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General

# Understanding the patho-anatomy of patellofemoral pain: A crucial foundation for comprehensive management

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Patellofemoral or anterior knee pain is a common cause of medical evaluation around the globe. It affects one in four individuals and is more frequent in females. It is considered a multifactorial disease in which conservative management must focus on the alterations found in the physical exam and radiologic images. Recurrence is high, as 39-40% of the patients continue with symptoms in one year of follow-up. Surgical management should be considered when symptoms persist after six months of conservative measures and when evident malalignments are identified. This article aims to establish and summarize the possible causes, involve the importance of the physical examination and the radiologic images suggested, as to consider the different treatment options that may be used to treat such a frequent and irregular pathology.

## INTRODUCTION

Knee pain is the second most frequent reason for medical evaluation regarding the musculoskeletal system, it encompasses various conditions affecting all age groups, with natural joint wear becoming predominant in older adults.[1,2]

Among individuals aged 15 to 30, a common diagnosis is patellofemoral pain, also known as chondromalacia or anterior knee pain, which has a prevalence of 45% with a significant predominance in females.[2] This condition is defined as a 'self-reported' pain of insidious onset due to overuse or misuse of the knee in the areas surrounding the patella. It is exacerbated when performing activities involving a load or a prolonged position with the knee in flexion.[3] It is usually diagnosed by exclusion, and if not managed promptly, it often progresses to diffuse and insidious pain.[4] Gaitonde et al.[5] have described a difference between patellofemoral pain and chondromalacia, in which chondromalacia has a radiographic chondral alteration seen in Magnetic Resonance, or it is seen directly through knee arthroscopy showing chondral softening in the patellofemoral joint. If malalignment is identified, the presence of symptomatology is related, but the degree of pain is variable.[4]

The pathophysiology of the condition has been reconsidered, attributing it to inappropriate training and high-demand and periodic physical activities where anatomical and mechanical structures directly impact the functioning of the joint.[2,3] Numerous studies attempt to link the condition with anatomical and mechanical structures related to the functioning and kinematics of the patellofemoral joint. There are four leading causes[1]: muscular imbalance that alters the biodynamics of the lower extremities,[2] patellar malpositioning that causes compression of the patellar articular facet,[3] impairment of proprioception, and[4] inflammation of soft tissues that could cause the symptomatology.[6-9]

Treatment is usually focused on strengthening the vastus medialis, the use of taping or orthoses, and some authors consider adding psychological management when mental health scales are altered.[10-12] Surgical intervention is rarely offered and is considered when there is no improvement with conservative management, finding chondral lesions 60% of the time. Inadequate management significantly increases the risk of developing patellofemoral osteoarthritis.[4,10,13]

Despite the high prevalence and different treatment modalities, the management of patellofemoral pain remains a significant challenge as it has a multifactorial etiology with mechanisms yet to be fully understood, highlighting the need for further research and innovation.[14-16] The objective of this review was to analyze the anatomical and functional variabilities (muscle imbalance, radiographic measure) to help in the correct diagnosis and appropriate treatment of patients with anterior knee pain.

## METHODS

A search strategy was designed by the authors. A combination of MeSH terms and keywords such as "knee pain", "patellofemoral syndrome", "patellofemoral pain syndrome", and "patellofemoral joint" were selected to find any type of manuscript. MEDLINE, Embase, Web of Science, and Scopus databases were searched from inception to May

2024, the search was manually completed to obtain additional relevant manuscripts from other sources. We included only manuscripts in the English language.

## EPIDEMIOLOGY

Patellofemoral pain is the most common reason for consultation among active young adults, with 19.4 million visits annually in the United States and 100,000 in the United Kingdom, generating expenses of nearly 213 billion dollars for therapeutic management and work disability.[2,13,17] It usually affects 1 in 4 individuals in the general population and is estimated to have an incidence of 22 per 1,000. The disease is more frequent in women, as its rate is 1.25 to 2.3 above men's. Two-thirds of those women perform regular sports activity, and one-third are not physically active.[1,4,18]

As 70% of patients with the disease are between 16 and 25 years old, universities and sports centers report that 8.5 to 25% of their students seek evaluation for this problem. It accounts for 35% of the chief complaints for orthopedic consultations of cyclists, 46% of runners, 15% of basketball players, and 25% of athletes.[2,4,18]

## ANATOMY AND BIOMECHANICS

Our anatomical focus is based on the patellofemoral joint, which comprises the patella and the femoral trochlea. The patella is the longest sesamoid bone in the body and is embedded in the substance of the quadriceps tendon. It acts as a fulcrum, improving the quadriceps strength by 33-50%, performing extension and control of knee flexion.[19]

The femur bone has two condyles that serve as stabilizers to prevent patellar dislocation. In an axial view, they have a difference of 3.4 mm in the posteroanterior measurement, the lateral condyle being the most prominent. Between both condyles, there is a depression of 5.2 mm called the femoral groove or trochlea.[10]

The quadriceps is composed of the union of the rectus femoris, the vastus medialis, and lateralis, in conjunction with the vastus intermedius. The vastus medialis is considered the primary dynamic restrictor, and its function is vital from 0 to 15 degrees of flexion to prevent lateral translation of the patella. The patellar tendon has a length of 3.5 to 5.5 cm. Its origin is the patella's inferior pole, and its insertion is in the tibial tuberosity.[10]

The joint has several stabilizers that prevent dislocation of the patella over the femoral trochlea, and they are classified as dynamic and static. The dynamic stabilizers are the quadriceps, the vastus medialis, the pes anserinus, and the biceps femoris. The static stabilizers are the patellar tendon, the medial patellofemoral ligament, the medial patellotibial ligament, the medial retinaculum, the lateral oblique retinaculum, the patellotibial band, the epicondyle patellar band, the lateral retinaculum, and the femoral condyles.[5,19,20]

The medial patellofemoral ligament is the most important static stabilizer, it originates proximal and posterior to the medial epicondyle and is inserted in the medial area of the patella. It restricts 53-60% of joint instability when the knee is between 0-30 degrees of flexion.[10,19]

Mechanically, the patella stabilizes as seen in **Table 1**.

The physiological valgus of the knee is 6-7 degrees. An increased valgus predisposes to a lateral displacement of the patella. Fulkerson and Hungerford refer to the "Valgus Law" as the two main forces acting on the patella being[1]: the force caused by the quadriceps vector and[2] the force caused by the patellar tendon vector.[21] The angle formed by these two vectors is called the Q angle **Figure 1**.

The average values are 14-15 degrees in men and 17-20 degrees in women; without gender distinction, it is considered 13.5 degrees +/- 4.5 degrees.[22] A higher value is related to a greater force and predisposition to poor patellar tracking. Some authors have found that a greater Q angle increases the neuromuscular reflex of the quadriceps, although it decreases the explosive force and vertical jump.[21, 23]

The flexion range that causes the most retro patellar stress is 20-90 degrees.[8,13] When the knee is at 20º of flexion, the patella exerts more pressure on the femoral condyle, and in those individuals who have a 10-degree increase in the Q angle, the joint stress between the patella and the femur increases by 45%.[24]

An objective form to measure and assess muscle activation and strength is the hamstring/quadriceps ratio, typically applied to athletes to determine readiness for demanding physical activity. It can be evaluated through concentric, eccentric, and isometric contraction. The expected value in healthy people ranges from 0.55-0.8. If there is a difference of ≥15% between the legs or the value is below 0.55 or above 0.98, the probability of injury increases by 4.66 times. The closer the value is to 0.8, the lower the risk of injury and the better the muscle is for physical demands.[25,26]

## PATHO-ANATOMY AND CLASSIFICATION OF PATELLOFEMORAL PAIN

It is crucial to distinguish the etiology of the pain when there is no related trauma. Generally, the cause of the pain is considered to come from the presence of patellar malalignment or patellar maltracking. Malalignment evaluates the relationship between the patella and the trochlear groove in a static position to determine if it is central, lateral, medial, high, or low. While evaluating the different relationships, they have reported that a high patella is associated with a greater joint compression force. Maltracking evaluates the abnormal translation of the patella with the trochlea in a dynamic position, so muscular forces such as those of the quadriceps have great relevance.[8,11,19]

As authors try to compare gender's possible factors to cause the pain, women have a propensity to a higher Q angle value, dynamic valgus, internal rotation of the hip/femur, an increase in the adduction force of the hip, and pronation of the foot with hypermobility of the patella and ligament laxity. They have a propensity for more weakness in the strength of the quadriceps, external rotators, extensors, and hip abductors.[18,21] Fulkerson et al.[27] identified

**Table 1. Stabilization of the patella during knee flexion.**

| Angle of knee flexion | Stabilization characteristics | Study |
|---|---|---|
| **Rest with extension** | Patella rests on the suprapatellar fat. | 10,20 |
| **0-30 degrees** | The set of the vastus medialis and the medial patellofemoral ligament gives its stabilization. The anchoring to the trochlea occurs at 20 degrees. | 10,19, 20 |
| **30-90 degrees** | The articular contact increases, and close to 90 degrees, the articular stress is absorbed. | 10,19 |
| **90-130 degrees** | Only some portions of the facets come into contact with the femoral groove, with an increase in the compression force that can increase up to eight times the body weight. | 10,20 |

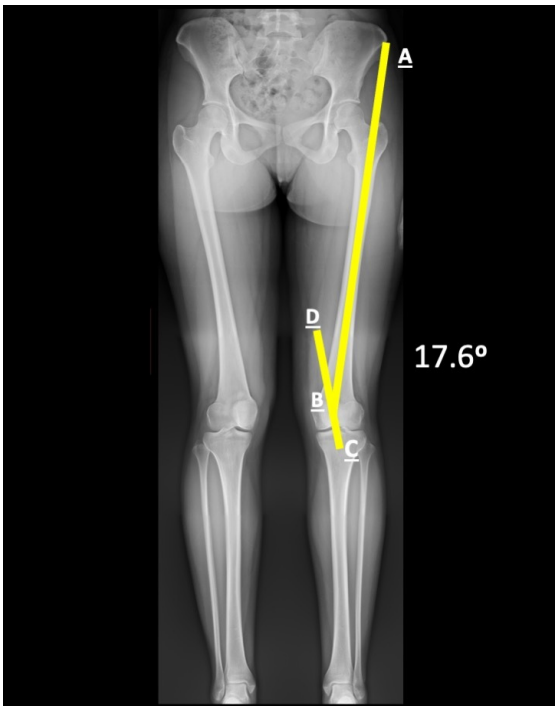


**Figure 1. Measurement of the Q angle in a 23-year-old female patient. Reference points are the anterior superior iliac spine, center of the patella, and tibial tuberosity. The angle is obtained by the lines AB and CD.**

that the individual or mixed alteration of the factors, as mentioned earlier, usually causes an overload in the patellar retinaculum, lateral facet, and subchondral bone of the patella, making the patellofemoral symptoms evident.

The gluteus maximus has been described as the primary hip extensor and is essential during ambulation and running. It makes an eccentric contraction and controls hip flexion and internal rotation when the foot falls on the ground during the "Weight Acceptance" phase. The gluteus makes a concentric contraction to make the toe-off when making the take-off. If the gluteus maximus weakens, the internal rotation could increase, directly impacting the knee joint.[3]

The gluteus medius is considered the primary hip abductor. When abduction power is required, the hip performs an internal rotation as a compensatory mechanism to improve abduction capacity. Conversely, femoral anteversion of 30-40 degrees causes a functional reduction that decreases the gluteus medius abduction capacity by 40-50%. Gluteal muscle weakness could predispose to an internal femur rotation to compensate for and improve muscle power, altering the natural biomechanics of other joints.[13,16,28]

The quadriceps promote knee movement, complete the knee extension, and restrict flexion as it is inserted into the proximal pole of the patella. The greater the force exerted during physical activities of daily living, such as going up and down, the more stress the patellar cartilage absorbs up to six times the body weight, irritating the subchondral bone.[13,29]

If the weakness of the abductors and external rotators of the hip and knee are identified, we can assume that the adductors and internal rotators can cause internal rotation and valgus during knee flexion movements, increasing the dynamic Q angle and, in turn, an increase in retro patellar stress.[13,14]

## PHYSICAL EXAMINATION

The physical exam involves subjective and objective analysis in addition to performing special tests.[1,2] It should begin with the inspection of the patient as they enter the examination room, seeking to find an altered gait, spine malalignment, limb discrepancy, knee flexion contracture, erythema, effusion, loss of muscle mass, feet mechanics, and the presence of footwear wear. The next step is to ask and seek the primary characteristics of patellofemoral pain, considering those data that may exclude it. Inquiry about pain while standing, sitting, or lying down and the increase of pain during ascending or descending stairs, as well as if it is present while maintaining a prolonged knee flexion, squatting, kneeling, or while running or jumping.[1]

The palpation of the patella should assess four components[10,30]: the glide, tilt, rotation, and anteroposterior position. The glide considers the mobility of the patella with 20º flexion in the medial and lateral axes, seeing if, during quadriceps contraction, the patella does a lateral displacement, which means vastus weakness or the presence of ligamentous instability. The tilt involves palpating the patella's lateral articular side by gently tilting it. A restric-

**Table 2. Knee tests for patellofemoral pain.**

| Test | Maneuver | Sensitivity | Specificity | Study |
|---|---|---|---|---|
| **Clarke's Test (Patellar Grind Test)** | It involves applying pressure with your hand on the proximal pole of the patella, applying downward and inward pressure while the leg is in extension, and the patient activates the quadriceps. The test is positive for patellar pathology when pain is obtained. | 39-48% | 67-75% | 2,5 |
| **Medial/ lateral facet patellar tenderness** | Pain while touching the articular portion of the patella on its medial or lateral facet while gliding the patella with the hand to expose the chondral surface. | 92% | 65% | 5,31 |
| **Pain in squats** | Pain while the patient actively makes a squat. | 91% | 50% | 5 |
| **Apprehension** | The patient is positioned with the knee at 30 degrees of flexion, and the physician applies lateral force to the medial border of the patella. It is considered positive when the patient feels uncomfortable and tries to extend the knee or end the test. | 7-32% | 86-92% | 5 |
| **Patellar Tilt Test** | The patient positions the knee at full extension and no muscle activation. The physician grabs the lateral border of the patella with both thumbs and tries to tilt upwards. If a restriction or inability to lift the lateral border approximately for 15 degrees, the test is positive for patellar lateral tightness. | 43% | 92% | 5,31 |

tion in tilt tells us about ligament or soft tissue shortening.[31] Rotation is evaluated with knee flexion and extension, looking for the presence of deviation of the patella over the femoral axis. The anteroposterior position refers to the location of the superior and inferior poles of the patella; if any inclination is shown during the evaluation, it could relate to the pinching of the fat pad.[10] Lastly, crepitus should be sought during joint mobility.[32]

Special tests are essential as they are sensitive and specific for diagnosis. The tests for patellofemoral pain are represented in **Table 2**.

Additionally, the hip and talocrural joints should be evaluated for the range of motion alterations or pain that may suggest their involvement in the pathology. The talocrural joint requires 10 degrees of dorsiflexion to perform a natural gait and 15-25 degrees to run. Hyperpronation of the foot causes an internal rotation of the tibia and the malalignment of the patella.[5,33]

The physician must evaluate atrophy, loss of strength, limitation of range of motion, and alterations of adjacent joints can play an important role in muscle performance. The evaluation of dynamic valgus should be performed with one leg and arms by the chest with the repetition of 5 squats to guide us toward a specific muscle malfunction. A dynamometer to quantify balance and muscle mechanics is recommended for thorough examination. Six muscle groups in the hip are evaluated: the adductors and abductors, flexors, extensors, and internal/external hip rotators.[5,14]

Muscle assessment starts proximally to distally; the patient is asked to step up and down to evaluate patellar mobility, along with the Trendelenburg test to assess gluteal weakness as this causes a femoral internal rotation and consequently compensatory pronation of the foot, altering the patellofemoral mechanics.[33] Various published studies demonstrate the weakness of at least five muscles involved with hip mobility, which predisposes to femoral internal rotation. They recorded poor eccentric control during knee flexion and extension movements with a dynamometer, overloading the patellofemoral joint.[3,6,14] Comparative studies recorded a 27% decrease in strength in abductor muscles, 30% in external rotators, 52% in extensors, and 24% in external rotators.[6]

The traditional theory of the weakness of the vastus medialis as the leading cause is that it fights alone against the lateral forces composed of the iliotibial band, lateral retinaculum, and vastus lateralis.[33]

The hamstring/quadriceps ratio can be evaluated for contraction speed, muscle balance, and function. This ratio is commonly used for ligament injuries as it reports the presence of muscle balance to authorize sports return activities. The average value is considered between 50-80%.[34]

A 5-6 degrees internal rotation of the femur causes an increase in patellofemoral stress. In the Single Leg Triple Hop test, a pelvic tilt with adduction, internal rotation of the knee, abductor weakness, and foot pronation are observed in patients with patellofemoral pain present both in the fall and take-off.[35]

Muscle weakness is a patellofemoral pain factor, but lack of flexibility is also crucial during evaluation. Non-flexible quadriceps increases the pressure between the femur and patella. The contracture of the iliotibial band could affect patellar function based on Kaplan's fibers that connect with the patella.[12]

Differential diagnoses must be considered and excluded, as they could give a similar physical exam: Chondral lesion, presence of a bone tumor, Hoffa's synovitis, Iliotibial Band Syndrome, presence of loose bodies, Osgood-Schlatter, osteochondritis dissecans, stress fracture, patellar/quadriceps tendinopathy, Sindin-Larsen-Johansson, symptomatic bipartite patella.[5]

## IMAGING STUDIES

The basic imaging studies include X-rays, computed tomography (CT) scans, and magnetic resonance image

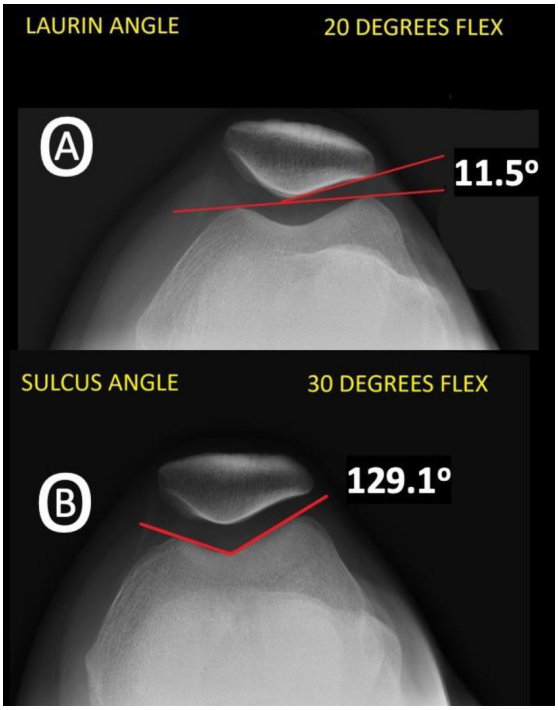


**Figure 2. Radiologic images to evaluate the patellofemoral articulation. A) Laurin angle is obtained at the intersection of the superior aspects of the femoral condyles and a line that delineates the lateral facet of the patella with an axial radiograph of the knee with 20 degrees of flexion. B) Sulcus angle is obtained with the articular surface of the femoral condyles that conformed to the femoral sulcus with an axial radiograph of the knee with 30 degrees of flexion.**

(MRI).[36] Radiographs are not strictly necessary for diagnosis, but even so, they are the initial study, helping to exclude other diagnoses and establish the progression of the disease. Traditional anteroposterior, lateral, and axial radiographs are routinely recommended.[37]

The axial X-rays can be taken with different degrees of flexion, helping measure congruence angles. The Laurin angle should be performed with a knee flexion of 20 degrees. The Sulcus angle is obtained from an axial radiograph with 30 degrees of flexion, also called the Merchant view. The normal value of 140 degrees provides information about potential joint damage to the area. Figure 2[29,37,38]

CT scan is used to obtain the Tibial Tuberosity-Trochlear Groove (TT-TG) measurement, which has an average value between 9-13 mm. When it is above 15 mm, it is associated with patellar instability.[10,19] Another use of CT scan is to assess patellar tracking by performing it at 30 degrees of flexion to assess joint congruence.[20,33]

MRI, a valuable instrument for the evaluation of soft tissues, cartilage quality, and bone structures, has the semi-quantitative score Magnetic Resonance Imaging Osteoarthritis Knee Score (MOAKS), which, by having 14 joint subregions to evaluate, has more precision of the damaged structures. The findings are usually minimal cartilage defects with the presence of hyperintensity or hypertrophy and lateralization of the patella that is sometimes also observed in healthy patients.[39-41] MacIntyre et al.[22] performed a dynamic MRI modality where they evaluated the presence of translation, angulation, flexion, and rotation of the patella during the flexion process, finding significant lateralization at 19 degrees of flexion. Of the patients with patellofemoral pain, 55% have contact between the patellar cartilage and the lateral groove.[30]

Planimetry is another proper study as it facilitates the measurement of the limbs' anatomical and mechanical axis, detecting any angular alteration, pelvic tilt and limb discrepancy.[42]

The anteroposterior pelvic X-ray and the hindfoot alignment view for assessing hindfoot valgus are usually reliable instruments for evaluating the hip joint and the mechanics of the foot and ankle.[43]

## TREATMENT

Currently, there is no established management for patellofemoral pain; the general objectives focus on modulating the mechanical factors that promote joint conflict. Non-surgical management is usually the first line of treatment.[1]

Conservative treatment is multimodal and consists of gradual muscular strengthening exercises, restoration of proprioception, rest from demanding or load-bearing activities, application of biological factors such as hyaluronic acid or platelet-rich plasma, and psychological care if needed. Strengthening is oriented to balance the abductor muscles and external rotators of the hip, quadriceps, and core. Working through stages to strengthen from proximal to distal, initial open chain exercises and a brief transition to the closed chain are recommended, increasing the demand by 10% per week for at least six weeks. If a muscle contracture is detected, adding stretching exercises.[4,5,14,44,45]

By maintaining muscle strength and balance, adults have 67% favorable results, and adolescents between 29-38%.[4] Several authors recommend doing the muscle balance program at least three times a week for six to eight weeks, modifying and adding possible orthoses, insoles, or analgesics according to the patient's individualized findings, obtaining a reestablishment in the limb's mechanics.[5,12,46,47]

The surgical option should be considered when an anatomical or mechanical finding influences poor tracking, and it has been treated for more than six months with strict conservative management without clinical improvement.[30] Among the surgical management options are realignment of the tibial tuberosity, ligament reconstruction, lateral retinaculum release, proximal realignment, and distal realignment, among other possibilities.[19,20]

Although the value of the adductor/abductor ratio has not been established, as well as the hamstring/quadriceps ratio concerning patellofemoral pathology, it would be interesting to consider implementing the values recommended by Rodríguez, Olson, and Lonie to evaluate if the desired values bring a benefit to this pathology.[34,48-50]

## CONCLUSION

The patellofemoral pain is caused mainly by malalignment of the patella, and with an altered tracking. Young female athletes are principally affected, with a high percentage of recurrence. Usually, radiographic measures and muscular test are necessary for the diagnosis. The treatment must be focused in strengthening and muscular balance.

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All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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