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UTC reliability in patellar tendons

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Abstract

Purpose: Ultrasound tissue characterization (UTC) is used in research and clinical practice to quantify tendon structure of the patellar tendon. This is the first study to investigate the inter- and intra-rater reliability for UTC of the patellar tendon on a large scale.

Method: Fifty participants (25 patellar tendinopathy, 25 asymptomatic) were recruited. The affected patellar tendons in symptomatic and right tendons in asymptomatic participants were scanned with UTC twice by one researcher and once by another. The same was done for contour marking (needed to analyze a UTC scan) of the tendon. Intraclass Correlation Coefficient (ICC(2,1)) for echo-types I, II, III, IV, aligned fibrillar structure (echo-types I+II) and disorganized structure (echo-types III+IV) were calculated. This was done for UTC scans as well as solely marking contours. Results: Inter-rater reliability showed fair to good ICC values for echo-types I (0.65) and II (0.46) and excellent ICC values for echo-type III (0.81), echo-type IV (0.83), aligned fibrillar structure (0.82) and disorganized structure (0.82). Intra-rater reliability showed excellent ICC values for echo-types I (0.76), III (0.88), IV (0.85), aligned fibrillar structure (0.88) and disorganized fibrillar structure (0.88) and a fair to good value for echo-type II (0.61). Contour marking showed excellent ICC values for all echo-types.

Conclusion: This study showed that UTC scans for patellar tendons have overall good intra-rater and inter-rater reliability. To optimize reliability of UTC scans of the patellar tendon, using the same rater and using aligned fibrillar structure (echo-types I +II combined) and disorganized structure (echo-types III + IV combined) as outcome measures can be considered.

Keywords: patella, tendinosis, grayscale, imaging, hypoechoic, patellar ligament, ultrasonography, UTC

Introduction

Patellar tendinopathy (jumper's knee) is an overuse injury of the patellar tendon, characterized by focal pain and dysfunction of the tendon.[1] In most cases the proximal part of the patellar tendon, near the apex of the patella is affected.[2] The incidence of patellar tendinopathy is particularly high in sports involving explosive movements; up to 45% of elite volleyball and 32% of elite basketball athletes suffer from this injury.[3] The prevalence of patellar tendinopathy in recreational athletes is also up to 14%.[4] This injury can cause a serious negative impact on sports participation and quality of life. One in every third patient with patellar tendinopathy presenting to sport medicine clinics is not able to return to sport within 6 months.[5] This injury can also affect the working life of patients, depending on the type of job; 8 to 50% of patients with patellar tendinopathy are impaired in performing their job.[6]

Ultrasound imaging is often used in the confirmation of the clinical diagnosis of patellar tendinopathy.[7] However, conventional grayscale ultrasound has limited ability to detect small intra-tendinous changes and is unable to quantify tendon structure.[8] Ultrasound tissue characterization (UTC, UTC imaging, Stein, The Netherlands) is an imaging technique specifically designed for tendons. It may be able to measure small changes in tendon structure instead of only relatively gross measures such as cross sectional area, size of hypoechoic zone or tendon diameter.[9-13] Transverse images of a tendon are captured to construct a 3-dimensional data block. From this data block UTC quantifies tendon structure by calculating the stability of brightness of the pixels over contiguous

transverse images. UTC has been developed and validated in veterinary medicine and accurately reflects histopathological findings in equine tissue.[14]

In humans, inter-rater reliability was determined for the UTC in Achilles tendons.[15] Although there is no 1:1 relationship between pain and symptoms, UTC is found to be reliable in quantifying the stability of the echo-pattern in the human Achilles tendon and can distinguish symptomatic from asymptomatic Achilles tendons.[15] Reliability of UTC in patellar tendons has only been studied in a small sample of non-symptomatic tendons (*n*=18).[16] Although reliability looks promising, more research is needed to confirm intra- and inter-rater reliability of the UTC for the patellar tendon.

To quantify tendon structure using UTC it is necessary to mark contours of the region of interest of the tendon before an automated UTC analysis is possible. This process is performed manually and since this involves human estimation of the tendon borders, it is prone to potential errors that might affect outcomes. This process of marking contours has never been tested for its reliability in patellar tendons, nor in Achilles tendons.

UTC is an imaging tool that is increasingly used for scientific research on patellar tendinopathy and clinical practice. This makes a sound interpretation of UTC data of patellar tendons essential. Therefore, the aim of this study is to assess inter- and intra-rater reliability of the UTC for the patellar tendon. This assessment will be done for conducting the UTC scan as well as marking contours.

Methods

Participants

A convenience sample of 50 participants was recruited, 25 participants with patellar tendinopathy and 25 participants without any symptoms of knee pain. Participants with patellar tendinopathy were patients of the Sports Medical Center of the University Medical Center Groningen or had previously participated in other patellar tendinopathy studies without imaging. They were clinically diagnosed with patellar tendinopathy by a sports physician or physiotherapist. The clinical diagnosis of patellar tendinopathy was defined as pain localized to the inferior pole of the patella during explosive activities (e.g. jumping, landing) and during a tendon pain provocation test (single leg decline squat). Participants were excluded if other knee pathology was present. Asymptomatic participants were recruited through recruitment posters with information of the study and network connections of the researchers. Participants were offered a free UTC scan with a report of their results. All participants needed to be at least 18 years old.

Study procedure

The Medical Ethical committee of the University Medical Center Groningen reviewed the study protocol and concluded that the study was not subject to the Medical Research Involving Human Subjects Act (2014/458). All participants gave written informed consent before inclusion in the study. Subsequently, participants filled out a general questionnaire including questions about gender, age, sports participation, length and weight. Participants with patellar tendinopathy also filled out a Victorian Institute of Sports Assessment-patella questionnaire (VISA-P) questionnaire and were asked for duration of their symptoms. The patellar tendon of every participant was scanned

three times. UTC scans were performed and contour marking was done by experienced physiotherapists/ researchers in UTC. Figure 1 shows the scans performed and contours marked for this study. A tendon was scanned twice by one researcher (MvA) and once by another (DH) in one session. Scans were anonymized and blinded for participant number, date and time of the scan before marking the contours. The contours of all scans were marked by one rater (LMR). Additionally, contours were marked three times for every first scan of the tendon by two different researchers (MvA 1x, LMR 2x). Contours were marked at least 1 year after the scans were performed to prevent recall bias. In participants with patellar tendinopathy, the symptomatic tendon was scanned; in case of bilateral complaints the side with the most severe complaints was chosen. In asymptomatic participants, the patellar tendon of the right leg was scanned.

UTC

Ultrasound Tissue Characterization scans were captured with a UTC machine including an ultrasound probe (SmartProbe 12L5-V, Terason 2000+; Teratech, Burlington, Maryland, USA), mounted in a tracking device (UTC Tracker, UTC Imaging, Stein, The Netherlands) with a concave stand-off pad. The tracking unit moves the ultrasound probe perpendicular along the tendon with a constant speed. The probe captures transverse grayscale images of the tendon every 0.2 mm. A 3-D image of the tendon was rendered from these images by the UTC software (UTC Analyzer v2.0.0; UTC Imaging, Stein, the Netherlands). Based on stability of the grayscale echo-pattern over 4.8 mm (window size 25), tendon structure was quantified in echo-type I, II, III and IV using the validated UTC.[15] Echo-type I represents the most stable echopattern of contiguous transverse images (parallel tendon fibres) and echo-type IV the least stable echopattern (disorganized structure). Echo-types I + II can be seen as aligned fibrillar structure and echo-types III + IV can be seen as disorganized structure. The tendon was analyzed over 20mm starting from the apex of the patella. This Region of Interest (RoI) was selected as it coincides with the most common site of pain and pathology and is similar to previous studies. [16;17] Contours around the tendon were marked for the RoI with a maximal gap size of 4.8mm. Figure 2 shows a UTC image of a patellar tendon with marked tendon contour, contours were defined in the features view. The scans were taken with the participant lying supine with their knee in an approximately 100˚ knee angle in which a clear transversal image of the tendon could be obtained (Figure 3). Since raters had to know which knee to scan, they were not blinded to the tendon being symptomatic or asymptomatic. The ultrasound parameters were standardized for all scans (12 MHz, focus = 2.8cm, depth = 4cm).

Data analysis

Descriptive statistics (mean and standard deviations) were calculated for participants characteristics and percentage of echo types (I-IV). Inter- and intra-rater reliability were determined with the Intraclass Correlation Coefficient (ICC(2,1)). ICCs for echo-types I, II, III, IV, aligned fibrillar structure (echo-types I+II) and disorganized structure (echo-types III+IV) were calculated. This was done for the UTC scans as well as solely marking contours of the tendon (Two way random, single measurement, absolute agreement). An ICC value < 0.4 was considered to be 'poor', a value of 0.4 – 0.75 was considered to be 'fair to good' and an ICC > 0.75 was considered to be excellent.[18] Additionally, standard error of measurement (SEM = SD of population ×√(1 − ICC) and minimal detectable change (MDC = 1.96 × SEM ×√2)) were calculated. All analyses were performed using IBM SPSS statistics v25.

Results

The characteristics of the 50 participants (25 symptomatic and 25 asymptomatic) included in this study are presented in Table 1. Participants with patellar tendinopathy had at least 3 months symptoms of patellar tendinopathy with an average duration of more than 3 years. Table 2 shows the mean echo-type percentages of the participants. The patellar tendons consisted on average of 95.5% ± 5.7 echo-type I and II and 4.5% ± 5.7 echo-type III and IV.

Inter- and intra-rater reliability values can be found in Tables 3 and 4. Table 3 shows the ICC values for UTC scans of the patellar tendon. ICCs for intra-rater reliability showed all excellent values, with exception of echo-type II, that showed a fair to good value. Inter-rater reliability values for echo-type I and II were fair to good, while echo-type III, IV and combined echo-types showed excellent values. MDC values ranged from 2.1% to 12.9% for the UTC scans of the patellar tendon. Difference in echo-type between symptomatic and asymptomatic participants is close to the MDC for echo-type I, the difference for echo-type II is small, echo-type III and echo-type IV show differences greater than the MDC (Table 2). All ICC values for inter- and intra-rater reliability of contour marking were excellent (Table 4). For contour marking of the patellar tendon, the MDC ranged between 0.7% and 5.7%.

Discussion

This is the first study to investigate the reliability of UTC scans in patellar tendons on a large scale. Results show excellent and fair to good ICC values, intra-rater MDC range is 2.1%-10.6% for separate echo-types and is 5.5% for aligned fibrillar structure (echo-types I+II) and disorganized structure (echo-type III+IV). The MDC range for inter-rater reliability is 2.2%-12.9% for separate echo-types and minimal detectable change is 6.6% for the combined echo-types. The reliability of marking patellar tendon contours for UTC scans is excellent with very high ICC values and low MDC values.

The inter- and intra-rater reliability show slightly lower values than previously reported for echo-type I and II in a smaller sample.[16] The ICC for inter-rater reliability of echo-type I was 0.65 (.45-.78) in the current study compared to 0.73 (.49-.91) previously reported and for echo-type II this was 0.61 (.41-.76) versus 0.73 (.49-.87). Intra-rater reliability for echo-type I was 0.76 (.61-.86) compared to .82 (.66-.91) previously reported and 0.61 (.41-.76) versus 0.82 (.65-.91) for echo-type II. Reliability values for echo-types III and IV were not reported in the previous study. A possible explanation for the lower reliability values is the inclusion of symptomatic tendons in the current study; more structural changes in a tendon structure potentially increases the chance of artefacts.

The ICC values found are lower than those found in a previous study on Achilles tendons.[15] This reliability study of UTC scans in Achilles tendons showed very high ICC values, 0.92 for echo-types I and II and 0.95 for echo-types III and IV. A possible explanation for this, is the joint angle during the UTC scan. The angle of the ankle seems easier to standardize (e.g. neutral position, 90°) than the knee angle.[19;20] Due to anatomical variations, the optimal knee angle to perform a UTC scan for the patellar tendon can vary. This knee angle is approximately 100 degrees of knee flexion, but might

need small adjustments by the examiner to obtain a clear image of the tendon. Furthermore, the near presence of the enthesis (apex of patella) might increase the chance of artefacts in the scan.

The sample size for this study (n=50) is considered to be good for reliability studies.[21] Separate ICCs for symptomatic and asymptomatic tendons were not calculated, because a sample size of 25 for reliability studies is considered to be poor.[21] As UTC scans for the patellar tendon are used in symptomatic tendons (differential diagnosis and monitoring) as well as asymptomatic tendons (monitoring and prevention), a group of symptomatic and asymptomatic participants was used. Due to the heterogeneity of the sample, the SEM and MDC values reported in this study may be higher than they would be in a homogenous group. Furthermore, the mean age of the participants matches with the age category in which patellar tendinopathy is most commonly seen.[22]

It can be concluded that UTC scans can be considered reliable for patellar tendons. However, MDC values have to be taken into account. Especially when echo-types I and II are used separately, the MDCs are relatively high. Therefore, it can be questioned if the UTC is reliable enough for detecting small changes in separate analyses of echo-types I and II for patellar tendons. Combining echo-types I + II (aligned fibrillar structure) and III + IV (disorganize structure) would solve this issue. We think that the current ICC and MDC values can be used as measures of repeatability in future studies. Since the SEM and MDC values of our study may be higher than in a homogenous group, additional reliability investigations might be of additional value in certain study designs. Intra-rater reliability showed higher ICC values than inter-rater reliability, therefore using the same rater increases the reliability of UTC outcomes. Manually marking the contours of the patellar tendon, which is part of the process in UTC analysis, has an excellent inter- and intra-rater reliability with low MDC values. It can be concluded that this process hardly influences the reliability of a UTC scan of the patellar tendon, therefore it does not seem to matter who marks tendon contours and a single (trained) rater for contour marking will be sufficient in future studies and clinical practice.

Perspective

Nowadays, UTC is increasingly used in scientific research and clinical practice as a tendon specific ultrasound measure to quantify tendon structure. This is the first study to investigate inter- and intra-rater reliability of UTC of the patellar tendon on a large scale. Reliability has already found to be excellent for Achilles tendons.[15] UTC scans for patellar tendons can reliably be used in research and clinical practice, although the MDCs found in this study have to be taken into account when interpreting UTC data of patellar tendons. UTC might be less suitable for detecting small changes in echo-types I and II, since relatively high minimal detectable changes are reported for these echo-types. For increased reliability of UTC scans of the patellar tendon, using the same rater and using aligned fibrillar structure (echo-types I +II combined) and disorganized structure (echo-types III + IV combined) as outcome measures can be considered.

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Table 1. Characteristics of participants (n=50)

Measure	Total group (*n*=50) Mean ± SD (min – max)	Asymptomatic participants (*n*=25) Mean ± SD (min – max)	Symptomatic participants (*n*=25) Mean ± SD (min – max)
Age (years)	26.1 ± 6.4 (19-51)	24.9 ± 2.6 (20-29)	27.3 ± 8.5 (19-51)
Height (cm)	178.0 ± 9.6 (162-200)	173.4 ± 7.2 (162-191)	182.7 ± 9.6 (165-200)
Weight (kg)	74.2 ± 10.7 (58-101)	69.0 ± 7.5 (58-90)	79.4 ± 11.0 (58-101)
Hours sports per week	6.1 ± 4.2 (1-22)	4.7 ± 3.9 (1-18)	7.5 ± 4.2 (2-22)
Grayscale changes on ultrasound	23/50	0/25	23/25
Duration of symptoms (months) (n=25)	39.1 ± 65.0 (3-288)	-	39.1 ± 65.0 (3-288)
VISA-P score (n=23)	62.4 ± 17.4 (29-91)	-	62.4 ± 17.4 (29-91)
Gender (male / female)	28 / 22	8/17	20/5

Table 2. Mean echo-type percentages of the participant's patellar tendons (UTC scan 1, rater 1).

	Total group (*n*=50) Mean ± SD	**Asymptomatic participants (*n*=25) Mean ± SD**	**Symptomatic participants (*n*=25) Mean ± SD**
Echo-type I %	62.4 ± 7.8	67.1 ± 5.7	57.6 ± 6.7
Echo-type II %	33.2 ± 5.1	32.4 ± 5.2	33.9 ± 5.0
Echo-type III %	3.1 ± 3.8	0.4 ± 0.5	5.8 ± 3.8
Echo-type IV %	1.4 ± 1,9	0.1 ± 0.2	2.7 ± 2.0
Echo-type I+II %	95.5 ± 5.7	99.5 ± 0.7	91.5 ± 5.7
Echo-type III+IV %	4.5 ± 5.7	0.5 ± 0.7	8.5 ± 5.7

Table 3. Intra- and inter-rater reliability of UTC scan of the patellar tendon.

	Intra-rater reliability			Inter-rater reliability		
Echo-type	**ICC (95% CI)**	**SEM**	**MDC**	**ICC (95% CI)**	**SEM**	**MDC**
I	0.76 (.61-.86)	3.83	10.6	0.65 (.45-.78)	4.64	12.9
II	0.61 (.41-.76)	3.18	8.8	0.46 (.21-.65)	3.77	10.4
III	0.88 (.80-.93)	1.34	3.7	0.81 (.69-.89)	1.67	4.6
IV	0.85 (.74-.91)	0.75	2.1	0.83 (.71-.90)	0.78	2.2
I+II	0.88 (.80-.93)	1.98	5.5	0.82 (.71-.90)	2.39	6.6
III+IV	0.88 (.80-.93)	1.98	5.5	0.82 (.71-.90)	2.39	6.6

ICC = Intra Class Correlation; CI = confidence interval; SEM = Standard Error of Measurement; MDC = Minimal Detectable Change

Table 4. Intra- and inter-rater reliability of contour marking of the patellar tendon in UTC scans.

	Intra-rater reliability			Inter-rater reliability		
Echo-type	**ICC (95% CI)**	**SEM**	**MDC**	**ICC (95% CI)**	**SEM**	**MDC**
I	0.99 (.97-.99)	0.95	2.64	0.94 (.85-.97)	1.99	5.51
II	0.97 (.94-.98)	0.93	2.58	0.84 (.12-.95)	2.07	5.74
III	0.98 (.97-.99)	0.51	1.42	0.93 (.85-.96)	1.03	2.87
IV	0.99 (.97-.99)	0.23	0.65	0.94 (.86-.97)	0.48	1.33
I+II	0.98 (.97-.99)	0.72	2.00	0.93 (.85-.96)	1.51	4.17
III+IV	0.98 (.97-.99)	0.72	2.00	0.93 (.85-.96)	1.51	4.17

ICC = Intra Class Correlation; CI = confidence interval; SEM = Standard Error of Measurement; MDC = Minimal Detectable Change