SYSTEMATIC REVIEW

Substantiating the predictive role of ultrasound imaging in athletes with lower limb tendinopathy: a systematic review

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Abstract

Objective: To explore the potential of ultrasound imaging to anticipate and monitor future symptoms of patellar or Achilles' tendinopathy.

Method: The systematic review comprised prospective studies that used ultrasound imaging of Achilles' OR patellar tendons in asymptomatic patients at baseline and measurements of pain and/or function at follow-up. The Critical Appraisal Skills Programme checklist used to assess study quality and it was done by two independent reviewers.

Results: Of the 19 studies reviewed, 9(47.3%) investigated patellar tendon alone, 6(31.5%) did both patellar and Achilles' tendon, and 4(21.2%) did Achilles tendon alone. The method of ultrasound administration was almost uniform for both the tendons. The studies showed that the use of ultrasound to predict lower limb tendinopathy was indefinite, but that a higher proportion of tendon disorganisation increased the risk of developing tendinopathy. In addition, promising results were obtained for the use of ultrasound in both Achilles' and patellar tendinopathy in monitoring the effect of load or treatment on tendon structure.

Conclusions: The included studies had participants from different sports. Tendon irregularities at baseline on ultrasound were related to increased risk and future occurrence of both patellar and Achilles' tendinopathy.

Key Words: Ultrasonography, Tendinopathy, Achilles' tendon, Patellar tendon.

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Introduction

Tendinopathy is used to represent the clinical picture of localized pain, tenderness and/or functional limitation that increases with loading. It is a highly prevalent musculoskeletal condition affecting both athletes and non-athletes. This musculoskeletal condition most commonly affects Achilles', patellar and rotator cuff tendons.[1] Different imaging modalities are used to visualise tendon structure and abnormalities, such as magnetic resonance imaging (MRI) and ultrasound, which appear to have similar accuracy and sensitivity levels. The use of ultrasound has increased among musculoskeletal practitioners because of its minimally invasive, quick and feasible application in sports and other conditions. Clinically, ultrasound has been used to image the tendons to rule out diagnosis, monitoring the interventions and rule out the risk of developing future symptoms. In athletic population, ultrasound has been used to image painful tendons and find out structural abnormalities, such as tendon thickening with hypoechoic areas, and increased vascularity.[2] Prospective studies have suggested that these structural abnormalities increased the probability of producing symptoms of tendinopathy in future. Therefore, it has been suggested that if these abnormalities are identified at baseline, the high-risk asymptomatic athletes can be ruled out and their training protocols and/or interventions can be modified to prevent the occurrence of future symptoms.[3] The cross-sectional designs of many studies exploring tendon structure describe that it is unclear whether structural abnormalities on imaging predict future symptoms, or whether they are just a normal physiological response to particular sporting demands which does not warrant an increased risk of future symptoms.[4] So, healthcare professionals are unable to understand whether to alter training regimes of athletes and/or intervention to prevent the future occurrence if they find structural abnormalities on imaging. Therefore, the current systematic review was planned to determine the ultrasound imaging in the prediction of future symptoms of lower limb tendinopathy.

Materials and Methods

The systematic review was done in January 2021 and comprised prospective studies that used ultrasound imaging of Achilles' OR patellar tendons in asymptomatic patients at baseline and measurements of pain and/or

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function at follow-up. The review was done in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement.[5] Ethical approval was obtained from the The Institutional Review Board committee of the University of Lahore (IRB-UOL-FAHS/829-I/2021). A detailed search strategy was designed and implemented using databases and key words along with Boolean operators (Table 1). The assessment of potential studies from database was done by two independent reviewers, and a third reviewer mediated any disagreements. The screening of titles and abstracts of the studies was done for eligibility after the removal of duplicates.

Table-1: Key words used as part of the search strategy.

Tendon/tendin AND
Knee OR patella AND
Jumper's knee OR Patellar tendinopathy OR Tendinitis OR Tendinosis OR Tendinopath OR tendonopath AND
Achilles OR Heel OR Tendo calcane OR Tendocalcane OR Tendoachilles OR Tendo achilles OR Achilles tendinitis AND
Ultrasound OR Ultrasonograph OR Sonograph OR UTC OR Ultrasonic imaging OR Diagnostic Ultrasound imaging AND
Risk OR Predict OR Associat OR Relat OR Correlat OR Develop OR Prognos OR Prospect* OR Longit OR ohort* OR Future OR Characters OR Grade OR Grading OR Classification OR Classify OR Staging.

Inclusion criteria: Prospective studies exploring the predictive role of patellar, or Achilles' tendon structure observed at baseline using ultrasound were included. The ultrasound readings must have been associated with a clinical outcome measure (pain and functional disability) to find the probability of developing patellar or Achilles' tendinopathy in future. The duration of follow-up must have been at least 24 hours, and the tendon analysis must have been done both quantitatively and qualitatively. The included studies must have been published in English over the preceding 2 decades and must have had participants regardless of age and could include tendinopathies of either mid-portion or point of insertion at patellar or Achilles' tendon as well as subjects with accompanying concurrent diseases.

Exclusion criteria: The studies evaluating only the development of tissue structure changes without associated clinical outcomes (pain and functional disability) and which explored changes in tendons other than patellar or Achilles' tendon and those investigating animal tendon structures were excluded. The studies with only abstracts available and had copyright issues were also excluded.

Assessment of methodological quality: Due to lack of any standard tool to check methodological quality of prospective studies of this nature, the Critical Appraisal Skills Programme (CASP) checklist for cohort studies was used.[6] There are 12 questions in the checklist, with the initial 2 being screening questions that can be answered quickly, and the remaining 10 questions investigating the conclusion, credibility and relevance to the local population. In the checklist, four questions (Nos: 2, 7, 8 and 9) investigate similar areas and were combined to review the studies. Hence, the appraisal of the included studies was done using eight leading questions. As the CASP has multiple reflections for every question, the key to reviewing studies is consistency. Therefore, the authors drew and agreed upon a criterion list for each question during the appraisal of the included studies. Since the CASP checklist was originally designed as an educational tool in workshop settings, there was no overall quality score for the included studies.

Data extraction: Data extracted from the included studies included patient demographic details, sample size, tendon structure measurement, total tendons that changed into symptomatic tendons along with normal or abnormal ultrasound imaging at baseline, and the description of tendon abnormal structural changes. Tendon pathologies were explained as any alteration in normal structure such as hypo-echogenicity, increased thickness, and hyper-vascularity seen on colour doppler ultrasound. The studies with similar clinical outcome measures, the involved tendons, the included subjects, and the prediction of symptoms in future led to pooled data analysis. For unavailable data, the methods needed clarification, and the corresponding authors of the original studies were approached. If after this contact, the missing data was not available, the studies were excluded.

Results

Studies identification: Of the 1,393 potentially relevant studies identified after electronic search, 884(63.5%) were excluded because of overlapping data. After screening of titles and abstracts of each study, 32(3.6%) full-text studies were recognised as potentially relevant. After screening the full text of the shortlisted studies, 13(40.6%) were excluded. The remaining 19(59.4%) studies were reviewed (Figure).

Features of the included studies: The included studies had similar mean age of the participants ranging 15-66 years. All the included studies had similar participant characteristics, and all 19 except 1 were from the sporting population; 5(26.3%) involved volleyball,[7-11] 2(10.5%) had basketball,[12,13] 3(15.8%) had soccer players,[14-16] 1(5.2%)

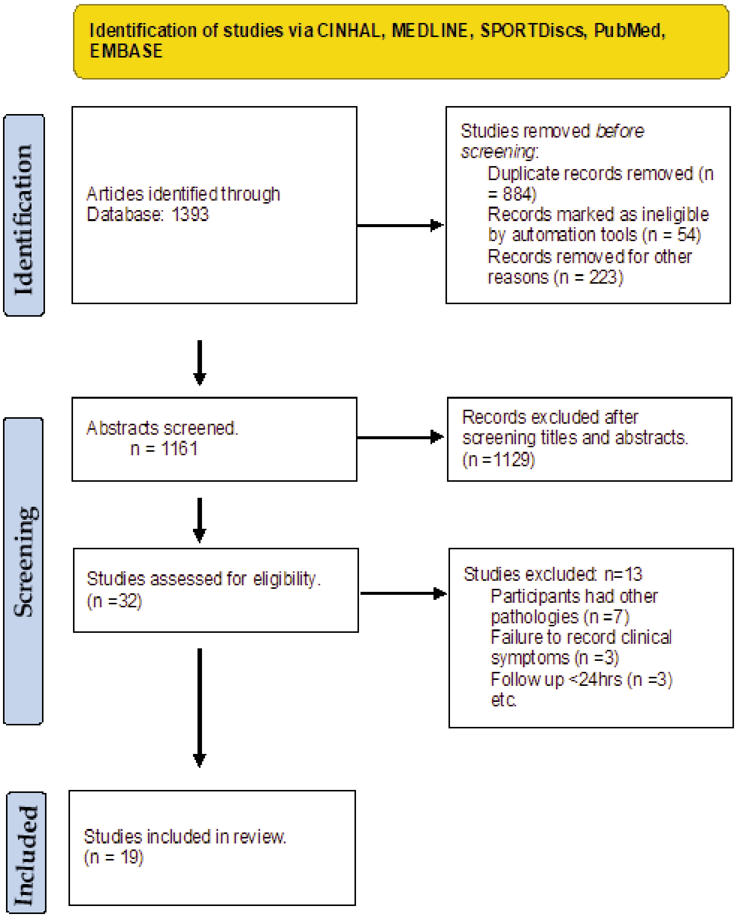

Figure: Preferred reporting item for systematic reviews and Meta-analyses (PRISMA) flow chart.

had elite fencers,[17] 3(15.8%) had runners' population,[18-20] 1(5.2%) involved badminton,[21] 2(10.5%) had ballet dancers,[22] and 1(5.2%) had different sports playing populations.[23] In contrast, 1(5.2%) study had patients from the general population.[24] Of the total, 6(31.6%) studies had only male participants,[9,12,14-16,18] and the remaining 13(68.4%) had participants of both genders. The period of follow-up had a wide range from 2 days to 4 years. All the included studies had ultrasound as tool of investigation for tendon structure, while only 1(5.2%) study included ultrasound tissue characterisation (UTC) for tendon structure evaluation.[7] Further, 9(47.4%)studies explored tendon thickness, hypo-echogenicity and vascularity,[8-11,14,17,19,20,24] 5(26.3%) studies investigated tendon thickness and hypo-echogenicity,[12,13,15,16,23] 2(10.5%) investigated thickness, hypo-echogenicity, intratendinous delamination and calcifications,[18,25] 2(10.5%) investigated hypo-echogenicity,[7,22] and 1(5.2%) investigated vascularity only.[21] There was a wide range of clinical outcome measures of pain, and/or function and consisted of subjective pain, and functional ability, such as the Victorian Institute of Sport Assessment (VISA) scale, performance special tests, like single leg squat and plyometric movements, and pain and tenderness on palpation (Table 2).

Table-2: Characteristics of the included studies

Author	Study design	Participant's demographics	Population	Tendon	Parameter examined	Structural change under US	US imaging and follow up
JC Benítez-Martínez et al.(2020)[12]	Prospective cohort study	n=73M26.8±4.8 years (Range N/A)	Elite basketball players	Patella	Thickness, Hypoechogenicity	Abnormal:1) hypoechoic areas 2)increased thickness.	US: Initial and follow-up
DM Cushman et al. (2020)[18]	Prospective cohort study	n=104 M (age:<18 years)	Distance runners	Patellar and Achilles	Thickness Hypoechogenicity Vascularity Tendon clefts Intratendinous calcifications	Abnormal: presence of 1) hypoechogenicity,2) intratendinous delamination (3) paratenon blurring [38],4) calcification, and 5) tendon thickening	US: Initial and follow-up (1,3,6& 12 mon.)
Rudavsky et al.(2018)[22]	Prospective cohort study	n=61(23M/34F) (range 11-18)	elite ballet dancers	Patellar	Hypoechogenicity	Abnormal: hypoechoic area on greyscale ultrasound for 2 or more time points	US: Initial and 6-monthly Follow-up: 2 y

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Author	Study design	Participant's demographics	Population	Tendon	Parameter examined	Structural change under US	US imaging and follow up
van Ark et al. (2016)[7]	Cohort study	n=41 (30M/11F) Mean age 17.2 (range 16-18)	Elite junior volleyball players	Patellar	Hypoechogenicity	Abnormal: Presence of Hypoechogenicity (undefined).	US: Initial and follow-up
Visnes et al.(2015)[8]	Cohort study	n=158 (84M/74F) Mean age 17(Range N/A)	Elite junior volleyball players	Patellar	Thickness Hypoechogenicity Vascularity	Abnormal: Presence of (1) Hypoechogenicity (undefined), or (2) increased vascularity (≥stage 2) as defined by Gisslen et al (2007)	US: Initial and 6-monthly Follow-up: 4 y (average: 1.7 y)
Ooi et al.(2015)[19]	Cohort study	n=41 (25M/16F) Mean age 37.25	Marathon runners	Achilles	Thickness Hypoechogenicity Vascularity	Abnormal: Presence of (1) increased tendon thickness (undefined), or (2) Hypoechogenicity (≥grade 2) according to a defined three-point scale (grade 1–3), or (3) vascularity (≥grade 2) according to a defined three-point scale (grade 1–3)	US: Initial (pre-race 1 wk) and 3 d post-race Follow-up: 10 d
Giombini et al.(2013)[17]	Cohort study	n=37 (15M/22F) Mean age 27.2 (16-36)	Elite fencers	Achilles and patellar	Thickness Hypoechogenicity Vascularity	Abnormal: Presence of (1) increased thickness (undefined), or (2) Hypoechogenicity (undefined), or (3) increased vascularity (≥stage 2) as defined by Gisslen et al	US: Initial and follow-up: Average 3y
Comin et al.(2013)[25]	Cohort study	n=79 (35M/44F) Mean age 27.4 (18-40)	Professional Ballet dancers	Achilles and patellar	Thickness Hypoechogenicity Vascularity Tendon clefts Intratendinous calcifications	Abnormal: Presence of (1) Hypoechogenicity, or (2) increased thickness, or (3) vascularity, or (4) intratendinous calcifications (all undefined)	US: Initial visit Follow-up: 24 mo.
Boesen et Al.(2012)[21]	cohort study	N = 86 (56 M, 30 F) Mean age: 21.7 (range N/A)	Badminton	Achilles patellarQuadriceps.	Vascularity	Abnormal: Presence of increased vascularity (≥grade 1) according to a defined six-point scale (grade 0–5).	US: Initial and follow-up: 8 mo.

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Author	Study design	Participant's demographics	Population	Tendon	Parameter examined	Structural change under US	US imaging and follow up
Hirschmuller et al.(2012)[20]	Cohort study	n=634 (425M/209F) Mean age 41.2 (17-73)	Long-distance runners	Achilles	Thickness Hypoechogenicity Vascularity	Abnormal: Presence of (1) increased thickness (undefined), or (2) Hypoechogenicity (undefined), or (3) presence of vascularity according to a defined five-point scale.	US: Initial visit Follow-up: 12 mo.
Jhingan et al. (2011)[14]	cohort study	n=18M (Mean age 23.5(22-27.5)	Elite soccer players	Achilles	Thickness Hypoechogenicity Vascularity	Abnormal: Presence of (1) increased thickness > 1 mm, or (2) Hypoechogenicity >1 mm, or (3) paratenon blurring, or (4) vascularity (undefined).	US: Initial visit Follow-up: 12 mo.
Malliaras et al. (2010)[9]	Ccohort study	n=58 (36M/22F) (range N/A)	Elite and recreational volleyball players	patellar	Thickness Hypoechogenicity Vascularity	Abnormal: Presence of (1) increased thickness (undefined), or (2) Hypoechogenicity (undefined), or (3) vascularity of at least one vessel in the sagittal plane >1 mm in length.	US: Initial and monthly Follow-up: 5 mo.
Fredberg et al.(2008)[16]	RCT	n=207M (Mean age 25)	Professional soccer players	Achilles and patellar	Thickness Hypoechogenicity	Abnormal: Presence of (1) thickness >0.5 mm in the Achilles and patellar tendon, or (2) Hypoechogenicity >0.5 mm in the Achilles tendon and >1 mm in the patellar tendon.	US: Initial and follow-up: 12 mo
Gisslén et al.(2007)[10]	Cohort study	N = 22 (11 M, 11 F) Mean age: 16.3 (15-16 at start)	Elite junior volleyball players	Patellar	Thickness Hypoechogenicity Vascularity	Abnormal: Presence of (1) increased thickness (undefined), or (2) Hypoechogenicity (undefined), or (3) vascularity (≥stage 2) to a defined four-point scale (grade 0–3)	US: Initial, regular intervals and follow-up (6 total) Follow-up: 3 y

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Author	Study design	Participant's demographics	Population	Tendon	Parameter examined	Structural change under US	US imaging and follow up
Gisslén et al. (2005)[11]	cohort study	N = 60 (29 M, 31 F) Mean age: 17.2 (15-19)	Junior volleyball players	Patellar	Thickness Hypoechogenicity Vascularity	Abnormal: Presence of (1) increased thickness (undefined), or (2) Hypoechogenicity (undefined), or (3) vascularity (≥stage 2) according to a defined four-point scale (grade 0–3)	US: Initial and follow-up: 7 mo
Khan et al.(2003)[24]	Cohort study	n=45 (27M/18F) Mean age 42	Patients from a university sports medicine centre	Achilles	Thickness Hypoechogenicity Vascularity	Abnormal: Presence of (1) increased thickness >6 mm, or (2) Hypoechogenicity (undefined) Presence of the above features were graded according to a defined three-point scale.	US: Initial & 12 mo. Follow-up: 24 mo.
Fredberg and Bolvig(2002)[15]	Cohort study	n=54M (Age range 18–35)	Professional soccer players	Achilles and patellar	Thickness Hypoechogenicity	Abnormal: Presence of (1) thickening >1 mm, or (2) Hypoechogenicity >1 mm.	US: Initial and follow-up: 12 mo
Cook et al.(2001a)[23]	Cohort study	n=24M (Mean age 27.5(18-40)	Athletes from various sports: basketball, cricket, netball, and Australian rules football	Patellar	Thickness Hypoechogenicity	Abnormal: Presence of (1) thickness, or (2) Hypoechogenicity (all undefined)	US: Initial and follow-up: 47.1 mo. (32=80 mo.
Cook et al.(2000)[13]	Cohort study	n=26 (8M/18F) Age range 14–18	Elite Junior basketball	patellar	Thickness Hypoechogenicity	Abnormal: Presence of (1) thickness, or (2) Hypoechogenicity (all undefined).	US: Initial & follow-up Follow-up: 16 mo (12-24 mo

Study quality and scoring: The study population and recruited participants of the included studies followed a predesigned inclusion criterion. However, these studies had a variety of methodological quality and measurement of clinical outcome measures. Few of the included studies did not follow the inclusion criteria completely and it may have influenced the inference and generalisability of the results. All the included studies had clear study aims and objectives, with appropriate study designs and methodological quality (Table 3).

Mostly, studies included 1-2 positions to execute ultrasound scan of patellar and Achilles' tendons: the supine positions and prone positions, respectively (Table 4). Of the supine position, various knee flexion angles were used: 20 degrees,[8,10] 30 degrees,[12,17] 90 degrees,[15], 22100 degrees,[7] 120 degrees.[18] Besides, 1(5.2%) study used patient in supine with knee extension,[11] while for Achilles', the ankle flexion was used at 90 degrees with feet hanging over the table.[14,15,17,18,20,24] Further, 1(5.2%) study evaluated anterior knee tendons with supine and 15 degrees knee flexion,[21] 5(26.3%) studies did not describe patient position for ultrasound scan.[9,13,16,23,25] Further, 6(31.6%) studies used proximal to distal approach for ultrasound scan,[7,8,15,17,22,25] while the rest of the studies did not describe the approach used. Only 2(10.5%) studies used unilateral ultrasound limb scan,[7,22] while the rest had bilateral scan of either patellar or Achilles' tendons.

Majority of the reviewed studies concluded that ultrasound could probably predict the future occurrence

Table-3: Critical appraisal summary of the included studies using the Critical Appraisal Skills Programme (CASP) Checklist for cohort studies

	Cohort studies												
Author	1	2	3	4	5a	5b	6a	6b	7	10	11	12	Score
JC Benítez-Martínez et al.(2020)[12]	Y*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
DM Cushman et al. (2020)[18]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Rudavsky et al.(2018)[22]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
van Ark et al. (2016)[7]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Visnes et al.(2015)[8]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Ooi et al.(2015)[19]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Giombini et al.(2013)[17]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	92%
Comin et al.(2013)[25]	Y	Y	N*	Y	N	N	Y	Y	Y	Y	Y	Y	75%
Boesen et Al.(2012)[21]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Hirschmuller et al.(2012)[20]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Jhingan et al. (2011)[14]	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	75%
Malliaras et al. (2010)[9]	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	75%
Gisslén et al.(2007)[10]	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	92%
Gisslén et al. (2005)[11]	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	83%
Khan et al.(2003)[24]	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	75%
Fredberg and Bolvig(2002)[15]	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	83%
Cook et al.(2001a)[23]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
Cook et al.(2000) [13]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%
	Randomized controlled trial												
Author	**1**	**2**	**3**	**4**	**5**		**6**		**7**	**9**	**10**	**11**	**Score**
Fredberg et al.(2008)[16]	Y	Y	N	N	N		N		Y	Y	Y	Y	60%

*Y= YES *N=NO.

of tendinopathy. However, some suggested there was either no or weak association with the structural abnormalities at baseline and future tendinopathy. Of the total, 1(5.2%) study suggested that there was no remarkable change in tendon structure (echo types I-IV) during the sports event,[7] and 1(5.2%) study concluded that ultrasound appearance of the tendon should not be solely responsible for the management of patellar tendinopathy.[23] In addition, 1(5.2%) study investigated tendon and suggested that there was no association between structural abnormality and future tendinopathy.[14]

Discussion

Role of ultrasound in predicting tendinopathy: The identification of risk factors of lower limb tendinopathy is very important owing to its significance in athletes taking part in different sports and to prevent the negative results and improving quality of life.[26] The tendon dimensions are usually visualised through MRI and ultrasound with the latter becoming popular and modality of choice among healthcare practitioners due to its affordability and accessibility in tendon disorders and sports medicine.[27] The current systematic review showed a compatible trend of high probability of developing future patellar and Achilles' tendinopathy if the tendons exhibited irregularities on ultrasound at baseline. It is therefore possible that asymptomatic individuals with structural changes in their tendons may serve as markers of future pathology, which is later regarded as increased pain and/or functional disability.[28] Due to effectiveness and uniformity of the included studies, the results can be used for the prevention and

Table-4: Ultrasound protocol administration and results of the included studies.

Authors	Patient position	Direction of the scan	Side	Clinical application	Region of interest	Results	Practical applications
JC Benítez-Martínez et al.(2020)[12]	Patellar: supine position with approximately 30° knee flexion, with pillow under the popliteal space.	Not described	Bilateral	Monitoring	5 mm distal to the inferior pole of the patella.	Of the 146 tendons, 91 had some degree of sonographic abnormality. Three main patterns were identified: I, II, III.	Patterns of sonographic abnormalities, including NV, demonstrated greater pain. Combination of 2 or more ultrasound abnormalities can determine variations in pain variations among basketball players.

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Authors	Patient position	Direction of the scan	Side	Clinical application	Region of interest	Results	Practical applications
DM Cushman et al. (2020)[18]	Achilles: Prone with the feet hanging over the table edge and the ankles flexed to 90° Patellar: supine with at 120-degree knee flexion	Not described	Bilateral	Predicting	Short-axis images were saved at the tendon location at its greatest width while longitudinal assessment was made in the midline tendon, centred over the area of maximum thickness.	24.1% of the Achilles tendon had structures abnormalities; and 23.1% of the patellar tendons before the race. The participants with tendon structural were 2–3 times more prone to develop pain within 1 year than those without	25% of the asymptomatic runners had structural changes, which lead to increased risk of Achilles and patellar tendon pain within 12 months.
Rudavsky et al. (2018)[22]	Patellar: patient in supine with 90°knee flexion.	From proximal to distal	Unilateral	Monitoring	1cm distal to the disappearance of the patellar inferior pole.	During the study, 9% of participants developed tendon pathology, out of which only 2-5% reported tendon pain.	Abnormality in proximal part of patella can occur during adolescence
van Ark et al. (2016)[7]	Patellar: supine, with approx. 100° of knee flexion	Proximal to distal	Unilateral	Monitoring	20mm distal from the apex of the patella	No remarkable changes in tendon structure (echo types I-IV) over the sports event.	Either the tendon structure is stable enough, UTC is not significant, or decreased tournament/time for considerable change.
Visnes et al.(2015)[8]	Patellar and quadricep: supine, with slight knee flexion (20°)	Proximal to distal	Bilateral	Monitoring	Proximal, mid and distal part of the tendons	Out of 141 asymptomatic athletes, only 22 athletes (35 patellar tendons) advanced to jumper's knee.	The risk factors to develop jumper's knee among adolescent volleyball athletes were hypoechoic areas and neovascularization at baseline. 7-11% increased quadriceps tendon thickness in healthy athletes, and no change in patellar tendon thickness.
Ooi et al.(2015)[19]	Achilles: Prone, legs hanging over the edge of the table.	Not described	Bilateral	Predicting	The mid portion of the free Achilles tendon (2–6 cm proximal to the calcaneal insertion)	Remarkable reduction in tendon stiffness was due to Marathon running ($p = 0.049$) and an increase in Doppler signals ($p = 0.036$). Achilles' tendon pain was observed in four out of 21 (19%) runners' post-race [VAS 4.0 (±1.9), VISA 74.2 (±10.1)]. Decreased stiffness of the tendon at baseline was correlated with post-marathon Achilles' tendon pain ($p = 0.016$).	The prior soft Achilles' tendon properties seen on sonoelastography may be a risk factor for occurrence of symptoms after running.

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Authors	Patient position	Direction of the scan	Side	Clinical application	Region of interest	Results	Practical applications
Giombini et al. (2013)[17]	Patellar and quadricep: supine with 30° knee flexion Achilles: the patient prone, the heels overhanging couch, and the ankles flexed to 90°	Proximal to distal	Bilateral	Predicting	10 mm proximal to the superior-posterior aspect of the calcaneus, the patellar tendon 5 mm distal to the patellar attachment, and the quadriceps tendon 10 mm proximal to its patellar insertion	At baseline readings, abnormal patellar tendon was probably more prone to develop symptoms than those normal ($P < 0.05$, Fisher's exact test), while US and PD abnormalities on Achilles and quadriceps tendons were not associated with development of symptoms over longer duration. A small percentage of tendons diagnosed as normal at baseline (1.45%) exhibited US abnormalities at follow-up of 3 years.	It is questionable that secondary investigations through PD gives more information or alter prognosis in patients with US diagnosis of tendinopathy.
Comin et al.(2013)[25]	Not described	Proximal to distal	Bilateral	Predicting	1 cm from both origin and insertion	There was weak association of moderate or severe hypoechoic defects with future development of symptoms of tendinopathy ($p=0.0381$); and no orrelation between any of the other ultrasound abnormalities and the symptoms development.	Ballet dancers have common sonographic abnormalities, but only the presence of focal hypoechoic changes are predictive of future symptoms development in tendons.
Boesen et Al.(2012)[21]	Achilles: Prone position with a pillow under the distal tibia with feet hanging over the table in slight plantarflexion. Anterior knee tendons: supine position with 15° knee flexion with a pillow (relaxed position).	Not described	Bilateral	Predicting	2 cm in the longitudinal direction of the tendon	36% experienced pain in 51 tendons (15%), ($P = .0002$). Abnormal flow was observed in (83%) at the beginning of the season compared with (48%) at the follow-up. ($P < .0001$). (68%). had abnormal flow. (85%) with abnormal flow at the start of the season were pain free. At the end of the season, (35%) had abnormal flow. Majority of the tendons (73%) were pain-free and abnormal flow at the beginning of the season were normalized (no pain and normal flow) at the end of the season.	It was impossible to establish any association between intratendinous flow and pain at the beginning of the season or at the follow-up (end of the season). Intratendinous flow at the beginning of the season could not predict symptomatic outcome at the end of the season.
Hirschmuller et al.(2012)[20]	Achilles: Prone position with the legs of the subjects hanging over the edge of the table and ankles passively flexed at 90°.	Not described	Bilateral	Predicting	Point 3 cm proximal to the calcaneal insertion and at its thickest.	The highest odds ratio (OR) for appearance of MPT within 1 yr was found for intratendinous blood flow ("neovascularization," $OR = 6.9$, $P < 0.001$). The subjects having positive	Healthy runners with diagnosis of intratendinous micro vessels in Achilles' tendon on PDU can predict the appearance of MPT symptoms.

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Authors	Patient position	Direction of the scan	Side	Clinical application	Region of interest	Results	Practical applications
						Achilles' tendinopathy history were found to have high risk. (OR = 3.8, $P < 0.001$). Another significant parameter was a spindle-shaped thickening of the tendon observed on PDU (Wald $\chi 2 = 3.42$).	
Jhingan et al. (2011)[14]	Achilles: Prone with their ankles in a relaxed position (approximately plantar grade).	Not described	Bilateral	Predicting	insertion on calcaneus (defined on US as the clearest image of the pre-Achilles bursa); the musculotendinous junction [the area examined on US where the last soleus fibres attach to the tendon and the midpoint of the two	mid-tendon thickness at baseline was greater (p=0.041) in tendons that had symptoms [median (IQR): 0.53 (0.51–0.55) cm] in the upcoming year than tendons remaining asymptomatic [0.48 (0.45–0.52) cm]	There was no association between the presence of baseline ultrasound signs and future development of symptoms in the upcoming years (Chi-Square: 1.180, p=0.277). A thicker tendon thickness of the mid-portion was considered as risk factor for future development of Achilles' tendinopathy in elite soccer players.
Malliaras et al. (2010)[9]	Not described	Not described	Bilateral	Predicting	Three categories on greyscale imaging; normal, diffuse thickening, hypoechoic	Painful tendons with hypoechoic regions (59%) and contain Doppler flow (42%) than tendons with diffuse thickening (pain in 43% and Doppler flow in 6%)	The transitions identified between normal, diffusely thickened tendons and those containing a hypoechoic region indicates that these greyscale US changes may show different phases of tendon pathology.
Fredberg et al.(2008)[16]	Not described	Not described	Bilateral	Predicting	6 mm from insertion at the lower patellar pole. The normal Achilles tendons thickness was measured 20 mm from the distal attachment at the calcaneus, and Achilles' tendons with increased thick-ness were measured at the thickest point.	The presence of ultrasonographic tendon abnormalities prior to season greatly increased the risk of developing tendon symptoms during the season (relative risk = 1.9; 95% CI, 1.2–3.1; P = .009).	With the use of ultrasonography, tendon changes in soccer players can be diagnosed prior to symptomatic appearance.

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Authors	Patient position	Direction of the scan	Side	Clinical application	Region of interest	Results	Practical applications
Gisslén et al.(2007)[10]	Patellar: Supine, first with the extended knee and then with the slightly flexed knee (20˚)	Not described	Bilateral	Predicting	Not described	Development of patellar tendinopathy in 2 of 25 (2 were excluded) tendons that were normal (clinical and US+PD) at inclusion and was also present in six tendons.	Normal clinical tests and ultrasound findings at the start indicated a low risk for these elite junior volleyball players to sustain jumper's knee during three school years with intensive training and playing.
Gisslén et al. (2005)[11]	Patellar: patient supine with extended knee.	Not described	Bilateral	Monitoring	Not described	The 20 clinically normal tendons with normal US and PD sonography at inclusion lead to the structural tendon changes, whereas neovascularisation was developed in 12 tendons.	The clinical diagnosis of patellar tendinopathy is most often accompanied with neovascularisation in the area with structural tendon changes. The finding of neo vessels might represent worsening of the condition.
Khan et al.(2003)[24]	Achilles: Prone, and feet hanging over the table in a relaxed position	Not described	Bilateral	Predicting	Transverse scan was used to measure tendon thickness by maximum anteroposterior diameter at a neutral position of the talocrural joint. The tendon was considered a thickened tendon with a diameter greater than 6 mm.	65% of the symptomatic tendons had abnormal morphology on US and 68% of asymptomatic tendons had normal morphology. Baseline US findings did not anticipate 1-year clinical outcome. No improvement in diagnostic qualities of US after the addition of colour and power Doppler	In chronic Achilles' tendinopathy, moderate correlation with clinical assessment on US and MRI. Association between Graded MRI appearance and clinical outcome, but no association with US.
Fredberg and Bolvig(2002)[15]	Patellar and Achilles: The ankle and knee flexed 90°.	Proximal to distal	Bilateral	Predicting	Tendons were considered abnormal, 2 to 5 cm proximal from the calcaneal insertion and of more than 1 mm in relation to the normal distal part of the tendon.	During preliminary examination, 11% of the Achilles' tendon had abnormal findings on US. it was observed that they had a 45% risk of developing symptoms of Achilles tendinosis. At the end of the season only one of the players with normal tendons developed symptoms of tendinopathy.	For the first time it is now credible to recognize risk factors for the development of serious tendon disorders in asymptomatic athletes.

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Authors	Patient position	Direction of the scan	Side	Clinical application	Region of interest	Results	Practical applications
Cook et al.(2001a)[23]	Not described	Not described	Bilateral	Predicting	Not described	Development of hypoechoic area in seven normal patellar tendons at baseline with only two produced symptoms, there is no association between baseline ultrasound changes and symptoms at follow-up.	Management of patellar tendinopathy should not be only relied upon ultrasonographic changes; assessment of the clinical features remains the foundation of significant management.
Cook et al. (2000)[13]	Not described	Not described	Bilateral	Predicting	Not described	During the study period, ultrasonographic changes were more likely to appear in males than females ($P < 0.025$), with more training hours per week ($P < 0.01$), while half (50%) of abnormal tendons in females became normal as observed on US.	It was impossible to anticipate the future development or resolution of tendon symptoms by qualitative or quantitative analysis of baseline ultrasonographic images.

management of patellar and Achilles' tendon disorders. The ultrasound scan values can identify the athletes at risk and provide prevention and interventions strategies, such as lower limb load management, during sports. However, there is lack of evidence to support the implementation of these strategies. Consistent with the results of the current review, a systematic review concluded that the presence of structural abnormalities, such as high-intensity zones on MRI, could predict future symptoms of lower back pain (LBP).[29]

Different clinical modalities, such as ultrasound and MRI, have been used in many academic and clinical discussions.[30] However, there is lack of direct relationship between tendon structural disorganisation and clinical symptoms, with images potentially producing confusing clinical pictures.[31] Similarly, asymptomatic populations have structural abnormalities in the tendons. Yépez et al. studied structural changes in asymptomatic soccer players and concluded that there was no correlation of these changes and clinical features of femoroacetabular impingement syndrome.[32] However, evidence suggests that unnecessary imaging can actually lead to adverse and negative effects on patients' health and behaviour.[33] One study showed that low-risk patients with LBP gave poor results in overall clinical outcomes (pain and individual health) after imaging, whereas patients without imaging procedures had better clinical outcomes.[34]

The current review showed the same ultrasound methods being applied to visualise tendon structural abnormalities. Most studies followed the Musculoskeletal Ultrasound Technical Guidelines: Knee, defined by the European Society of Musculoskeletal Radiology.[35] These uniform methodologies warrant the uniformity of scientific results and facilitate comparisons and analysis. The standard protocol used for ultrasound scanning includes position of the patient, scan direction, side of the tendon and area of interest. For ultrasound readings in research settings, unilateral scanning is sufficient. However, sometimes contralateral asymptomatic tendon exhibits symptoms of tendinopathy.[36] Therefore, in clinical practice, bilateral scan is recommended. This helps the clinicians to assess tendon irregularities to prevent future occurrence of tendinopathy.

Limitations

The current review comprised only studies demonstrating the role of traditional ultrasound. A newer modality, the UTC, or sonoelastography, is gaining importance in tendon disorder management and may prove to be revolutionary in terms of providing high-resolution insight into the tendon structure and providing objective measures of tendons compared to the traditional ultrasound. Only one of the studies reviewed had used

UTC as the modality of choice. Similarly, MRI is commonly used to check tendon abnormalities. Another limitation is the use of variety of terminologies to explain "abnormal tendon". This can lead to overestimation or underestimation of future clinical symptoms development. Another limitation is the inclusion of only athletic population, given the high prevalence of tendinopathies in non-athletic population.

Conclusion

There was found to be a substantial role of ultrasound imaging in predicting the onset of future Achilles' and patellar tendinopathies. These findings are potentially important and can be used to prevent and treat tendon disorders. However, there is only moderate association between both factors of tendon abnormalities and future occurrence of clinical symptoms. Similarly, asymptomatic population has high prevalence of tendon abnormalities. So, in predicting overall clinical picture of tendinopathy, one element should be ultrasound imaging. Combining the examination of the tendon imaging with other factors associated with the onset of pain, such as training loads and psychosocial health, may improve the management related to the prediction of Achilles' or patellar tendinopathy.

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