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NON-OPERATIVE MANAGEMENT OF ANTERIOR KNEE PAIN (M FREDERICSON AND T BESIER, SECTION EDITORS)

Physical Examination and Patellofemoral Pain Syndrome: an Updated Review

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Abstract

Purpose of Review Patellofemoral pain syndrome (PFPS) accounts for 25 to 40% of all knee disorders. Diagnosis of PFPS is primarily based on history and physical examination, but the findings on physical examination are often subtle and do not consistently correlate with symptoms described. Yoon and Fredericson published a review article in 2006 detailing the physical examination maneuvers most frequently used to assist clinicians in the accurate diagnosis and treatment of PFPS, and our aim in this review is to provide an update on this previous article focusing on the literature published over the past 15 years regarding the topic.

Recent Findings Since publication of Fredericson's original review article, there have been studies building on the literature specifically surrounding Q angle, patellar tilt, crepitus, strength and functional testing, and physical examination maneuver clustering. Additionally, multiple studies have been conducted on the use of musculoskeletal ultrasound (US) as a diagnostic tool for PFPS.

Summary Recent literature has further supported Q angle (when measured utilizing a standardized protocol), crepitus, weakness of hip abductors and extensors, and weakness detected in functional testing as predictors of PFPS while finding inconsistent evidence behind lateral patellar tilt as a predictor of PFPS. The reliability of most physical examination tests alone remain low, but clustering physical examination findings may provide better sensitivities and specificities in diagnosing PFPS. Musculoskeletal US is rapidly gaining popularity, and decreased vastus medialis obliquus (VMO) volume, asymmetry in gluteus medius thickness, intra-articular effusions, and quadriceps and patellar tendon thicknesses have shown value in diagnosing those with PFPS. Additionally, US has the advantage of providing dynamic examination as well as evaluation of the patellofemoral joint in newborns and infants as a predictor of future patellofemoral instability. Further studies are needed to establish the gold standard for diagnosing PFPS and what US findings are truly predictive of PFPS.

Keywords Patellofemoral pain syndrome · Anterior knee pain · Physical examination · Musculoskeletal ultrasound

This article is part of the Topical Collection on *Non-Operative Management of Anterior Knee Pain*

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Introduction

Patellofemoral pain syndrome (PFPS) is a common condition that accounts for 25 to 40% of all knee disorders [1••, 2–4]. The condition is multifactorial in origin and includes conditions previously referred to as chondromalacia patella and runner's knee [1••]. PFPS is defined as pain around or behind the patella aggravated by activities that load or compress the patellofemoral joint such as squatting, ascending and descending stairs, jumping, and running [2, 5–7]. Up to 78% of PFPS patients report chronic pain 5–20 years after rehabilitation [8–10], and a study of patellofemoral osteoarthritis (PFOA) patients waiting to undergo an arthroplasty showed that 22% of them described preceding PFPS in their adolescence and early adult years [11]. Emerging evidence has suggested that these two conditions are on a continuum [12] and that underlying biomechanical factors that may predispose to PFPS may also predispose to PFOA, such as weak hip abductors [13] and patella shape [14]. It is important to note here that biomechanical studies, including these two, are often cross-sectional so inherently can suggest association but cannot prove causation. Large cohort prospective studies would be required to prove causation. Either way, an accurate diagnosis of PFPS is imperative to begin appropriate management early in order to prevent lingering issues [1••].

Diagnosis of PFPS is primarily based on history and physical examination because although imaging can show signs of patellar maltracking and/or patellofemoral chondrosis suggestive of PFPS, these findings are often non-specific, and there are patients with completely unremarkable imaging who still have pain [1••]. Unfortunately, the findings on physical examination for the condition are often subtle and do not consistently correlate with symptoms described [15], and clinical studies have not always demonstrated biomechanical differences between patients with PFPS and healthy individuals [16–18]. However, a systematic physical examination can still call attention to factors that contribute to patellofemoral malalignment and thus be used to guide treatment [19].

Yoon and Fredericson published a review article in 2006 detailing the physical examination maneuvers most frequently used to assist clinicians in the accurate diagnosis and treatment of PFPS [19]. Our aim in this review is to provide an update on this previous article focusing on the literature published over the past 15 years regarding the topic. Since publication of Fredericson's original review article, there have been studies building on the literature specifically surrounding Q angle, patellar tilt, crepitus, strength and functional testing, and physical examination maneuver clustering. Additionally, musculoskeletal ultrasound (US) has become increasingly prevalent and available for clinicians and is considered an extension of the physical examination. We have thus included studies highlighting the utilization of US as a diagnostic tool for PFPS. This updated review will further assist clinicians in the accurate diagnosis and treatment of this common, yet difficult to accurately diagnose, disorder.

Methods

An extensive literature search was performed via MEDLINE based on the following keywords: patellofemoral pain syndrome, anterior knee pain, extensor mechanism disorder, lateral patellar compression, physical exam, muscle strength, Q angle, patellar tilt, patellar tracking, crepitus, and ligamentous laxity. The search included journal articles published between 2005 and 2021. A total of 368 articles resulted, and all their abstracts were reviewed. Emphasis was placed on those evaluating the description and reliability of physical exam maneuvers assessing anterior knee pain and patellofemoral pain syndrome. Articles that met these criteria were pulled from the Stanford Lane Online Library in their entirety and evaluated.

Updates on Physical Examination Findings and Maneuvers

Please refer to Table 1 for a summary of recent findings on the topics as discussed below.

Q Angle

The Q angle was first defined by Brattstrom [29] and is a measure of the patellar tendency to move laterally when the quadriceps muscle is contracted. The greater the angle, the greater this tendency that may predispose a patient to PFPS [19]. The Q angle is formed by the line connecting the anterosuperior iliac spine (ASIS) to the center of the patella and the line connecting the center of the patella to the middle of the anterior tibial tuberosity. Aglietti et al. previously cited normal values of 14° ± 3° for men and 17° ± 3° for women [30]. Grelsamer et al. found similar mean values of 13.3° for men and 15.7° for women. Interestingly, they also found that men and women of equal height demonstrated similar Q angles (with taller people having slightly smaller Q angles) so concluded that the slight difference in Q angles between men and women is more likely explained by the fact that men tend to be taller than women rather that the unproven explanation that women have a wider pelvis than men [20]. Either way, Q angle values in the past have been found to be highly variable which can be attributed to the lack of standardization when measuring the Q angle (e.g., standing versus sitting and quadriceps muscle activated versus quadriceps muscle relaxed) as well as examiner variance [30, 31]. This variability may explain the unclear relationship between a higher Q angle and PFPS as some studies have showed a clear relationship between a higher Q angle and PFPS [30], while others have failed to demonstrate a difference between patients with PFPS and healthy individuals [18, 19, 32].

The value of measuring the Q angle has been brought into question due to these inconsistent results [33] and has led to the development of the tibial tubercle to trochlear groove (TT-TG) distance which utilizes magnetic resonance imaging (MRI) rather than the physical examination to assess tubercle lateralization. However, lateralization of the tibial tubercle is still known to play a role in normal functioning of the patellofemoral joint, and the Q angle remains the only method to assess lateralization of the tibial tubercle without resorting to expensive, and perhaps unnecessary, imaging studies [34••]. Smith et al. [21] thus recommended establishing a "standardized clinical Q angle protocol."

In order to do this, Merchant et al. [34••] utilized a practical, standard protocol for measuring the Q angle. Subjects were placed supine, knees extended, and relaxed on the

Table 1 Update on studies for patellofemoral pain syndrome (PFPS) tests

Test	Reliability & validity	Comments	Source
Q angle	"Standard Q angle": mean of 14.8° with 95% CI) of ±5.4° for all, mean of 13.5° with 95% CI of ±5.2° for men, mean of 15.9° with 95% CI of ±4.8° for women. No significant difference between right and left knees of males or females. 2.4° difference between male and female means found to be due to the average height difference	30 men and 27 women without history of knee problems or family history of patellar dislocations. Both knees were measured on each subject	Merchant et al. [20]
Patellar tilt	Patellar tilt (LR+ = 5.4 and LR- = 0.6) to diagnose PFPS	Meta-analysis. 5 studies met criteria (one study had high methodological quality, two studies had good methodological quality, and two studies had low methodological quality)	Nunes et al. [21]
Crepitus	Crepitus was more common in women with PFPS (50.7%) compared to those without (33.3%) ($X^2 = 4.17$; $p = 0.031$)	65 women with PFPS and 51 pain-free women in study	de Oliveira Silva et al. [22]
Strength testing	The PFPS group had significant deficits compared to the control group in isometric strength (21-25%) for hip abduction (ES = 0.98) and extension (ES = 0.85)	16 with PFPS and 16 controls in study	Nunes et al. [23]
Functional testing	The PFPS group was 15% slower climbing stairs (ES = 0.90), performed 12% fewer chair stands (ES = 0.62), and forward hopped 20% shorter (ES = 0.79)	16 with PFPS and 16 controls in study	Nunes et al. [24]
Clustering	Cluster 1 showed sensitivity of 64% and specificity of 93% in diagnosing PFPS. Cluster 2 showed sensitivity of 56% and specificity of 96%	Study included 279 subjects, 75 of who had PFPS Cluster 1: < 40 yo and either isolated anterior knee pain or medial patellar facet tenderness Cluster 2: age 40–58 yo, isolated anterior or diffuse knee pain, mild to moderate difficulty descending stairs, medial patellar facet tenderness, and full passive knee extension	Decary et al. [1••]
VMO volume, insertion level, and fiber angle measured with US	All 3 measurements were significantly smaller in the PFPS group ($p < .05$). Multivariate analysis of variance has revealed a Wilks λ value of .845 and an F value of 5.640 ($p = .001$)	58 patients with PFPS included (31 with bilateral involvement ➔ 89 knees total)	Jan et al. [25]
Gluteus medius muscle thickness measured with US	15.9 ± 19.3% vs. 4.4 ± 21.9%, $p < 0.05$	PFPS patients (n=27) had significantly large left-right side imbalance in muscle thickness during activation	Payne et al. [26••]
Knees with PFP had a significantly higher prevalence of intra-articular effusion	$p = .018$	$N = 67$, with PFPS found in 54.5%. Population was young female dancers (7th graders)	Siev-Ner et al. [27]
Quadriceps and patellar tendon thickness measured with US	Quadriceps tendon thickness values of ≥ 0.54 cm were found to have 80% sensitivity and 71% specificity for PFPS diagnosis in the ROC curve analysis Patellar tendon thickness values of ≥0.35 cm were found to have 66.7% sensitivity and 67.7% specificity for PFPS diagnosis in the ROC curve analysis	n=61 (30 with PFPS, 31 controls) (28 men and 33 women; mean age: 30.79 ± 6.55 years)	Kizikaya et al. [28]

CI confidence interval, *US* ultrasound, *VMO* vastus medialis obliquus, *ROC* receiver operating characteristic, *ES* effect size examination table with the patella pointing up (anteriorly). The examiner then marked the center of the tibial tubercle with a small ink dot. Draper et al. [35] had previously found that measuring with a long-armed goniometer was more accurate than a short-armed one, so Merchant et al. used an eight inch plastic goniometer with an extendable long arm to reach the ASIS. The subject was asked to hold the long arm at his or her ASIS. The examiner then placed the goniometer pivot at the center of the patella and assured that the patella and goniometer pivot were centered over the distal femur at the trochlear entrance with one hand. Using the other hand, the Q angle was measured with the short arm of the goniometer. With this protocol for the "standard Q angle," the mean Q angle was 14.8° with a 95% confidence interval (CI) of ±5.4° for all subjects. For men, the mean was 13.5° with a 95% CI of ±5.2°, and for women, the mean was 15.9° with a 95% CI of ±4.8°. There was no significant difference between right and left knees of males or females, and the 2.4° difference between male and female means was found to be due to the average height difference between the two groups. Merchant et al. were thus able to provide a standardized Q angle measurement protocol to assess tibial tubercle lateralization without resorting to expensive imaging studies and provide a reliable reference for clinical comparison [34••].

Patellar Tilt

Excessive lateral tilt of the patella can lead to decreased medial patellar mobility and abnormally high forces between the lateral facet of the patella and the lateral trochlea of the femur [22]. The method of performing the patellar tilt test has been described by Grelsamer and McConnell [36]: the test is performed with the knee extended and the quadriceps relaxed with the patient in supine position. To determine the degree of medial and lateral patellar tilting, you compare the height of the medial patellar border with that of the lateral patellar border. The examiner places his or her thumb and index finger on the medial and lateral border of the patella, and both digits should be of equal height. The patella is laterally tilted if the digit palpating the medial border is more anterior than the digit palpating the lateral border and vice versa [19].

More recently, Nunes et al. performed a meta-analysis looking at the diagnostic accuracy of physical examination maneuvers to diagnose PFPS and found that two tests, the patellar tilt test and squatting, showed a trend for the diagnosis of PFPS. However, their statistical values did not represent clear evidence regarding diagnostic properties as suggested previously in the literature [37].

Crepitus

Crepitus is often present as a symptom or sign in patients with PFPS, but there is no close association between crepitus and pain. Previously, Johnson et al. [38] found that 94% of healthy women and 45% of healthy men studied exhibited patellofemoral crepitus. Oliveira Silva et al. observed that crepitus was more common in women with PFPS (50.7%) compared to healthy controls (33.3%). Women who presented with knee crepitus had four times greater odds to have PFPS compared to healthy controls. However, knee crepitus had no relationship with self-reported clinical outcomes of women with PFPS [39].

Muscle Strength

Quadriceps muscle weakness is commonly seen in patients with PFPS [23, 24, 40], as is weakness in hip abduction and external rotation [41]. More recent studies have continued to support this as Nunes et al. studied 32 physically active people (16 with PFPS, 16 controls) and found isometric strength deficits in hip abduction and extension in those with PFPS compared to those without [25].

In athletes, manual muscle testing does not consistently detect muscle strength deficits. Thus functional testing may be preferred. Previously Loudon et al. [26••] found that five different functional performance tests (anteromedial lunge, stepdown, single-leg press, bilateral squat, and balance and reach) to have high intra-rater reliability and to correlate with changes in pain scale. Nunes et al. recently tested patients with PFPS and controls with functional tasks and found that PFPS patients were slower climbing stairs, performed 12% fewer chair stands, and forward hopped 20% shorter [27]. This emphasizes the importance of both strengthening (of the core, hip girdle, and knee musculature) and neuromuscular retraining in the treatment of those with PFPS.

Clustering Physical Examination Findings

Since there is no single diagnostic test for PFPS, Merchant [28] previously recommended that the diagnosis be based on a cluster of objective findings from physical examination [19]. Decary et al. attempted to do this formally by looking at 279 patients, 75 of which had a diagnosis of PFPS (26.9%). They identified different diagnostic clusters combining elements from history and physical examination and found two with high specificities (93% and 96%, respectively) for the diagnosis of PFPS. Cluster 1 was age less than 40 years old and either isolated anterior knee pain or medial patellar facet tenderness. Cluster 2 was age 40–58 years old, isolated anterior or diffuse knee pain, mild to moderate difficulty descending stairs, medial patellar facet tenderness, and full passive knee extension. Interestingly, they also found three clusters with high sensitivities to exclude PFPS. Cluster 1 was age less than 58 years old; medial, lateral, or posterior knee pain; and medial or lateral patellar facet tenderness. Cluster 2 was age less than 58 years old, diffuse or lateral knee pain, medial or lateral patellar facet tenderness, and restricted passive knee extension. Cluster 3 was age 58 years old or older [1••].

Musculoskeletal Ultrasound

Musculoskeletal US has become increasingly prevalent and available in recent years, and there has been a good amount of literature published on its use as a diagnostic tool for PFPS. The use of US has the advantage of avoiding radiation, being non-invasive, and being easily performed in the clinic setting, all while having less of a financial burden than other advanced imaging modalities such as MRI. Many studies have looked at different ways to formally evaluate the patellofemoral joint and its different muscle attachments.

Jan et al. studied differences in sonographic findings of the vastus medialis oblique (VMO) in patients with PFPS and healthy adults. Jan et al. found that the insertion level, fiber angle, and VMO volume were all significantly smaller in the PFPS group than in the control group [42•]. Payne et al. measured gluteus medius muscle thickness at rest and during contraction in patients with PFPS and controls. Muscle activation was calculated as the percentage change between the two. Both of these variables were found not to be significantly different between those with PFPS and healthy controls. Interestingly, PFPS patients did have significantly larger left-right side imbalances in gluteus medius muscle activation than controls. Additionally, among those with PFPS, the magnitude of asymmetry of gluteus medius muscle activation correlated with knee pain scores [43••]. Nunes et al. also found no difference when comparing gluteus medius muscle thickness (and proportion of non-contractile tissue of the gluteal musculature) measured by US in PFPS patients versus controls [25]. Thus, asymmetry rather than the actual thickness of the gluteus medius muscle at rest and during contraction is what seems to be the main indicator of symptoms in patients with PFPS. Once again, causation cannot be inferred as these are cross-sectional studies. Siev-Ner et al. studied 67 young female dancers (54% diagnosed with PFPS) and found that patients with PFPS had a significantly higher prevalence of intra-articular effusions [44•]. Kizilkaya et al. measured quadriceps tendon thickness in patients with PFPS and controls and found that quadriceps tendon thickness of ≥0.54 cm had 80% sensitivity and 71% specificity for PFPS. They also measured patellar tendon thickness and found that patellar tendon thickness of ≥ 0.35 cm had 66.7% sensitivity and 67.7% specificity for PFPS diagnosis [45•].

In addition to convenience, US gives the clinician the added benefit of capturing dynamic measurements of the patellofemoral joint during knee movement. However, due to the complex multiplanar movement of the patella, only a few US methods have been studied. Shih et al. developed a method for dynamic tracking of the patella which has been the most studied. In this method, patients are fitted with a modified functional knee brace with a mounted ultrasound probe. The probe was placed perpendicular to the skin at the lateral edge of the superior border of the patella. Patella positioning was then measured by taking the distance between the patella and the lateral condyle of the femur. Using this measurement, the researchers were able to track the position of the patella and degree of movement during the knee's entire motion arc. They took measurements in several other knee movements such as squatting, stepping, and sitting and found significant differences in lateral tracking [46••, 47, 48]. They were able to validate their study comparing it to dynamic MRI and found good inter and intra-rater reliability [49, 50]. Unfortunately, the accuracy of the system was reduced near full knee extension, which can be problematic as the highest degree of patellar maltracking typically occurs with full knee extension [50]. Furthermore, if a patient has a patella that laterally displaces further than the femoral condyle, obtaining this measurement becomes extremely difficult.

To address this limitation, a novel but less proven US technique has been proposed by Bailowitz et al. In this method, the distance between the midpoint of the patella and the highest point of the lateral trochlear groove is used as a way to quantify lateral patellar displacement at full extension with quadriceps contraction [51••]. However, this study is still undergoing validation and has not been tested on symptomatic patients yet.

Another area where US can have a significant impact is in the evaluation of the patellofemoral joint in newborns or infants as a predictor of future patellofemoral instability. Due to lack of complete ossification of bones, radiographs are of limited value in this patient population, and MRIs are often difficult to obtain without high costs and sedation. Similar to how US has aided in the early identification of hip dysplasia, US is starting to be used to assess for patellofemoral dysplasia as well and shows promise as a screening tool for trochlea dysplasia. Both Oye et al. and Kohlhof et al. evaluated different ultrasonographic values and found that measurements including the trochlea sulcus angle, trochlea index, and lateral to medial trochlear facet ratio can all be accurately assessed by ultrasound with good reproducibility and low operator dependency [52, 53].

At this time, we do not feel that the use of US for the diagnosis of PFPS has been well-established enough to change standard clinical practice. Current limitations include validation of measuring methods and the ability to prove causation between certain US findings and PFPS. Additionally, musculoskeletal US remains operator dependent. This, however, should improve as more providers are being trained in its use. Once these limitations are addressed, routine US examination in office for patient with potential PFPS may be deemed useful in the future.

Conclusions

We have provided an updated review on Fredericson's previous article on the most common methods for the clinical diagnosis of PFPS. Recent literature has further supported Q angle (when measured utilizing a standardized protocol), crepitus, weakness of hip abductors and extensors, and weakness detected in functional testing as predictors of PFPS while finding inconsistent evidence behind lateral patellar tilt as a predictor of PFPS. The reliability of most physical examination tests alone remain low and can be variable, but there has been more evidence showing that clustering physical examination findings may provide better sensitivities and specificities in diagnosing PFPS. Musculoskeletal US is rapidly gaining popularity among clinicians and is a major area to build upon in the diagnosis of PFPS. Some studies have shown decreased VMO volume, asymmetry in gluteus medius thickness, intra-articular effusions, and quadriceps and patellar tendon thicknesses to have value in diagnosing those with PFPS. Additionally, US has the advantage of providing dynamic examination of the patellofemoral joint as well as evaluation of the patellofemoral joint in newborns and infants as a predictor of future patellofemoral instability. The clinical diagnosis of PFPS remains difficult even as we develop more reliable methods of measuring anatomical structures and function because of our inability to directly measure pain. Also as noted earlier in the paper, the majority of studies on PFPS are cross-sectional, which inherently can show association but not causation. Further studies, especially those that are longitudinal in design, are needed to establish the gold standard for diagnosing PFPS and what US findings are truly predictive of PFPS.

Declarations

Human and Animal Rights and Informed Consent This article does not contain studies with human or animal subjects performed by any of the authors.

Conflict of Interest Donald Kasitinon, Wei-Xian Li, Eric Xue Song Wang, and Michael Fredericson declare that they have no conflicts of interest.

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