mentioned studies only reported SRD values for the midportion region and the majority only included asymptomatic individuals. A study by Docking et al (2016) did use UTC and included both AT patients and asymptomatic individuals and reported a minimal detectable change (MDC) of 0.5 mm.[11] However, this was only based on intra-observer agreement after scanning eight Achilles tendons and without distinguishing between the midportion and insertional region.[11]

Lower Reliability for Measuring Thickness of the Insertional Achilles Tendon Region

We observed that the ICC values for Achilles tendon thickness measurements were lower for the insertional region compared with the midportion. To our knowledge, this is the first study to comprehensively evaluate thickness measurements in the insertional region, as previous investigations have focused solely on the midportion.[9,12,14,15,23,27] The diminished reliability of thickness measurements in the insertional region may be attributed to the unique anatomical properties of this region. Specifically, the insertional part of the tendon has a less straight course compared with the midportion. The appearance of tissue-structures on ultrasound are angle-dependent, a phenomenon referred to as anisotropy, where tissue structure might appear to be hypoechoic due to the positioning of the ultrasound probe.[7,28,29] The "rotated" trajectory of the insertional region is more susceptible to anisotropy which may lead to angle-generated artifacts on ultrasonographic images, potentially resulting in reduced measurement reliability.[7,29] Our study is the first to show that it is likely that patients with midportion AT will be identified with increased thickness of the Achilles tendon midportion. However, the measurement error in the insertional area may be too large to detect a change in thickness between patients and asymptomatic individuals as the SRD values exceed the mean difference between insertional AT patients and asymptomatic individuals.

Conventional US Procedure Has Similar Reliability as Standardized US Procedure

Our study is the first in this field to compare a standardized US procedure (UTC) to the conventional US procedure. Only a limited number of studies have evaluated the application of UTC to the insertional region of the Achilles tendon,[30,31] as the predominant body of literature primarily examines the use of UTC for identifying alterations in the tendon structure at the midportion.[9,27,32] In the current study, the reliability for thickness measurements between the two methods was excellent for the midportion region and good for the insertional region. This means that both procedures can be used in the clinical or research setting. It also emphasizes that our reliability results for the UTC-based approach can be extrapolated to the conventional US procedure. As conventional US is more readily available in most cases and is used in the clinical setting most often, it is useful to know that it is as reliable as the UTC procedure in assessing tendon thickness. Although for the insertional region, there might be a clinically relevant difference between both methods since the SRD was 2.27 mm (more than half of the mean maximum thickness in the patients with insertional AT).

Strengths and Limitations

Our study has several strengths as we adhered to the relevant guidelines for conducting and reporting in reliability studies. The study was large enough to answer the specific research questions.[33] Participants and raters were representative and raters were blinded to each other's and previous measurements and to patient characteristics and additional cues.

Nonetheless, this study is subject to certain limitations that warrant consideration. First, thickness measurements of the Achilles tendon using conventional US were only conducted once and by a single physician as part of standardized routine care. Consequently, our capacity to assess intra- and inter-rater reliability for conventional US measurements was restricted, and we were only able to report on reliability between conventional US and UTC based on the measurements taken by that particular researcher. However, we were particularly interested in the translation of standardized (UTC) measurements to daily clinical practice, and we showed that there is an excellent to good reliability between both procedures.

Second, the experience in US between both raters ranged from three to 15 years. To reduce potential examiner influence, we used a standardized protocol for collecting and analyzing UTC data.

Third, both raters were not blinded to disease status, and the order of examination was not varied, which could have induced information and recall bias respectively. For this reason, we decided to have at least 8 months between the measurements of the conventional US and the UTC for one researcher (RJDV) and 16 weeks between the UTC scan and first UTC measurements (TSV). This makes recall bias less likely. Next to this, the UTC data collection procedure in both groups was only performed by one rater. Consequently, we did not obtain data on the reliability of the UTC procedure itself. The finding of excellent to good reliability in translation from UTC measurements to conventional US makes it less likely that the UTC procedure itself has a large influence, which is confirmed by previous studies showing excellent reliability of the UTC scanning procedure.[27,34]

Future Perspectives

Future research should focus on obtaining a large dataset of reference values for Achilles tendon thickness in asymptomatic individuals in order to adequately distinguish between changes characteristic of tendinopathy (increased tendon thickening) and "normal" morphological appearance. The SRD values in both the midportion and insertional region identified in the current study will aid in interpreting these between-group differences. This will likely have a major impact on interpreting US assessment for patients with AT.

Conclusion

This study offers valuable insights into the reliability of US-based thickness measurements in patients with Achilles tendinopathy and individuals with asymptomatic Achilles tendons. We showed excellent reliability for accurately measuring the US thickness of the midportion and good reliability of measuring the insertional region in patients with Achilles tendinopathy. Significantly lower ICC and higher SRD values were observed for the reliability of thickness measurements in the insertional region when compared with the midportion. As the SRD values exceed the mean difference in tendon thickness between insertional AT patients and asymptomatic individuals, we recommend interpreting US thickness with caution in patients with insertional Achilles tendinopathy. Thickness measurements with the standardized US (UTC) procedure were similar to conventional US. In order to accurately discriminate between changes indicative of tendinopathy, such as increased tendon thickening, and morphological changes that fall within the range of normal variation, future research should prioritize the acquisition of ultrasonographic reference values for tendon thickness in symptomatic and asymptomatic individuals. This will likely impact on the role of US in assessing patients with AT.

Ethics Statement

This trial has been approved by the Medical Ethics Committee (MEC-2020-0585, MEC-2021-0033).

Patient Consent Statement

Written informed consent was obtained from all subjects before inclusion.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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