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A soft patellar tendon on ultrasound elastography is associated with pain and functional deficit in volleyball players

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ABSTRACT

Objectives: To investigate the diagnostic performance of grey scale Ultrasound (US), power Doppler (PD) and US elastography for diagnosing painful patellar tendinopathy, and to establish their relationship with Victorian Institute of Sport Assessment-Patella (VISA-P) scores in a group of volleyball players with and without symptoms of patellar tendinopathy.
Design: Cross-sectional study.
Methods: Thirty-five volleyball players (70 patellar tendons) were recruited during a national university volleyball competition. Players were imaged with conventional US followed by elastography. The clinical findings of painful patellar tendons were used as the reference standard for diagnosing patellar tendinopathy. In addition, all participants completed the VISA-P questionnaires.
Results: Of the 70 patellar tendons, 40 (57.1%) were clinically painful. The diagnostic accuracy of grey scale US, PD and elastography were 60%, 50%, 62.9%, respectively, with sensitivity/specificity of 72.5%/43.3%, 12.5%/100%, and 70%/53.3%, respectively. Combined US elastography and grey scale imaging achieved 82.5% sensitivity, 33.3% specificity and 61.4% accuracy while routine combination technique of PD and grey scale imaging revealed 72.5% sensitivity, 43.3% specificity and 60.0% accuracy. Tendons in players categorized as soft on elastography had statistically significantly greater AP thickness ($p < 0.001$) and lower VISA-P scores ($p = 0.004$) than those categorized as hard. There was no significant association between grey scale US abnormalities (hypoechogenicities and/or fusiform swelling) and VISA-P scores ($p = 0.098$).
Conclusions: Soft tendon properties depicted by US elastography may be more related to patellar tendon symptoms compared to grey scale US abnormalities. The supplementation of US elastography to conventional US may enhance the sensitivity for diagnosing patellar tendinopathy in routine clinical practice.

1. Introduction

Patellar tendinopathy is common among active athletes particularly those involved in jumping sports such as basketball and volleyball.[1] A failed healing response of the tendon at histology, clinically patients with patellar tendinopathy present with localized pain and tenderness in the patellar tendon that is aggravated by high load stretch-shortening cycle (running, sprinting, and jumping).[2,3] The condition is difficult to treat effectively and can significantly limit or even prevent sporting activity.

Ultrasound (US) and magnetic resonance imaging (MRI) are commonly used to confirm a clinical diagnosis of patellar tendinopathy. Both imaging modalities can reveal morphological changes in tendon such as tendon swelling and collagen fibres

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disorganization. However, such morphological changes are not necessarily associated to symptoms, as athletes can have painful tendons without structural change or structural change without pain.[4] For example, Cook et al. found that 22% of asymptomatic elite athletes had structural hypoechoic changes of the patellar tendon. The authors concluded that the presence of an US hypoechoic change in an elite athlete with anterior knee pain does not confirm a diagnosis of patellar tendinopathy.[4] The presence of Doppler US signals in the degenerated tendon has been suggested as a clue to symptomatology but in other studies, Doppler signal has been identified among active, asymptomatic athletes such as volleyball players.[5,6] There is a need to better understand the relationship between US imaging findings and pain, while exploring imaging methods that may yield more clinically useful data.

Real-time US elastography is a relatively new US based technique that evaluates the elastic properties of tendons.[7] To date, several studies applying US elastography to assess Achilles tendinopathy and common extensor tendinopathy have been published with promising results.[8,9] De Zordo et al. compared 25 patients who presented with Achilles tendinopathy and 25 gender-matched controls using a clinical diagnosis of "pain" as the reference standard. The research team found that US elastography and grey-scale US achieved accuracy of 97% and 93%, respectively, in diagnosing clinically symptomatic Achilles tendinopathy.[9] To our knowledge however, no studies have investigated the clinical feasibility of US elastography in the assessment of patellar tendinopathy. The primary aim of this study was to investigate the diagnostic performance of US elastography, grey scale, power Doppler (PD) US and combination techniques in confirming clinically painful patellar tendon in a cohort of high risk athletes. We set out to explore whether the supplement of US elastography to conventional US improve the routine sonographic diagnosis of patellar tendinopathy, which may in turn, impact on early diagnosis, management and rehabilitation of patients with tendinopathy. The secondary aim was to investigate the relationship between elastographic measures, grey scale US, PD imaging, and Victorian Institute of Sport Assessment-Patella (VISA-P) scores.

2. Methods

The Queen Mary University of London Research Ethics Committee approved the study and written informed consent was obtained from each participant. The inclusion criterion was participation in the 2011 British University Volleyball Championships. A convenience sample of men and women with and without symptoms of patellar tendon pain was recruited from the cohort of volleyball players participating in the tournament. Fifty of the 150 players were approached between games in the championship. The exclusion criteria were prior patellar tendon surgery, injury (partial or complete rupture) of the patellar tendon in the past two years, on-going infection near the tendon, earlier treatment with steroid injection in the vicinity of the tendon, diabetes or systemic inflammatory disease. Participants completed a VISA-P questionnaire for each patellar tendon. The VISA-P questionnaire is a valid and reliable disease specific measure for assessing the severity of symptoms and functional ability in patients with patellar tendinopathy.[10] Results can range from 0 to 100, where 100 represent the perfect score with full function. The clinical examination of the patellar tendon in all participants was performed by a specialist physiotherapist (D.E.) who was also one of the co-authors of the present study. A diagnosis of a painful patellar tendon was made when localized pain was induced in the region of the patellar tendon with loading activities such as squatting and jumping.[11] Additionally, the eligible participants completed a self-administered questionnaire in which the demographic information (age, gender, height), smoking history,[12] volleyball activity (minutes of volleyball) prior to US, possible history of patellar tendon injury or surgery, and pain at presentation were obtained. All participants were asked not to disclose any knee injury history to the radiologist performing the US scans.

All participants were examined with grey-scale US and PD imaging using the Philips iU22 US scanner (Eindhoven, Philips Healthcare, Netherlands) that was equipped with a high resolution L17-5 MHz linear transducer. A single radiologist (P.J.R.) with over 16 years musculoskeletal experience evaluated and imaged the right and left patellar tendons of each participant. The radiologist was blinded to the players' VISA-P scores, history of patellar tendon pathology and pain at presentation. The patellar tendon was initially examined in the longitudinal and transverse planes using conventional B-mode (grey scale) and Doppler US. A standardized, preprogrammed grey scale US scanning protocol (with optimized scanning parameters such as depth, frequency, focal zone) was used to ensure consistency of results obtained between patients. The patellar tendon was examined with the knee in 20–30° flexion (with a wedge immobilizer placed under the knee) in order to stretch the extensor mechanism and avoid possible anisotropy related to the concave profile that the patellar tendon assume in full extension. A viscous scanning gel at room temperature (Aquasonic 100; Parker Laboratories Inc, Fairfield, New Jersey) was used to improve contact between the transducer and the skin. The maximum antero-posterior (AP) thickness of the patellar tendon was measured in the transverse plane. The absence or presence of grey scale abnormality (normal/abnormal) was graded according to the criteria suggested previously by Cook et al..[13] A grey-scale US abnormality was defined as either (i) the presence of discrete hypoechoic area > 2 mm (reproducible in both the longitudinal and transverse planes), and/or (ii) fusiform swelling without hypoechoic regions.[13] The patellar tendon was classified as normal if both of these features were absent, or abnormal if any one or both were present (Fig. 1).

Each patellar tendon was examined for presence of intratendinous vasculature using PD imaging with slow perfusion settings (pulse repetition frequency of 1000 Hz, low wall filter settings of 75 Hz).[14] The participant was positioned with the knee fully extended and relaxed. Care was taken to minimize tendon compression and therefore obliteration of small vessels whilst scanning. The colour intensity was set marginally below the artefact threshold. A standard 15 mm sampling box was placed on the longitudinal image with the greatest vascular density centred over the patellar tendon. The Doppler signal of the patellar tendon was dichotomized as either absent or present. Patellar tendons were designated as "vascular" if they demonstrated a vessel within the sampling box in the sagittal plane that was estimated to be greater than 1 mm in length.[15]

After recording the grey scale and PD US images, real-time US elastography was performed with a linear L12-5 MHz transducer on the same US machine. Light repetitive compression was applied over the patellar tendon with the hand-held transducer. Transducer pressure was applied vertically, perpendicular to the patellar tendon and was adjusted according to the real-time visual indicator for compression on the right side of the screen. The visual compression bar has two colour indicators: green and grey. A green compression bar indicates quality elastogram with appropriate tissue deformation while a grey bar denotes excessive or too little pressure. Care was taken to hold the probe perpendicular to the patellar tendon to avoid anisotropy when performing grey-scale US and to avoid "tissue shifting" artefact (occurs when the region of interest moves out of plane) when performing US elastography.[9] In the present study, we used a graduated colour strain map (red–yellow–green–blue) to categorize the elastographic findings. The presence of a "blue

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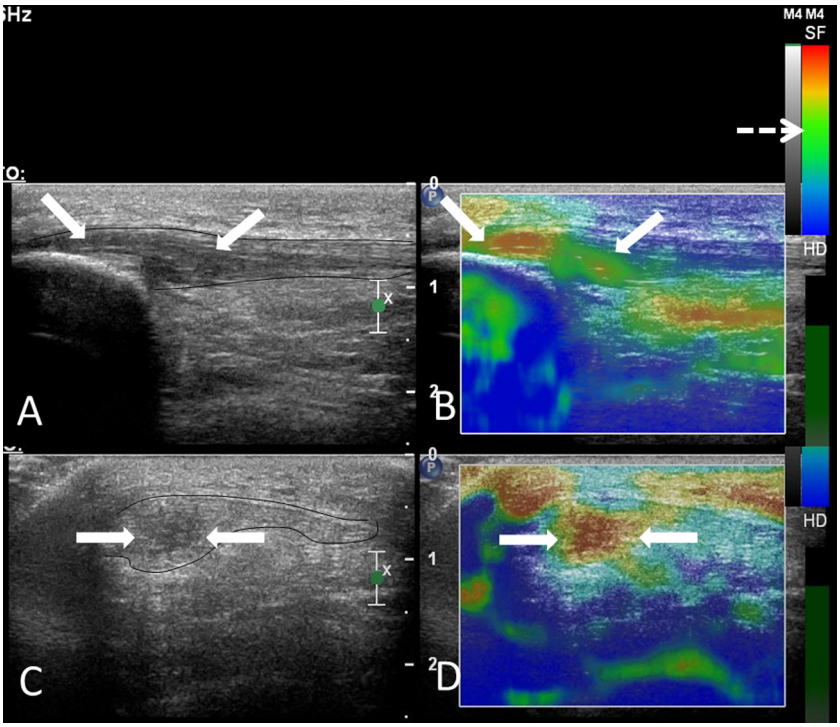

Fig. 1. Twenty-five year-old male presented with left knee pain. (A) Longitudinal B-mode ultrasound demonstrates fusiform thickening in the proximal end of the patellar tendon (between lines) with intratendinous hypoechoic changes (arrows) predominantly involving the deep fibers. (B) Corresponding longitudinal elastogram shows focal intratendinous green to yellow with red colouring (arrows), indicating softening of the proximal patellar tendon consistent with patellar tendinopathy. The elastography colour map bar is shown on the top right corner of the image (dashed arrow). (C) Axial B-mode ultrasound of the patellar tendon of the same patient showing the focal hypoechoic areas (between arrows) consistent with the degenerative changes seen in (A). The hypoechoic areas are shown up on axial elastogram, (D) as mainly red and yellow colouring compatible with soft, tendinopathic changes (between arrows). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and/or green" coded tendon represents a hard (elastic), healthy texture while a "yellow and/or red" coded tendon indicates a diseased tendon with soft (less elastic) properties as validated by De Zordo et al..[9] The radiologist ranked the appearance of a tendon as hard if the patellar tendon was coded as blue and/or green colour, and soft if the patellar tendon was coded as yellow and/or red colour (Fig. 1B and D).

Statistical analysis was performed using SPSS software (version 21.0 for Windows, IBM, Chicago, USA). The sensitivity, specificity and accuracy of grey scale US, PD imaging, US elastography and combined techniques in diagnosing painful patellar tendinopathy (reference standard) were calculated. For combination techniques, positivity was defined when either of the imaging tests were positive for patellar tendinopathy. The Mann Whitney U test was used to compare the VISA-P scores and AP thickness of the patellar tendon according to the imaging appearance on grey scale (normal or abnormal tendons) and according to either 'hard' or 'soft' tendon appearance on US elastography. Agreements between grey-scale, Doppler and US elastography were investigated using the Cohen's Kappa coefficient. Kappa value ≤0.20 was considered as poor agreement; 0.21–0.40 as fair agreement; 0.41–0.60 as moderate agreement; 0.61–0.80 as substantial agreement, and 0.81–1.00 as strong or almost perfect agreement. The alpha level was set at 0.05 for all analyses.

3. Results

Fifteen players were excluded after applying the exclusion criteria. Thirty five of the 50 (70%) players (70 tendons, 15 males, 20 females; mean (SD) age of 22.2 (3.1) years; range 18–30 years) entered the study. Of the 70 patellar tendons examined, 40 tendons (57.1%) from 25 participants (15 presented with bilateral symptoms) were clinically painful, while 30 (42.9%) were asymptomatic. The mean (SD) VISA-P score in the cohort was 81.5 (16.8), and 11 of the 70 tendons (15.7%) had a VISA-P score of 100. We did not observe any difference in the clinical symptoms of patellar tendinopathy (as depicted on VISA-P) with respect to gender and age distribution.

The sensitivity, specificity and diagnostic accuracy of US elastography, grey-scale US, PD and combined techniques in diagnosing clinically painful patellar tendons is shown in Table 1. Combination techniques of grey scale US and elastography achieved an overall sensitivity of 82.5%, specificity of 33.3% and accuracy of 61.4% while routine combination technique of PD and grey scale imaging revealed 72.5% sensitivity, 43.3% specificity and 60.0% accuracy.

Grey scale US abnormalities were present in 46 (46/70 (65.7%)) patellar tendons with five (5/70 (7.1%)) tendons demonstrating abnormal PD features. Forty-two out of the 70 tendons (60.0%) were classified as soft. A total of 17 patellar tendons with abnormal grey scale features and 14 tendons with soft elastography properties (in 14 participants altogether) were not painful clinically. Of these, 11 tendons in eight participants had both grey scale abnormalities and soft elastography properties.

Regarding relationship between imaging measures, patellar tendons categorized as soft on US elastography had statistically significantly larger AP thickness ($p < 0.001$) and lower VISA-P scores ($p = 0.004$) than those categorized as hard (Table 2). There was no significant association between grey scale US abnormalities (hypoechogenicities and/or fusiform swelling) and VISA-P scores ($p = 0.098$). The Kappa agreement between US elastography and grey-scale US was 0.451, with the modalities agreeing in 74.3% (52/70) of cases in diagnosing asymptomatic (17/52) and

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Table 1
Sensitivity, specificity and accuracy of grey scale ultrasound, elastography and power Doppler ultrasound in diagnosing clinically painful patellar tendon ($N = 70$ patellar tendons).

	Characteristics	Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV (%)	NPV (%)
a.	Grey scale ultrasound	72.5	43.3	60.0	63.0	54.2
b.	Elastography	70.0	53.3	62.9	66.7	57.1
c.	Power Doppler ultrasound	12.5	100	50.0	100	46.2
Combination						
	a + b	82.5	33.3	61.4	62.3	58.8
	a + c	72.5	43.3	60.0	63.0	54.2

PPV: positive predictive value, NPV: negative predictive value.

Table 2
VISA-P score and AP thickness for each grey scale ultrasound and elastography category among 35 volleyball players ($N = 70$ patellar tendons).

		VISA-P score, Mean (SD)	AP thickness, mean (SD) (mm)
Grey scale	Abnormal	79 (18.3)	3.8 (.10)
	Normal	87 (11.9)	3.3 (0.6)
p-Value[a]		0.098	0.023
Elastography	Soft	77 (17.3)	3.9 (0.9)
	Hard	89 (13.6)	3.2 (0.5)
p-Value[b]		0.004	<0.001

p-Value[a] Mann Whitney *U* test, comparing the VISA-P scores, AP thickness of the patellar tendon according to the grey scale imaging appearance (abnormal or normal tendons).
p-Value[b] Mann Whitney *U* test, comparing the VISA-P scores, AP thickness of the patellar tendon according to the elastography imaging appearance ('soft' or 'hard' tendons).

clinically painful patellar tendon (35/52). When US elastography was compared with PD US, no significant agreement was observed ($k = 0.049$).

4. Discussion

In this cohort of high performance jumping athletes with mild degree of patellar tendon alterations, we demonstrate that US elastography, grey scale and PD US were moderately accurate in differentiating participants presenting with clinically painful patellar tendon from asymptomatic participants. Also, US elastography was associated with grey scale imaging abnormalities as well as pain and functional deficits (VISA-P scores). Although confirmation of a clinical diagnosis of patellar tendinopathy has traditionally been based on the presence of sonographically detected hypoechogenicities and/or tendon swelling,[16] our data show no evidence of a statistically significant association between grey scale US abnormalities and athletic pain and dysfunction (VISA-P scores) ($p = 0.098$). In contrast, the significant association between US elastography and VISA-P implied that the presence of soft, less elastic tendon properties may be more related to patellar tendon symptoms than the hypoechoic tendons.

In a prospective study evaluating the clinical and imaging outcome of patellar tendinopathy of 101 volleyball players over a competitive season, Malliaras and Cook observed that not only were there symptomatic patellar tendons with normal tendon morphology on US, but also that asymptomatic tendons with tendon abnormalities were common.[17] Their findings have been reproduced in subsequent cross-sectional studies.[18] The authors explained that their observations may in part result from the suboptimal sensitivity of the US system in detecting the tendon pathology. The intratendinous pathological changes such as mucoid degenerations, proteoglycans depositions, microtears or oedema may occasionally present as isoechoic changes and make routine diagnostic process challenging.[19] The present study shows that it might be possible to improve the sensitivity and accuracy in detecting clinically painful patellar tendinopathy by adding elastography to conventional technique. The potential clinical value of elastography may be in the evaluation of patients presenting with clinically symptomatic patellar tendinopathy but non-US evident disease.[7] In this scenario, elastography could be applied to detect modification of the elastic properties of tendinopathic tendons in relation to the surrounding healthy tendon tissues that may share the identical grey scale US features. In addition to the morphology and vascularity data obtained by conventional US, US elastography can provide information about tissue elasticity, which is related to patellar tendon symptoms. Therefore, evaluation of tendon elasticity may be a useful option for clarifying symptomatic patellar tendinopathy in routine clinical settings.

However, the specificity of grey scale imaging and US elastography as well as combined techniques were low. A possible explanation of the low specificities likely related to the fact that 17 patellar tendons with abnormal grey scale features and 14 tendons with soft properties (in 14 participants) were clinically asymptomatic leading to false positive results. We suggest that the coexisting asymptomatic intratendinous softening and abnormal grey scale US demonstrated in eight of these 14 participants (11 tendons) may represent early, subclinical alterations. Our suggestion is supported by the recent work of Klauser et al. which showed that US elastography could detect histologically confirmed Achilles tendon degeneration in all cases whereas grey-scale US could detect only 85.7%.[19] Although a different tendon (the Achilles tendon) was studied, we believe the same phenomenon may be true for patellar tendons considering that both the Achilles and patellar tendons are weight-bearing tendons that lack a true tendon sheath and are surrounded by paratenon.[20] However, large scale, longitudinal studies are needed to confirm our hypothesis.

In line with previous findings,[8,9] our data demonstrates that symptomatic tendons were more likely to be classified as soft rather than hard on US elastography. However, the diagnostic values in the present study were lower compared to the previous studies. The discrepancy might be ascribed to the differences in the US equipment used, patient population (athletes versus recreational sports population) and types of tendon evaluated. Also, US elastography is a real-time, operator dependent imaging tool in which the experience of the operator performing the US scans and examination technique might affect the study outcome. The clinical value of US elastography in the assessment of patellar tendinopathy needs to be established in future large scale studies.

Theoretically, a hypertrophic tendon would have led to a greater stiffness if tendon composition were the same.[21] However, we observed that the AP thickness of the patellar tendon was significantly greater in athletes with soft tendon characteristic on US elastography. This can be interpreted to mean that degenerative changes with substantial collagen disorganization and increased ground substance impact both the elastic and structural properties of the patellar tendon.[22]

Although it has been suggested that neovascularization (the growth of new vasculature in areas of poor blood supply) is associated with chronic tendinopathy and may contribute to pain perception, we only identified PD activity in five (7%) tendons. This

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probably suggests that the patellar tendon alterations detected in this particular population was mild, or the sensitivity of PD vascularization was low. All tendons that showed vascularization during PD scanning were scored as abnormal on grey scale US, and four of these five tendons (80%) had 'soft' texture on elastography. It is conceivable that the presence of intratendinous vascularity alters the elastic properties of the tendon which could in part explain these findings.[23] Interestingly, we did not find any relationship between PD imaging and US elastography but we demonstrate perfect specificity of PD in detecting painful patellar tendinopathy. The low sensitivity of PD, however, is likely attributable to the sensitivity of the US machine, imaging technique (patients position, probe pressure) and small sample size.[24] Given its excellent specificity, it may increase the overall diagnostic performance in imaging the painful patellar tendon when it is used in conjunction with grey scale and US elastography which yielded improved sensitivity.

MRI and US are well suited to image tendon pathologies. US is the preferred imaging technique for a specific area of pain or clinical suspicion of pathology, whereas MRI allows for a global assessment of a region of concern.[25] The choice to use either MRI or US has traditionally depended on the operator's experience, the availability of the imaging modality and the strengths of the modality in depicting pathology. At present, MRI is considered the gold standard imaging modality in the evaluation of patellar tendon pathologies such as tendinopathies or tears at most centres in the United States.[25] Conventional US supplemented with elastography may be able to evaluate these changes at a lower cost and faster than MRI. In addition, these imaging tools allow dynamic assessment of muscles and tendons, direct correlation with patient symptoms and quick acquisition of contralateral images for comparison. However, we emphasize that US elastography should not be used as a stand-alone imaging modality but rather as a complementary imaging tool similar to the use of colour or PD US.[26] Correlation with baseline grey-scale US is still necessary.

There were several limitations to this study. The radiologist was not blinded to the results of the grey scale US when performing the elastography imaging and this may have led to bias when classifying the elastography images. It is technically challenging to achieve complete blinding as both the grey scale and US elastography scans were performed by the same operator. The intra- and inter-operator reliability of US elastography was not examined in the present study. However, using different US machines, transducers and patient set-ups, this technique has previously been shown to have acceptable intra- and inter-operator agreement.[27,28] Furthermore, the availability of a pressure indicator on the screen on some commercial US units with elastography compatibility gives instant feedback to the operator regarding the amount of pressure applied. This helps to reduce inter- and intra-operator variability during image acquisition. We did not control for the level of activity before performing the US examinations. This factor can be an important confounder, as tendons exhibit vascular changes in response to physical activity.[29,30] Nonetheless, we only identified PD signal in five (7%) tendons. We believe this factor would not greatly affect the study outcome. We acknowledge that a higher frequency probe (such as L17-5 MHz as used on the grey-scale US in the present study) would be more appropriate for assessing the elasticity of the patellar tendon. We used a lower frequency linear probe (L12-5 MHz) for elastography imaging because the elastography software was not available on the L17-5 MHz probe in our existing US machine. The subjective interpretation of the visual strain map represents another potential limitation. Newer development of semi-quantitative strain ratio may provide more accurate and objective measures of relative tendon stiffness. Further studies directed to evaluate the feasibility of strain ratio measurements in diagnosing patellar tendinopathy are currently underway.

5. Conclusion

US elastography provides a non-invasive means of estimating patellar tendon elasticity and may represent a valuable supplement to conventional US in routine assessment of symptomatic patellar tendinopathy. Future studies are needed to establish the usefulness of this diagnostic algorithm in the clinical context.

6. Practical implications

- US elastography is a feasible clinical tool in the evaluation of symptomatic patellar tendinopathy in high performance athletes. The presence of soft tendon properties on US elastography is associated with increasing patellar tendon thickness, and is more related to patellar tendon pain and functional deficit compared to grey scale US abnormalities.
- The supplementation of US elastography to conventional US may increase the sensitivity and accuracy for diagnosing painful patellar tendinopathy and may also be helpful in patients in whom grey scale US findings are inconclusive.
- These findings may assist sports clinicians in assessing the relevance of US abnormalities among active athletes and contribute to more effective rehabilitation when tendon alterations occur.

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