Comparative Accuracy of Magnetic Resonance Imaging and Ultrasonography in Confirming Clinically Diagnosed Patellar Tendinopathy

Stuart J. Warden,*[†‡] BPhysio (Hons), PhD, Zoltan S. Kiss,[‡§] MBBS, FRANZCR, Frank A. Malara,[‖¶] MBBS, FRANZCR, Alistair B. T. Ooi,[‡] Jill L. Cook,[#] BAppSci (Physio), PhD, and Kay M. Crossley,[‡] BAppSci (Physio), PhD

From the [†]Department of Physical Therapy, School of Health and Rehabilitation Sciences, Indiana University, Indianapolis, Indiana, [‡]Centre for Health, Exercise and Sports Medicine, School of Physiotherapy, The University of Melbourne, Melbourne, Victoria, Australia, [§]Department of Radiology, Mercy Private Hospital, Melbourne, Victoria, Australia, [‖]Victoria House Medical Imaging, Prahran, Victoria, Australia, [¶]Department of Radiology, Austin Health, Heidelberg, Victoria, Australia, and [#]Musculoskeletal Research Centre, School of Physiotherapy, La Trobe University, Bundoora, Victoria, Australia

Background: Diagnosis of patellar tendinopathy is based primarily on clinical examination; however, it is commonplace to image the patellar tendon for diagnosis confirmation, with the imaging modalities of choice being magnetic resonance imaging (MRI) and ultrasonography (US). The comparative accuracy of these modalities has not been established.

Hypothesis: Magnetic resonance imaging and US have good (>80%) accuracy and show substantial agreement in confirming clinically diagnosed patellar tendinopathy.

Study Design: Cohort study (diagnosis); Level of evidence, 2.

Methods: Magnetic resonance imaging and US (gray scale [GS-US] and color Doppler [CD-US]) features of 30 participants with clinically diagnosed patellar tendinopathy and 33 activity-matched, asymptomatic participants were prospectively compared. Accuracy, sensitivity, specificity, positive and negative predictive values, and the likelihood of positive and negative test results were determined for each technique.

Results: The accuracy of MRI, GS-US, and CD-US was 70%, 83%, and 83%, respectively ($P = .04$; MRI vs GS-US). The likelihood of positive MRI, GS-US, and CD-US was 3.1, 4.8, and 11.6, respectively. The MRI and GS-US had equivalent specificity (82% vs 82%; $P = 1.00$); however, the sensitivity of GS-US was greater than MRI (87% vs 57%; $P = .01$). Sensitivity (70% vs 87%; $P = .06$) and specificity (94% vs 82%; $P = .10$) did not differ between CD-US and GS-US.

Conclusions: Ultrasonography was more accurate than MRI in confirming clinically diagnosed patellar tendinopathy. GS-US and CD-US may represent the best combination for confirming clinically diagnosed patellar tendinopathy because GS-US had the greatest sensitivity, while a positive CD-US test result indicated a strong likelihood an individual was symptomatic.

Keywords: anterior knee pain; jumper's knee; MRI; tendinitis; ultrasound

*Address correspondence to Stuart J. Warden, BPhysio (Hons), PhD, Department of Physical Therapy, Indiana University, 1140 West Michigan Street, CF-326, Indianapolis, IN 46202 (e-mail: stwarden@iupui.edu).

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Patellar tendinopathy (PT) refers to a clinical condition characterized by activity-related anterior knee pain associated with focal patellar tendon tenderness.[27] Its prevalence is 14% in elite athletes,[32] and it causes many to cease their athletic careers.[24] Because the prevalence of PT is high in sports that involve jumping,[32] it is commonly referred to as "jumper's knee."[3,8,17,19,24,32] This is misleading, however, as the condition

is found in many individuals who do not participate in jumping sports.[6,8,25,32,50] Another popular term used to describe the condition is "patellar tendinitis." However, histopathologic studies have consistently shown the pathologic changes underlying PT are degenerative (tendinosis) rather than inflammatory (tendinitis).[20,25,26,54] Because tendinosis and tendinitis refer to distinct histopathologic conditions that cannot be assessed clinically, the term PT has been advocated to be used clinically to describe overuse conditions of the patellar tendon.[27,29,34]

The diagnosis of PT is based primarily on clinical examination, where it presents as activity-related anterior knee pain associated with well-localized, palpable patellar tendon tenderness.[13,43,53] Although clinical examination represents the gold standard in the diagnosis of PT, it is commonplace to image the patellar tendon, with the 2 most commonly used modalities being magnetic resonance imaging (MRI) and gray-scale ultrasonography (GS-US).[1,5,43,53] Both provide excellent anatomic representation of the patellar tendon, and histopathologic studies have shown the characteristic tendinopathy appearances observed with both MRI and GS-US to be due to the underlying tendon pathologic changes.[25,42,44,54] However, on both MRI and GS-US, it is not uncommon for symptomatic tendons to have the appearance of normal asymptomatic tendons, and for positive PT images to be present in asymptomatic tendons.[9-12,18,25,33,35,41,42,45,51] This has raised concerns regarding the usefulness of imaging in PT and, in particular, whether MRI or GS-US is more accurate in confirming the presence of clinically diagnosed PT.

The aim of the current study was to prospectively compare the accuracies of MRI and GS-US in confirming clinically diagnosed PT. On the basis of a review of the literature,[53] we hypothesized that both forms of imaging would have good (>80%) accuracy and that they would show substantial agreement. Secondary aims were to determine (1) the presence on MRI and ultrasonography (US) of local abnormalities associated with PT, (2) the reliability of MRI, and (3) the accuracy of color Doppler US (CD-US).

MATERIALS AND METHODS

Study Design and Approvals

The MRI, GS-US, and CD-US features of a cohort of patients with clinically diagnosed PT (symptomatic group) were prospectively compared with those of a cohort of activity-matched controls (asymptomatic group), according to the Standards for Reporting of Diagnostic Accuracy.[4] The Human Research Ethics Committee at the university approved the study, and all participants provided written informed consent.

Symptomatic Group

Over a 20-month period (October 2003 to May 2005), 115 consecutive patients with suspected PT were recruited using a variety of methods, including articles published in local newspapers, notices/flyers posted in local physical therapy and medical clinics, and notification of the study in the staff newsletter and on payslips at the university. Inclusion was via a 2-stage process consisting of a telephone interview and clinical examination, and was based on the fulfillment of predetermined criteria (Table 1). Forty-five patients were deemed suitable for inclusion based on the phone interview, and they were subsequently examined by an independent physical therapist (with 10 years of experience) under the supervision of 2 experienced sports physical therapists (J.L.C. and K.M.C. with 28 and 20 years of experience, respectively). Fifteen patients were excluded after the clinical examination, predominantly as a result of symptoms inconsistent with PT. Thus, the symptomatic group consisted of a total of 30 participants.

Standard demographic (sex, age, height, weight, body mass index [BMI], leg dominance, and number of sporting hours per week) and disease-specific data were obtained at the time of inclusion. Leg dominance was defined as the leg the participant predominantly jumps with. Disease-specific data included assessment of the duration and intensity of symptoms and the quantification of functional capacity. Intensity of symptoms was assessed using 10-cm visual analog scales (VAS) for usual (VAS-U) and worst (VAS-W) tendon pain on activity in the preceding week. These scales are valid and reliable in the assessment of anterior knee pain.[14] Functional capacity was quantified using the Victorian Institute of Sport Assessment (VISA) score, a validated measure of knee function in athletes with PT.[52] The scale ranges from 0 to 100, with 100 indicating full, pain-free function; a score below 80 is indicative of PT.[8]

Asymptomatic Group

A group of 33 activity-matched, asymptomatic control participants were recruited from local sporting clubs, mostly via notices/flyers or by direct recruitment in person. Inclusion was based on the fulfillment of predetermined criteria (Table 1). Standard demographic data (sex, age, height, weight, BMI, leg dominance, and number of sporting hours per week) were obtained at the time of inclusion.

Magnetic Resonance Imaging

Imaging in both groups was performed no more than 1 week after clinical examination. Participants in the symptomatic group with bilateral symptoms had their more symptomatic leg, as determined from VAS-U and VAS-W measures, imaged. The dominant leg was imaged in participants in the asymptomatic group.

Magnetic resonance imaging was performed using a 1.5-T magnet (GE Signa Horizon LX MRI system, GE Medical Systems, Milwaukee, Wis) and an extremity-array coil. The participant's knee was placed within the coil in a position of full extension. The MRI protocol consisted of the following pulse sequences: (1) a sagittal proton density-weighted sequence (repetition time [ms]/echo time [ms], 2920-4500/33-40; echo-train length, 10; bandwidth, 42 kHz; field of view, 160 mm; image matrix, 512 × 384 pixels; number of

TABLE 1
Inclusion and Exclusion Criteria for Symptomatic and Asymptomatic Participants[a]

Symptomatic Participants	
Inclusion Criteria	Exclusion Criteria
Age >18 years Currently partaking in sports >1x/week (or would be if not for PT symptoms) Clinical signs and symptoms consistent with PT, including: • Pain on at least 1 of jumping/landing, running, or changing directions • Patellar tendon pain on palpation • Symptoms sufficient to affect exercise/activity for >6 months with gradual onset • VISA score of <80	Concurrent or alternative symptomatic knee condition History of: • Knee pain beginning as a result of trauma • Episodes of knee locking or giving way • Patellar tendon surgery • Knee injection in the previous 6 months Contraindications for MRI
Asymptomatic Participants	
Inclusion Criteria	Exclusion Criteria
Age >18 years Currently partaking in organized sports >1x/week, particularly sports known to be associated with PT (ie, basketball, volleyball, soccer)	History of: • PT/symptoms suggestive of having undiagnosed PT • Knee symptoms, including pain, locking, or giving way • Surgery into knee or patellofemoral joint • Knee injection in the previous 6 months Current condition affecting ability to walk Contraindications for MRI

[a]PT, patellar tendinopathy; VISA, Victorian Institute of Sport Assessment; MRI, magnetic resonance imaging.

excitations, 2; section thickness, 3.5 mm; gap, 0 cm), (2) an axial proton density-weighted sequence (repetition time [ms]/echo time [ms], 3800/32; echo-train length, 10; bandwidth, 25 kHz; field of view, 150 mm; image matrix, 512 × 384 pixels; number of excitations, 1; section thickness, 3.5 mm; gap, 0 cm), and (3) a sagittal short inversion time inversion-recovery (STIR) sequence (repetition time [ms]/echo time [ms]/inversion time [ms], 3800/32/120; echo-train length, 10; bandwidth, 21 kHz; field of view, 160 mm; image matrix, 256 × 224 pixels; number of excitations, 2; section thickness, 4.0 mm; gap, 0 cm).

Magnetic resonance images were blindly analyzed en masse by a board-certified musculoskeletal radiologist (F.A.M.) with 4 years of experience. Proton-density weighted images were assessed for altered signal intensity within the patellar tendon and increased size in the anteroposterior direction, which are indicative of patellar tendon structural changes and PT (Figures 1A and 1B).[25,44,54] In addition, the definition of the posterior border of the patellar tendon (Figure 1B) and altered signal intensity within the patella and infrapatellar fat pad were assessed (Figure 1C). The STIR images were used to account for possible false-positive findings on the proton-density weighted images due to magic angle artifacts in patellar tendon signal intensity (Figure 1C). To be categorized as having PT on MRI, individuals needed to have altered signal intensity within the patellar tendon on both proton-density weighted and STIR images. This was indicated by loss of the normal low (black) signal on proton-density weighted sequences with persistent signal hyperintensity on the STIR sequence in the same region. Intraobserver reliability for MRI was determined by having the radiologist read the scans on 2 occasions, 1 week apart. The order of the images was varied between reads to avoid reading-order bias.[40] To permit assessment of interobserver reliability, magnetic resonance images were also read en masse and blindly on 1 occasion by the other radiologist associated with the study (Z.S.K.), who has 20 years of experience.

Ultrasonography

The US assessments were performed with a high-resolution 10 to 14-MHz linear transducer (General Electric Logiq 9, GE Medical Systems, Milwaukee, Wis), by a single board-certified musculoskeletal radiologist (Z.S.K.) with 20 years of experience. The radiologist was blind to both symptom status and MRI findings and was not permitted to question the participants regarding symptoms. Both GS-US and CD-US were assessed in the longitudinal (sagittal) and transverse (axial) planes. During GS-US, the knee was flexed and the quadriceps muscles tensed to stretch out the tendon. Care was taken to position the probe perpendicular to the tendon to avoid false-positive findings due to anisotrophy.[25] During CD-US, the knee was extended and the quadriceps muscles relaxed to prevent physical constriction of the blood vessels. The CD-US was performed in all tendons regardless of GS-US findings.

During GS-US, the presence of a hypoechoic region and/or fusiform swelling within the patellar tendon was assessed, which are indicative of patellar tendon structural changes and PT (Figures 2A and 2B).[25,42] During CD-US, patellar tendon vascularity was assessed and tendons were categorized as either normal or as having neovascularization (Figure 2C).

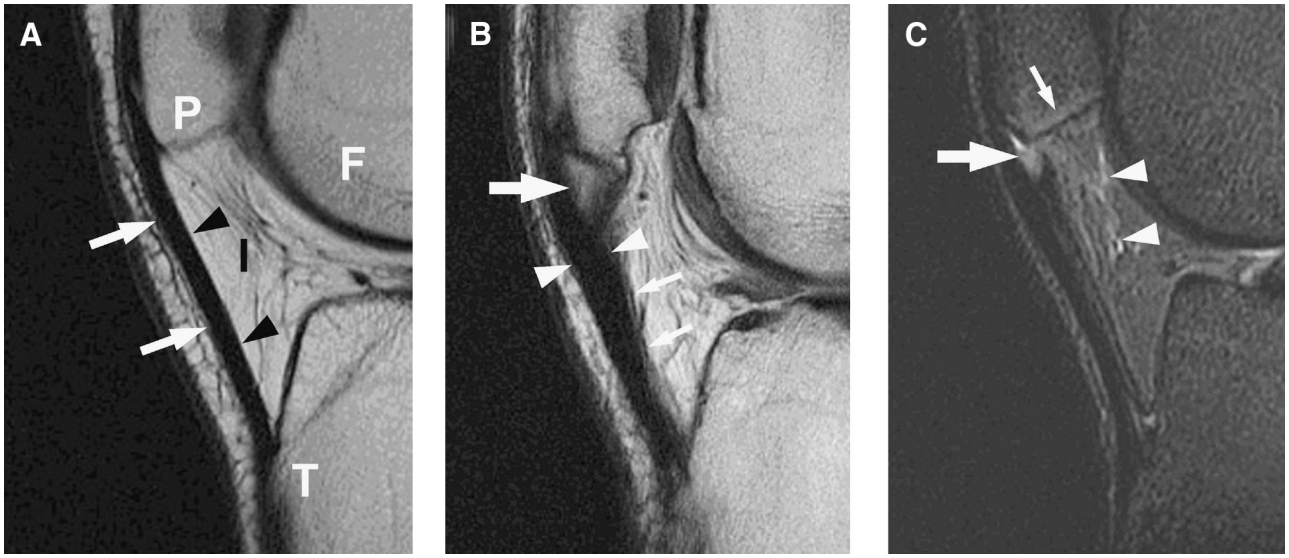

Figure 1. Magnetic resonance images of the patellar tendon and regional structures in the sagittal plane. A, asymptomatic 23-year-old female subject, imaged using proton-density weighted magnetic resonance imaging (MRI) (3800/36). There is normal signal intensity within the patellar tendon (arrows), and it has relatively uniform thickness in the anteroposterior direction along its length from the inferior pole of the patella (P) to the tibial tuberosity (T). Note the definition of the posterior border of the tendon (arrowheads). Other regional structures include the distal femur (F) and infrapatellar fat pad (I). B, symptomatic 29-year-old male subject, imaged using proton-density weighted MRI (3450/35). There is altered signal intensity within the proximal patellar tendon (large arrow) and increased tendon size in the anteroposterior direction (arrowheads), indicative of tendinopathy. There is also loss of definition of the posterior tendon border (small arrows). C, symptomatic 31-year-old male subject, imaged using short inversion time inversion-recovery MRI (3800/32/120). There is altered signal intensity within the proximal patellar tendon (large arrow), inferior pole of the patella (small arrow), and infrapatellar fat pad (arrowheads).

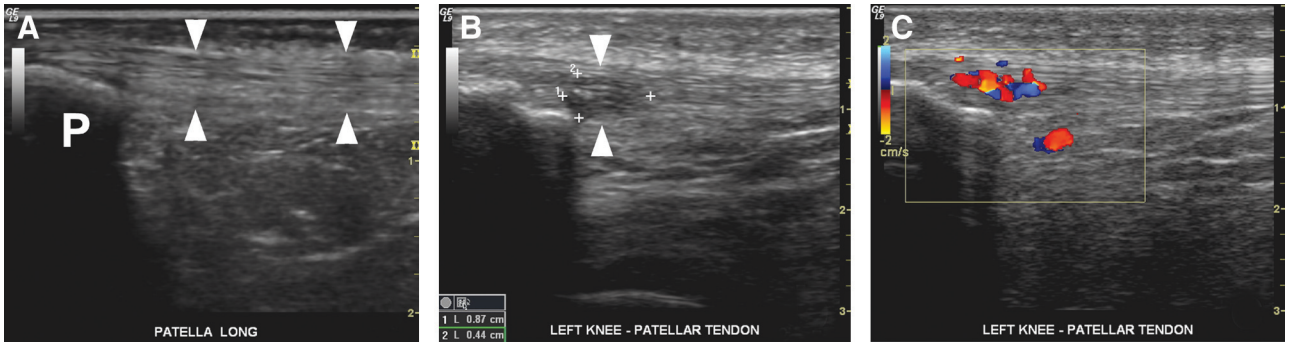

Figure 2. Ultrasonography images of the proximal patellar tendon in the longitudinal (sagittal) plane. A, asymptomatic 25-year-old male subject with normal gray-scale ultrasonography (GS-US) image at the level of the inferior pole of the patella (P). There is a normal fibrillar pattern within the tendon and the tendon has relatively uniform thickness in the anteroposterior direction (arrowheads). B, symptomatic 24-year-old male subject, imaged using GS-US. There is a wedge-shaped hypoechoic region at the inferior pole of the patella and increased tendon size in the anteroposterior direction (arrowheads), indicative of tendinopathy. C, same patient as B, imaged using color Doppler ultrasonography with a 20 × 16-mm region of interest placed over the proximal patellar tendon. Neovessels are present at the same location as the hypoechoic lesion identified using GS-US and along the posterior margin of the tendon.

Reliability of US assessments was not examined in the current study because the radiologist has previously been shown to have high intratester and intertester reliability with himself and a colleague, respectively.[2,28]

Data Analysis and Statistical Evaluation

Data were recorded by a nonradiologist investigator (A.B.T.O.) who accompanied participants during imaging to ensure that radiologists remained blind to symptom status. An investigator (S.J.W.) not involved in the execution of examinations or the evaluation of images analyzed the data. Chi-square (χ^2) analyses, mean differences, and 95% confidence intervals (95% CI) of the mean were used to assess for group differences in categorical and continuous demographic data, respectively. The accuracy, sensitivity, specificity, positive and negative predictive values, and likelihood of positive and negative test results of MRI, GS-US, and CD-US were derived. The accuracy of each modality was assessed using χ^2 analyses, while the McNemar test for

TABLE 2
Demographic Data for Asymptomatic and Symptomatic Groups[a]

Variable	Asymptomatic[b]	Symptomatic[b]	χ^2 Analysis
Sex (male to female)	22:11	20:10	1.00
Leg dominance (right to left)	29:4	26:4	0.89
Variable	**Asymptomatic[c]**	**Symptomatic[c]**	**Mean Difference (95% CI)**
Age (y)	25.0 (6.7)	27.0 (6.8)	2.0 (–1.3; 5.4)
Height (m)	1.77 (0.88)	1.77 (0.89)	0.3 (–4.7; 4.1)
Weight (kg)	72.1 (11.6)	79.5 (15.6)	7.4 (0.6; 14.2)[d]
BMI (kg/m^2)	22.8 (2.5)	25.2 (3.9)	2.4 (0.8; 4.1)[d]
Sport (h/wk)	3.4 (1.6)	4.2 (2.7)	0.8 (–0.3; 1.9)

[a]CI, confidence interval; BMI, body mass index.
[b]Data are number of cases.
[c]Data are mean (standard deviation).
[d]Significant mean difference between asymptomatic and symptomatic groups.

paired proportions was used to compare the disease detection rates between the modalities. A P value of $< .05$ for either test was considered to be statistically significant. Agreement between the modalities in confirming clinical diagnosis, and intraobserver and interobserver reliability of MRI was assessed using kappa (κ) tests. Pearson correlation coefficients (r) were calculated to assess the relationship between quantitative GS-US and clinical measures.

RESULTS

Demographic Data

There were no group differences in the number of male versus female participants, side of leg dominance, age, height, or sport hours per week; however, the symptomatic group was significantly heavier and had a higher BMI than the asymptomatic group (Table 2). Participants in the symptomatic group had a median 3-year (range, 1 to 11 years) history of moderate (VAS-U: median, 6; range, 1 to 10; VAS-W: median, 8; range, 2 to 10) symptoms that negatively influenced functional capacity (VISA score median, 60; range, 27 to 80). Symptoms were bilateral in 13 participants and unilateral in 17. The dominant leg was the most symptomatic leg in 26 of the 30 symptomatic participants.

Diagnostic Accuracy of MRI and GS-US

The diagnostic accuracies of MRI and GS-US are shown in Table 3. Both MRI and GS-US were accurate in categorizing participants according to clinical diagnosis ($P < .01$ and $P < .001$, respectively; χ^2 analyses) (Table 3). However, the accuracy of GS-US was superior to that of MRI (83% vs 70%, $P = .04$; McNemar test). The greater accuracy of GS-US over MRI resulted from its better ability to categorize symptomatic participants (sensitivity = 87% vs 57%, $P = .01$; McNemar test). In comparison, there were no differences between MRI and GS-US in categorizing asymptomatic participants (specificity = 82% vs 82%, $P = 1.00$; McNemar test). As a result of accuracy differences, there was only fair agreement between MRI and GS-US ($\kappa = 0.40$), with the modalities agreeing in 69.8% of cases. The modalities agreed that PT was present in 18 participants and absent in 26 participants. Disagreement occurred in 19 participants. When comparisons were restricted to the symptomatic and asymptomatic groups, MRI and GS-US disagreed in 11 (of 30) and 8 (of 33) participants, respectively. GS-US correctly categorized 10 (of 11) and 4 (of 8) of the symptomatic and asymptomatic participants when MRI did not, respectively (Figures 2B and 2C and 3).

TABLE 3
Diagnostic Accuracy of MRI and GS-US in PT[a]

Variable	MRI[b]	GS-US[b]	McNemar Test
Asymptomatic (present/absent)	6/27	7/26	—
Symptomatic (present/absent)	17/13	26/4	—
Accuracy (%)	70 (60-83)	83 (73-92)	0.04[c]
Sensitivity (%)	57 (37-75)	87 (69-96)	0.01[c]
Specificity (%)	82 (65-93)	82 (65-93)	1.00
Positive predictive value (%)	74 (52-90)	81 (64-93)	—
Negative predictive value (%)	68 (51-81)	87 (70-96)	—
Likelihood of positive test result	3.1 (1.4-6.9)	4.8 (2.3-9.9)	—
Likelihood of negative test result	0.5 (0.3-0.8)	0.2 (0.1-0.4)	—

[a]MRI, magnetic resonance imaging; GS-US, gray-scale ultrasonography; PT, patellar tendinopathy.
[b]Parentheses indicate 95% confidence interval.
[c]Significant difference between MRI and GS-US.

Associated Abnormalities on MRI and GS-US

The diagnostic accuracies of associated abnormalities on MRI and GS-US are shown in Table 4. There was no relationship on GS-US between clinical diagnosis of PT

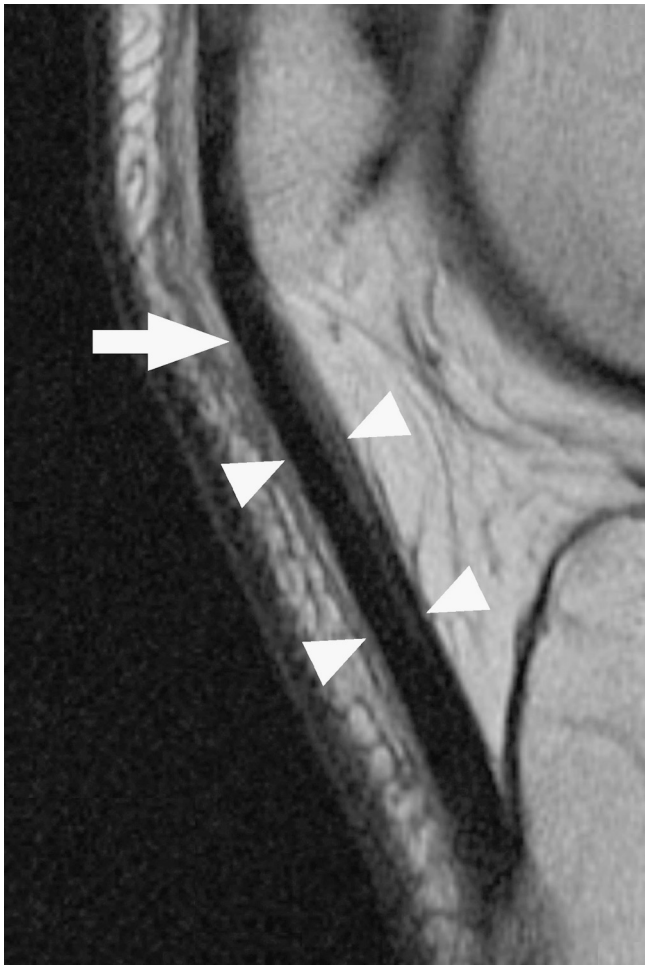

Figure 3. Symptomatic 24-year-old male subject, imaged using proton-density weighted magnetic resonance imaging (4050/38). Note the absence of altered signal intensity within the proximal patellar tendon (arrow) and relatively uniform thickness of the tendon in the anteroposterior direction along its length (arrowheads). This contrasts with this participant's gray-scale ultrasonography and color Doppler ultrasonography images (Figures 2B and 2C), which confirmed the clinical diagnosis.

and abnormalities of the posterior tendon border or infrapatellar fat pad (accuracy = 57% and 51%, respectively, $P = .24$-$.34$; χ^2 analyses). However, on MRI there were more abnormalities of the posterior border of the patellar tendon and infrapatellar fat pad in the symptomatic group than in the asymptomatic group (accuracy = 67% and 63%, respectively, all $P < .03$; χ^2 analyses). This indicates that posterior border and infrapatellar fat pad abnormalities on MRI were related to clinical diagnosis. Abnormalities of the patella on MRI were not related to clinical diagnosis of PT (accuracy = 57%, $P = .06$; χ^2 analysis).

Reliability of MRI

The reliability of MRI is shown in Table 5. There was substantial intraobserver and interobserver agreement for the presence of altered patellar tendon signal intensity and/or size on MRI. Similarly, there was substantial to almost perfect intraobserver agreement for the presence of an abnormal patellar tendon border and infrapatellar fat pad. In contrast, interobserver agreement for the presence of an abnormal patellar tendon border and infrapatellar fat pad, and both intraobserver and interobserver agreement for the presence of an abnormal patella were moderate.

Correlation Between Quantitative GS-US and Clinical Measures

Because GS-US had superior accuracy and, in particular, sensitivity in confirming clinical diagnosis, correlations between cross-sectional area of the hypoechoic region on GS-US and disease-specific clinical measures were explored. This was not performed for MRI as its sensitivity was poor (57%), indicating that it was not predictive of clinical symptoms. There were no correlations between cross-sectional area of the hypoechoic region on GS-US and either number of sporting hours per week, symptom duration, VAS-U, VAS-W, or VISA score (all $r = -.14$ to $.15$, $P = .43$ to $.92$).

Diagnostic Accuracy of CD-US

The diagnostic accuracy of CD-US is shown in Table 6. CD-US had good accuracy in categorizing participants according to clinical diagnosis ($P < .001$; χ^2 analysis). This resulted from its moderate ability to correctly categorize symptomatic participants (sensitivity = 70%) and its excellent ability to categorize asymptomatic participants (specificity = 94%). There was moderate agreement between CD-US and GS-US in categorizing participants according to clinical diagnosis ($\kappa = 0.59$), with the modalities agreeing in 79.4% of cases. Both modalities agreed that PT was present in 21 participants and absent in 29 participants. Disagreement occurred in 13 participants. When comparisons were restricted to the symptomatic and asymptomatic groups, CD-US and GS-US disagreed in 7 (of 30) and 6 (of 33) participants, respectively. There were no significant differences between CD-US and GS-US in correctly categorizing symptomatic ($P = .06$, McNemar test) or asymptomatic ($P = .10$, McNemar test) participants.

DISCUSSION

This study prospectively compared the accuracies of MRI and GS-US in confirming clinically diagnosed PT. On the basis of a review of the literature,[53] we hypothesized that both forms of imaging would have good accuracy and that they would show substantial agreement. While GS-US had good accuracy, the accuracy of MRI was moderate and there was only fair agreement between the 2 imaging modalities. The accuracy of GS-US was superior to that of MRI in confirming clinical diagnosis. This resulted from the better ability of GS-US compared to MRI in confirming the presence of symptoms (sensitivity), and its equivalent ability to confirm when PT was not diagnosed on clinical examination (specificity). It did not result from reliability issues associated with reading of the magnetic resonance images. In addition to having superior accuracy to

TABLE 4
Diagnostic Accuracy of MRI and GS-US of Tissue Abnormalities in PT[a]

	Tendon Border[b]		Fat Pad[b]		Patella[b]
Variable	MRI	GS-US	MRI	GS-US	MRI
Asymptomatic (present/absent)	0/33	4/29	6/27	1/32	0/33
Symptomatic (present/absent)	9/21	7/23	13/17	0/30	3/27
Accuracy (%)	67 (55-78)	57 (44-70)	63 (52-75)	51 (38-64)	57 (45-69)
Sensitivity (%)	30 (15-49)	23 (10-42)	43 (25-63)	0 (0-0.1)	10 (3-28)
Specificity (%)	100 (87-100)	88 (72-97)	82 (65-93)	97 (84-100)	100 (87-100)
Positive predictive value (%)	100 (66-100)	64 (31-89)	68 (43-87)	0 (0-0.1)	100 (29-100)
Negative predictive value (%)	61 (47-74)	56 (41-70)	61 (46-76)	52 (39-65)	55 (42-68)
Likelihood of positive test result	NC	1.9 (0.6-5.9)	2.4 (1.0-5.5)	NC	NC
Likelihood of negative test result	0.7 (0.6-0.9)	0.9 (0.7-1.1)	0.7 (0.5-1.0)	1.0 (1.0-1.1)	0.9 (0.8-1.0)

[a]MRI, magnetic resonance imaging; GS-US, gray-scale ultrasonography; PT, patellar tendinopathy; NC, not calculated (because calculation denominator = 0).
[b]Parentheses indicate 95% confidence interval.

TABLE 5
Intraobserver and Interobserver Agreement for Magnetic Resonance Imaging

Intraobserver Agreement (n = 28)				
	Agree[a]			
Abnormality	Present	Absent	Disagree[a]	κ
Abnormal patellar tendon signal and/or size	6	19	3	0.73
Abnormal patellar tendon border	4	23	1	0.87
Abnormal fat pad	6	19	3	0.73
Abnormal patella	1	24	3	0.46
Interobserver Agreement (n = 33)				
	Agree[a]			
Abnormality	Present	Absent	Disagree[a]	κ
Abnormal patellar tendon signal and/or size	10	17	6	0.63
Abnormal patellar tendon border	3	25	5	0.46
Abnormal fat pad	3	24	6	0.42
Abnormal patella	1	30	2	0.47

[a]Data are number of cases.

TABLE 6
Diagnostic Accuracy of CD-US in PT[a]

Variable	CD-US[b]
Asymptomatic (present/absent)	2/31
Symptomatic (present/absent)	21/9
Accuracy (%)	83 (73-92)
Sensitivity (%)	70 (50-85)
Specificity (%)	94 (78-99)
Positive predictive value (%)	91 (72-99)
Negative predictive value (%)	78 (62-89)
Likelihood of positive test result	11.6 (3.0-45.2)
Likelihood of negative test result	0.3 (0.2-0.6)

[a]CD-US, color Doppler ultrasonography; PT, patellar tendinopathy.
[b]Parentheses indicate 95% confidence interval.

MRI, GS-US also had the advantage of being easily coupled with CD-US. Color Doppler ultrasound independently had good accuracy as a result of its moderate ability to confirm when PT was diagnosed on clinical examination (sensitivity) and its very good ability to confirm when clinical examination was negative for PT (specificity).

Numerous previous studies have investigated the individual diagnostic accuracies of MRI[18,22,25,35,36,44,48,49,54] and GS-US[8-11,21,25,28,33,36,39,42,51] in confirming clinically diagnosed PT. Although both modalities have been found to be relatively accurate in isolation, few studies have directly compared MRI and GS-US to determine whether one modality is actually more accurate than the other. Davies et al[15] found that both MRI and GS-US were able to demonstrate patellar tendon changes with good correlation for the site of the lesion in a

cohort of patients with clinically diagnosed PT. Similarly, Khan et al[25] demonstrated a good correlation between MRI and GS-US in a cohort of athletes with histopathologically confirmed PT. However, because neither of these studies included a cohort of asymptomatic control participants, their ability to assess the comparative accuracy of the imaging modalities was restricted. Similarly, it is not possible to infer the comparative accuracies of MRI and GS-US from studies into their isolated accuracies; such an approach is compromised given the heterogeneity between studies in terms of participants, equipment, radiologists, and analyses.

Given the lack of scientific data supporting one modality over another, the choice of whether to use MRI or GS-US in confirming PT has historically been based on individual preference and modality availability rather than diagnostic accuracy. However, the results of the current study indicate that GS-US combined with CD-US may represent the imaging approach of choice. The gray-scale ultrasonography should be used given its good sensitivity (87%), while CD-US should be implemented given its high positive predictive value (91%). Expressing these values in clinically relevant terms, the current study found the likelihood of positive GS-US and CD-US test results to be 4.8 and 11.6, respectively. These indicate that the likelihood that an individual patient has a clinical diagnosis of PT is increased by approximately 5- and 11-fold given a positive GS-US and CD-US finding, respectively. That is, if GS-US and, in particular, CD-US results are positive, it is more likely than not that that individual patient has PT.

Magnetic resonance imaging was not as accurate as GS-US in the current study. However, it is possible that MRI has a role in imaging patients with suspected PT due to its greater ability to image associated structures. Loss of definition of the posterior border of the patellar tendon has frequently been reported in PT,[16,44,54] while pathologic changes in the patella and infrapatellar fat pad may coexist with or cause similar symptoms to PT.[23,47] Abnormalities of the posterior border of the patellar tendon and infrapatellar fat pad were significantly related to clinical diagnosis in the current study, and the relationship between pathologic changes in the patella and clinical diagnosis approached significance ($P = .06$). However, assessment of these features did not enhance the accuracy of MRI. All cases of abnormal tendon border and patella occurred in symptomatic participants who also had patellar tendon structural changes on MRI. Thus, the addition of these entities did not improve MRI sensitivity over that obtained using tendon structural changes alone as the criterion. Assessment for infrapatellar fat pad abnormalities was positive in 3 symptomatic participants who did not have patellar tendon structural changes on MRI. Thus it is possible that the infrapatellar fat pad abnormalities detected in these participants represent distinct disease entities unrelated to PT. However, 2 of the 3 had patellar tendon structural changes on US, suggesting that PT coexisted in these participants.

Imaging in the current study was not 100% accurate when using clinical diagnosis as the reference-standard. Some participants with a clinical diagnosis of PT had imaging appearances consistent with normal asymptomatic tendons, while some participants with no history of PT symptoms had imaging appearances consistent with the presence of a tendon pathology. This was not unexpected, and supports previous studies reporting that imaging appearance does not necessarily reflect clinical diagnosis and symptoms of PT.[9-12,18,25,33,35,41,42,45,51] Confirming this, and as shown in previous studies,[7,28,33,42] no correlation was found between the severity of tendinopathy symptoms on clinical measures (VAS-U, VAS-W, and VISA) and tendon appearance on imaging (cross-sectional area of the hypoechoic region on GS-US) in the current study. Likewise, numerous authors have found imaging unable to distinguish outcome after surgical intervention for PT.[7,31] These data indicate that imaging remains an adjunct to a thorough clinical examination by a skilled clinician and cannot be used to determine intervention or outcome.[30]

Although GS-US was more accurate than MRI in confirming clinically diagnosed PT, this result needs to be considered in light of potential biases.[40] Participant selection and the application of the reference-standard test may have influenced accuracy; however, participants were prospectively sampled, included by a trained therapist according to preset criteria, matched for activity levels, and assessed with each imaging technique. Adoption of these measures minimized the influence of the participant sample and reference-standard test on the comparative accuracy of the modalities. Similarly, the selection of the reader samples and the performance and interpretation of the tests are not considered to have significantly biased the results. Tests were all performed on the same equipment according to standard protocols, and the radiologists were found to have substantial intraobserver and interobserver agreement. Given the restriction of these potential biases, the findings are considered generalizable to other participants and radiologists. However, the findings may not be generalizable to other imaging procedures. While imaging in the current study was performed according to standard clinical protocols, it is possible that alternative procedures, such as the use of other MRI sequences or the introduction of a contrast agent,[37,38] may alter diagnostic accuracy. Similarly, the use of alternative techniques may influence diagnostic accuracy, such as the use of power Doppler US instead of CD-US, as has been shown for Achilles tendinopathy.[46] These require further consideration and investigation.

In conclusion, this study found both MRI and US to be accurate in confirming PT; however, US was found to be the modality of choice. Gray-scale ultrasound had greater accuracy than MRI in confirming the clinical diagnosis, while a positive CD-US result was highly indicative that an individual patient was symptomatic. Based on these results, we suggest that GS-US and CD-US be used in combination to confirm clinically diagnosed PT.

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