Review Article

Quadriceps tendinopathy: a review—part 1: epidemiology and diagnosis

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Contributions: (I) Conception and design: All authors; (II) Administrative support: All authors; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Abstract: Overuse injuries of the extensor mechanism of the knee are common in both athletes and non-athletes and usually occur during activities associated with repetitive loading, stress, and knee extension. Historically, they have been labeled as Jumper's knee due to the high prevalence seen in the athletic community. In many published reports, the name "patellar tendinopathy" is used to describe this disorder of the quadriceps tendon at the patellar insertion, and the names are often used interchangeably. Numerous reports have been published describing extensor mechanism injuries in athletes, but there is a paucity of studies that focus on quadriceps tendinopathy. In addition, there is no universally accepted classification system for tendon pathology. Therefore, we performed a comprehensive literature review of these studies. This review consists of 2 parts. In the first part we review: (I) epidemiology and (II) diagnosis of quadriceps tendinopathy in the athlete as well as the general population. In the second part we discuss: (I) classification; (II) prognosis; and (III) treatment results.

Keywords: Quadriceps; tendinopathy; epidemiology; diagnosis

Submitted Jan 23, 2019. Accepted for publication Jan 25, 2019.
doi: 10.21037/atm.2019.01.58
View this article at: http://dx.doi.org/10.21037/atm.2019.01.58

Introduction

Anterior knee pain is a very common problem seen in the outpatient clinics focused on musculoskeletal disorders, which has a broad differential, and may be often generalized by practitioners as chondromalacia patella and/or patellofemoral syndrome (1). However, quadriceps tendinopathy is an important cause of anterior knee pain, that is most commonly seen in athletes due to chronic degenerative tendon changes from repetitive loading, stress, and extension of the knee (2-5). It is often found co-existing with patellar tendinosis, which most commonly involves the tendon distally, but also the quadriceps muscle proximally. Historically, both entities have been labeled as Jumper's knee due to the high prevalence seen in athletes, and both have often been treated in a similar manner due to their similarity (2,5-9). In many published reports, the name "patellar tendinopathy" is used to describe tendinopathy of the quadriceps tendon. More recently, an association of anterior knee pain and patellar tendinosis in community-based non-athletic patients, who have an increased body mass index (BMI) was found (10). These findings highlight the importance of surveillance of this entity as a cause of anterior knee pain in the non-athlete population.

Quadriceps tendinopathy is a clinical diagnosis characterized by activity-related anterior knee pain with localized tenderness at the superior border of the patella. Multiple authors have developed classification

schemes which correlate persistence of symptoms with activity levels and have categorized them into early and late stages (5,11,12). The use of diagnostic imaging such as radiographs, magnetic resonance imaging (MRI), and various forms of ultrasound such as grey-scale, high resolution, color Doppler, and elastography have been studied extensively in athletes (13-18). It is not uncommon for asymptomatic athletes to have structural changes within tendons, however, symptomatic patients have consistently revealed morphologic changes of localized tendon thickening, hypoechoic areas, and increased vascularity (13,14). While conventional imaging modalities detect tendon structural changes, a strong link between structural changes and clinical symptoms does not exist (19,20). The need for future correlative imaging studies to assess structural changes might prove invaluable for the diagnosis and management of these disorders.

Historically, management of quadriceps tendinopathy has been based on the classification systems of Blazina, Roels, and Ferretti which correlated treatment based on the stage of symptoms. It is initially managed non-operatively. In the earlier stages of quadriceps tendinopathy, this approach has shown superior outcomes compared to surgical treatment, which is typically reserved for later stages and/or patients who have failed first-line non-operative measures (4,9,12,21,22). In addition, injections of platelet rich plasma (PRP) and sclerosing agents such as polidocanol have shown symptomatic relief in those who have failed first line conservative measures (23-26).

To the best of our knowledge, there is limited literature focusing directly on quadriceps tendinopathy, especially in the non-athlete population. In addition, there is a clear demand for both a gold standard in diagnostic imaging, as well as the need for a standard classification system for this and all tendon pathologies. Therefore, we performed a comprehensive literature review of these studies. This review consists of two parts. In the first part we review: (I) epidemiology and (II) diagnosis of quadriceps tendinopathy in the athlete as well as the general population. In the second part we discuss: (I) classification; (II) prognosis; and (III) treatment results.

Methods

A comprehensive literature search using PubMed, EBSCO Host, and SCOPUS was performed for this review of quadriceps tendinopathy. We searched studies from January 1977 to January 2017.

We used various combinations of the following terms to perform the search: [quadriceps tendinosis] [quadriceps tendonitis], [quadriceps tendinopathy], [patellar tendinosis], [patellar tendinopathy], and [jumper's knee].

We reviewed 106 abstracts to determine reports that might be appropriate and identified 62 potentially relevant studies for further evaluation. We excluded 26 reports that were not in English or not relevant to the current topic. We excluded 7 studies performed on animal subjects. We then assessed the references of reports and found an additional 5. Therefore: 34 studies were included in the final review.

Results

Epidemiology

Multiple studies have demonstrated quadriceps tendinosis in patients due to high stress and repetitive loads on the extensor mechanism of the knee (*Table 1*). A retrospective study of 613 athletes by Lian *et al.* (7) examined the prevalence of jumper's knee across 9 different sports.

Overall prevalence of jumper's knee was seen in 14.2% athletes. In addition, 8% reported previous symptoms, suggesting a prevalence of current or prior symptoms in 22%. The highest prevalence was seen in sports associated with high impact ballistic loading of the knee extensors: volleyball (44.6%), basketball (31.9%), while there were no cases in cycling (P<0.001). Lowest prevalence was seen in combined team handball and soccer in both men (13.5%) and women (5.6%; P=0.042). Athletes who had current jumpers knee had a higher mean weight (83.6 *vs.* 77.3 kg; P<0.001), were taller (186 *vs.* 181 cm; P<0.001), and were involved in significantly more weight training (3.5 *vs.* 2.5 hrs/wk; P<0.001), as well as jump training (1.1 *vs.* 0.5 hrs/wk; P<0.001).

A cross sectional survey by Zwerver *et al.* (2) evaluated the prevalence and risk factors of jumper's knee in 891 non-elite athletes across 7 different sports. Overall prevalence of jumper's knee was 8.5%, with the highest prevalence seen in volleyball players at 14.4%, followed by handball 13.3%, basketball 11.8%, track and field 6.9%, field hockey 5.1%, korfball 4.8%, and soccer 2.5% (P=0.001). Higher prevalence's were seen in males (10.2%) compared to females (6.4%; P=0.048). Risk factors associated with jumper's knee included younger age (23 *vs.* 24 years; P=0.002), taller height (185 *vs.* 181 cm; P=0.002), and higher weight (77.4 *vs.* 73.6 kg; P=0.06).

A retrospective study of 176 non-athlete patients in

Table 1 Epidemiology of tendinopathy

Reference	Level of evidence	Number of patients	Application	Results/findings
Epidemiology of tendinopathy				
Toppi *et al.* (27), 2015	II	176 middle age woman without significant knee pain	Determine prevalence of MRI defined patellar tendinopathy, identify RF, if PT associated with knee pain in community based non-athletic population. 176 patients with 2-year follow up	Univariate analysis demonstrated higher levels of physical activity and greater vastus medialis cross sectional areas 1,130 *vs.* 1,047 mm^2 were associated with increased prevalence of patellar tendinopathy that was independent for age and BMI (P=0.02). At two year follow up 148 women had MRI's demonstrating that 46 of 148 (31%) had of patellar tendinopathy at baseline. Persistence of patellar tendinopathy was observed in 20 of 46 (43.5%) participants and was associated with worsening of knee pain (P=0.04)
Fairley *et al.* (28), 2014	II	297 patients with no hx of knee pain	Cross sectional study. Determine prevalence of MRI defined patellar tendinopathy in community based asymptomatic adults to evaluate if any association of PT with obesity and body composition	MRI defined patellar tendinopathy was positively associated with current or past history of obesity, and is common in a community setting with a prevalence of 84 of 297 (28.3%) patients (P<0.001). A higher prevalence of patellar tendinopathy was seen with current heavier weight at 78.9 *vs.* 71.3 kg (P<0.001), history of heavier weight at younger age at 64.3 *vs.* 59.2 kg (P<0.001), heaviest lifetime weight of 78.7 *vs.* 71.1 kg (P<0.001), as well as a higher BMI with 27.2 *vs.* 25.4 kg/m^2 (P=0.001)
Zwerver *et al.* (2), 2011	II	891 non-elite athletes	Determine the prevalence and risk factors of jumper's knee in male and female non-elite athletes across 7 different sports: basketball, volleyball, handball, korfball, soccer, field hockey, and track and field. Cross sectional survey Questionnaires with age, sex, BMI, height, weight, sport history and sporting per week	Overall prevalence of jumper's knee was 76 of 891 (8.5%) athletes. The highest prevalence seen in volleyball 22 of 76, handball 14 of 76, and basketball 15 of 76, and the remaining track and field 10 of 76, field hockey 5 of 76, korfball 7 of 76, and the lowest prevalence in soccer players 3 of 76 (P=0.001). Highest prevalence was seen in males 51 of 502 (10.2%) *vs.* female athletes in 25 of 389 (6.4%) (P=0.048). Risk factors associated with jumper's knee included younger age 22.8 *vs.* 24.1 years (P=0.002), taller height 185 *vs.* 181 cm (P=0.002), and those who weighed more 77.4 *vs.* 73.6 kg (P=0.06)
Lian *et al.* (7), 2005	II	613 elite athletes	Determine the prevalence of jumpers' knee in elite male athletes across 9 different sports: high jump, 100/200 m sprint, basketball, ice hockey, volleyball, orienteering, road cycling, soccer, team handball, wrestling. Female athletes from handball and soccer were examined	Overall prevalence of current jumpers' knee 87 of 613 (14.2%), previous reported symptoms in 51 (8%) suggesting a prevalence of 138 (22.5%). Highest prevalence seen in volleyball at 44.6%, basketball 31.9%. Low prevalence in females with 6 team handball and soccer compared to corresponding male sports with a prevalence of 18 (P=0.042). Athletes who had current jumpers knee weight more 83.6 *vs.* 77.3 kg, were taller 186 *vs.* 181 cm, and were involved in significantly more weight training 3.5 *vs.* 2.5 hrs/wk as well as jump training at 1.1 *vs.* 0.5 hrs/wk, (P<0.001). Highest prevalence in high impact ballistic loading of the knee extensors

Table 1 (*continued*)

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Reference	Level of evidence	Number of patients	Application	Results/findings
Diagnostic imaging in tendinopathy				
Docking *et al.* (19), 2016	I	91 patients Achilles or patellar tendons	Used UTC to evaluate the overall structure and cross sectional areas of pathologic and normal tendons	Pathologic tendons demonstrated increased mean cross sectional areas at 99.1 *vs.* 83.6 mm² Achilles tendon, and 154.9 *vs.* 130.8 mm² for patellar tendons (P≤0.005), as well as larger AP diameters 8.4 *vs.* 6.5 mm Achilles and 7.8 *vs.* 6.0 mm for patellar tendons (P≤0.005). compensate for areas of disorganization
Ooi *et al.* (29), 2016	II	35 patients: 70 patellar tendons	Comparing diagnostic performance of grey scale US, PD US, and US elastography for diagnosing painful patella tendinopathy	US elastography had higher diagnostic accuracy compared to grey-scale and power Doppler alone, the combination of elastography and grey-scale US had the highest sensitivity and accuracy of 82.5% and 61.4% compared to combination of PD and grey-scale with 72.5% and 60.0%. Tendons classified as soft on elastography had significantly greater patellar AP thickness with means of 3.9mm *vs.* 3.8mm on grey-scale (P<0.001) and lower VISA-P scores compared to those labeled as hard 77 *vs.* 89 (P<0.004)
Cassel *et al.* (13), 2015	II	760 adolescent athletes	Determine prevalence of symptoms and morphologic changes of patellar and Achilles tendons in adolescent athletes using high resolution US and power Doppler US. 1,516 AT, 1,512 PT	Symptomatic patellar tendinopathy had a higher rate of hypoechogenicities, hyperechogenicities and vascularization's within tendons compared to asymptomatic tendons at 17 (43.5%) *vs.* 35 (2.5%) (P<0.001). The patellar tendinopathy group had increased tendon thickness compared to healthy tendons at 3.8±0.7 *vs.* 3.5±0.5 mm (P=0.01). Patellar tendinopathy had higher anthropometric values compared to healthy subjects in regards to age of 14.2±2.1 *vs.* 12.9±1.8 years, height of 166±13 *vs.* 160±13 cm, and weight of 59±18 *vs.* 50±12 kg (P≤0.003).
Masci *et al.* (30), 2015	II	9 patients with chronic Achilles tendinopathy	Evaluate the use of ultrasound tissue characterization (UTC in detecting and monitoring tendon structural changes in patients who underwent plantaris tendon removal and Achilles tendon scraping	The use of UTC is a valuable tool for detecting structural changes and monitoring healing processes. At 6 month follow up, UTC released significant increase in tendon structural organization 88.33 to 91.33 (P<0.001) as well as increased VISA-A scores from 56.8 preoperatively to 93.3 postoperatively 33 (P<0.001)
Visnes *et al.* (14), 2015	I	158 total patients, 141 asymptomatic, 17 symptomatic	Assessing relationship between development of ultrasound changes in patellar and quadriceps tendons in asymptomatic athletes and the development of symptomatic tendinopathies	Ultrasound findings of hypoechoic areas and neovascularization at baseline were determined to be risk factors for developing symptoms of jumper's knee (OR 3.3, 95% CI: 1.1–9.2. Males with increased proximal and mid-portion quadriceps tendon thickness at baseline went on to develop symptoms with proximal 5.0±0.2 mm, mid-portion 4.6±0.2 mm *vs.* asymptomatic males with proximal 4.5±0.1 mm, mid-portion 4.3±0.1 mm (P=0.02)
Pappas *et al.* (15), 2016	II	24 asymptomatic patients	Determine the prevalence of pathologic MRI findings of knees in asymptomatic high level basketball players, before and after season using 3.0T MRI	They found MRI changes consistent with patellar tendinopathy in 20 (83%) preseason and 19 (90%) postseason images and quadriceps tendinopathy in 18 (75%) preseason and 19 (90%) postseason images, although these changes were not significant (P=0.34 and P=0.17)

Table 1 (*continued*)

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Reference	Level of evidence	Number of patients	Application	Results/findings
Giombini *et al.* (16), 2013	I	37 patients	Determine if asymptomatic gray scale ultrasound changes of quadriceps, patella and Achilles tendons in elite fencers, modify over time, are related to development of symptoms and functional impairment. Relationship between US abnormalities, neovascularity, and pain	Structural changes only with abnormal labeled patellar tendons at baseline were more likely to develop symptoms (P<0.05) compared with that of Achilles, and quadriceps tendons which were not predictive of future symptoms or change in functional status over 3 years
Comin *et al.* (17), 2012	II	79 patients	79 ballet dancers Achilles and patellar tendons evaluated by US measuring proximal/distal tendon diameters to assess for hypoechoic change, intra-tendon defect, calcification and neovascularity. Followed over 24 months	Sonographic abnormalities common among dancers. Baseline ultrasound changes consisting of focal moderate to severe hypoechoic changes were present in 19 of 79 patellar and Achilles tendons of which only 3 of 7 (43%) from both tendon groups were found to be weakly predictive of tendon related disability (P=0.0381)
van Schie *et al.* (31), 2010	II	26 patients	Evaluate the use of UTC in quantifying human tendon structural changes and discriminate between asymptomatic and symptomatic tendons	Symptomatic tendons revealed less three-dimensional stability echo pattern: 51.5% *vs.* 76.6% (P<0.001). Symptomatic tendons had greater thickness 9.2 *vs.* 6.8 mm (P<0.001). UTC can quantitatively evaluate structural tendon changes and differentiate symptomatic and asymptomatic tendons
Bashford *et al.* (32), 2008	II	20 patients	Evaluate the use of Ultrasound B-mode images on quantification of tendon structure in symptomatic and asymptomatic Achilles tendinopathy	Structural tendon changes detected with 80% accuracy
Pfirrmann *et al.* (18), 2008	I	61 patients	Assess the frequency of quadriceps and patellar tendinosis in professional beach volleyball players comparing dominant leg and contralateral leg, and to correlate ultrasound findings with clinical symptoms	Quadriceps Tendinosis is as common as patellar Tendinosis in professional beach volleyball players; only the structural changes found in the quadriceps tendons were predictive of anterior knee pain. The mean quadriceps tendon thickness for dominant and non-dominant legs in athletes with tendinopathy was 8.4 and 8.5 mm compared to normal tendons of 6.4 and 6.4 mm (P<0.001 for both). Abnormal echo texture in quadriceps tendons was found in 11 of 18 (61.1%) dominant legs and 16 of 26 (61.5%) non-dominant legs, only the findings in the dominant leg were significant (P=0.001). Positive power Doppler signals within quadriceps tendons with means of 0.3 and 0.4 for dominant and non-dominant legs, and were significant only for dominant legs (P=0.049 *vs.* 0.346). Calcifications in quadriceps tendons with means of 0.9 in dominant leg and 1.1 non-dominant legs and were only significant in non-dominant legs (P=0.049 *vs.* 0.864)
Warden *et al.* (33), 2007	I	63 patients	30 patients clinically diagnosed patellar tendinopathy, 33 control. Determine accuracy of MRI *vs.* US in diagnosis PT	They found the diagnostic accuracy of grey-scale US to be 83% *vs.* 70% with MRI (P=0.04). Sensitivity of Grey-scale US was higher than MRI at 87% *vs.* 57% (P=0.01). No significant difference was found in grey-scale US and color Doppler sensitivity at 70% *vs.* 87% (P=0.06) and specificity at 94% *vs.* 82% (P=0.10)

MRI, magnetic resonance imaging; RF, risk factor; PT, physical therapy; BMI, body mass index; UTC, ultrasound tissue characterization; AP, anterior-posterior; OR, odds ratio; CI, confidence interval.

a community setting at two-year follow up performed by Toppi *et al.* (27) examined the prevalence of patellar tendinopathy defined by MRI, risk factors, and association of patellar tendinopathy with pain. Overall prevalence of MRI-defined patellar tendinopathy was 30.1%. Univariate analysis demonstrated that higher levels of physical activity and greater vastus medialis muscle cross sectional areas (1,130 *vs.* 1,047 mm^2) were associated with an increased prevalence of patellar tendinopathy that was independent of age and BMI (P=0.02). A total of 148 women had MRIs at two year follow up, of which 31% had patellar tendinopathy at baseline. Persistence of patellar tendinopathy was observed in 43.5% and was associated with worsening of knee pain (P=0.04). A study of 297 non-athlete asymptomatic patients of ages between 50 and 79 years by Fairley *et al.* (28) demonstrated that MRI-defined patellar tendinopathy was positively associated with a current or past history of obesity, and was common in a community setting with a prevalence of 28.3% (P<0.001). Higher prevalence's of patellar tendinopathy was seen with taller heights (170 *vs.* 167 cm; P<0.001), current heavier weight at 78.9 *vs.* 71.3 kg (P<0.001), history of heavier weight at younger ages (18 to 21 years old) at 64.3 *vs.* 59.2 kg (P<0.001), heaviest lifetime weight of 78.7 *vs.* 71.1 kg (P<0.001), a higher BMI (27.2 *vs.* 25.4 kg/m^2; P=0.001), as well as in males compared to females (54% *vs.* 46%; P<0.001). Furthermore, fat free mass and fat mass measurements were obtained in 78% of participants. A higher prevalence of patellar tendinopathy was seen in patients with a higher fat free mass (52 *vs.* 44 kg; P<0.001), however, there was no significant difference in fat mass between the two groups (28 *vs.* 26 kg; P=0.21).

In summary, quadriceps tendinopathy has been extensively studied in the athletic population. More recent studies reveal quadriceps tendinopathy does exist in non-athlete patients in a community setting, and there are associations linked to obesity, overall heavier weights, and increased height. There is a clear need for further studies to identify risk factors and prevalence of quadriceps tendinopathy in the non-athlete population.

Diagnostic imaging

The use of diagnostic imaging including radiographs, MRI's and various types of ultrasound techniques, such as grey-scale, high resolution, color Doppler, and elastography, have been studied extensively (16,17). The use of radiographs may demonstrate degenerative changes such as patellar pole elongation from osteophyte formation, as well as tendon calcifications (11,34). Structural changes within tendons may often be found in asymptomatic patients, which pose a challenge when predicting who will possibly become symptomatic.

A prospective study of 158 student volleyball players (312 tendons) performed by Visnes *et al.* (14) evaluated the relationship between hypoechoic changes and neovascularization within the patellar and quadriceps tendons and knee pain. They found that 16% of the asymptomatic athletes went on to develop activity-related anterior knee pain. Ultrasound findings of hypoechoic areas and neovascularization at baseline were determined by multivariate logistic regression to be risk factors for developing symptoms [odds ratio (OR) 3.3, 95% confidence interval (CI): 1.1–9.2]. Compared to an asymptomatic group, symptomatic athletes had increased baseline ultrasound changes of hypoechoic areas (55% *vs.* 10%) and neovascularizations (48% *vs.* 4%). In the symptomatic group, increases from baseline hypoechoic areas (83 from 55%) and neovascularizations (74 from 48%) were observed at the time of diagnosis which persisted until the last examination. In addition, among asymptomatic males, for those who went on to develop symptoms, there was a larger mean baseline tendon thickness, when compared to those who remained asymptomatic (proximal 5.0 *vs.* 4.5 mm; P=0.02; mid-portion 4.6 *vs.* 4.3 mm; P=0.02). No changes in patellar tendon thickness were observed in athletes. Pappas *et al.* (15) used MRIs to evaluate structural changes of tendons before and after a season of basketball in 24 asymptomatic collegiate basketball players. A high prevalence of MRI changes was found in asymptomatic athletes; MRI changes consistent with patellar tendinopathy in 83% preseason and 90% postseason images and quadriceps tendinopathy in 75% preseason and 90% postseason images. However, these changes were not significant, and did not have a clinical correlation (P=0.34, P=0.17). These results highlight the need for further research on diagnostic imaging.

Pfirrman *et al.* (18) sonographically evaluated the patellar and quadriceps tendons of 61 professional volleyball players, of which quadriceps tendinosis was diagnosed in 34 (55.7%). They found that only thickening and structural changes found in the quadriceps tendons were predictive of anterior knee pain. Compared to the asymptomatic group, symptomatic athlete's had ultrasound changes consisting of increased mean quadriceps muscle tendon thickness (8.4 *vs.* 6.4 mm; P<0.001), loss of fiber visibility and hypoechoic areas in 16 (61%) of tendons (P=0.001), as well as a mean positive power Doppler signals of 0.3 (P=0.049).

Studies have also compared the diagnostic accuracy of different imaging modalities. A prospective study of 35 volleyball players (70 tendons) by Ooi *et al.* (29) found that the diagnostic accuracy of grey-scale US, power Doppler and US elastography for diagnosing patellar tendinopathy to be 60%, 50% and 62%, with sensitivities/specificities of 72.5%/43.3%, 12.5%/100%, and 70%/53.3%. The combination of elastography and grey-scale US had higher sensitivity (82.5% *vs.* 72.5%) and accuracy (61.4% *vs.* 60.0%), when compared to the combination of power Doppler and grey-scale US. A similar study by Warden *et al.* (33) evaluated 33 patients who had clinically diagnosed patellar tendinopathy and determined that grey-scale and color Doppler ultrasound were more accurate than MRI in confirming clinically diagnosed patellar tendinopathy. Compared to MRI, grey-scale US had a higher diagnostic accuracy (83% *vs.* 70%; P=0.04), as well as a sensitivity (87% *vs.* 57% P=0.01).

A retrospective study of 1,512 patellar tendons and 1,516 Achilles tendons from 760 adolescent athletes performed by Cassel *et al.* (13) determined the prevalence of tendinopathy, symptoms, and intratendinous changes of tendons using high resolution and power Doppler US. Symptomatic patellar tendinopathy had a higher rate of hypoechogenicities, hyperechogenicities and neovascularization within tendons compared to asymptomatic tendons (43.5% *vs.* 2.5%; P<0.001), as well as increased mean tendon thickness compared to healthy tendons (3.8 *vs.* 3.5 mm; P=0.01). Compared to healthy subjects, the patellar tendinopathy group had higher mean age (14.2 *vs.* 12.9 years), higher mean height (166 *vs.* 160 cm), and were heavier with mean weight (59 *vs.* 50 kg; P≤0.003).

New imaging modalities

Conventional imaging modalities have greatly improved the accuracy and sensitivity of detecting pathologic tendon changes. However, major limitations still exist in regard to the lack of a standardized classification scheme that correlates treatment protocols, as well as imaging that can quantify structural and mechanical properties. The need for future correlative imaging work to assess structural changes might prove invaluable for the diagnosis and management of quadriceps tendinopathy.

More recently, ultrasound tissue characterization (UTC) was developed for veterinary use to quantify tendon integrity of horses, with results validated by equine tendon histology (35,36). It's use in humans has been also reported in several studies (37-39). UTC utilizes images over the length of the tendon to quantified three-dimensional stability. A case-control study by van Schie *et al.* (31) evaluated the use of UTC for quantifying the tendon structure in twenty-six human Achilles tendons with midportion tendinopathy. Based on algorithms created from equine studies, UTC stability echo patterns were assigned 4 different echo types: (I) highly stable; (II) medium stable; (III) highly variable; and (IV) constant low intensity and variable distribution. Type I and II structural echoes were characterized as stable, whereas, types III and IV were characterized as having a lack of stability. Compared to symptomatic tendons, asymptomatic tendons revealed a higher percentage of type I and II stability echo patterns (76.6% *vs.* 51.5%; P<0.001), and lower unstable type III and IV patterns (23.4% *vs.* 48.4%; P<0.001). Symptomatic tendons also demonstrated a greater thickness compared to the asymptomatic tendons (9.2 *vs.* 6.8 mm; P<0.001). In the symptomatic group, 3 of the tendons had normal tendon structure, and 6 of the asymptomatic tendons had abnormal structures. The accuracy of UTC quantification of tendon structures was determined to be 83%. Furthermore, this was the first study to determine the inter-observer reliability of ultrasound imaging which was at 0.92–0.95. However, this technique is relatively new, not commonly used, and has not been studied extensively in humans.

Among the different imaging modalities, ultrasound is a safe, inexpensive, and accurate tool that may be used in diagnosing quadriceps tendinopathy and helping to guide options for symptomatic relief. Although, structural changes may be found in asymptomatic patients, consistent changes are found within the tendons of symptomatic patients. Various forms of US can be used for this purpose including grey-scale, high resolution, color Doppler, and elastography, and UTC. To date, there is no gold standard imaging or classification scheme to guide treatment of tendinopathy. Development of an imaging based tendinopathy classification scheme would prove invaluable for diagnosis, management, and prognosis of quadriceps tendinopathy.

Acknowledgements

None.

Footnote

Conflicts of Interest: M Chughtai: Cymedica; DJ Orthopaedics;

Peerwell; Performance Dynamics Inc.; Refelection; Sage Products; Stryker. P Saluan: AAOS Now; Arthrex, Inc.; Equalizer, LLC; Middle Path Innovations, LLC; Pediatric Orthopaedic Society of North America.MA Mont: AAOS, Cymedica, DJ Orthopaedics, Johnson & Johnson, *Journal of Arthroplasty*, *Journal of Knee Surgery*, Microport, National Institutes of Health (NIAMS & NICHD), Ongoing Care Solutions, Orthopedics, Orthosensor, Pacira, Peerwell, Performance Dynamics Inc., Sage, Stryker: IP royalties, Surgical Technologies International, Kolon TissueGene. J Genin: Ferring Pharmaceuticals. The other authors have no conflicts of interest to declare.

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Cite this article as: King D, Yakubek G, Chughtai M, Khlopas A, Saluan P, Mont MA, Genin J. Quadriceps tendinopathy: a review—part 1: epidemiology and diagnosis. Ann Transl Med 2019;7(4):71. doi: 10.21037/atm.2019.01.58

