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

Update of Risk Factors, Diagnosis, and Management of Patellofemoral Pain

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Abstract

Purpose of Review Patellofemoral pain is the most common cause of anterior knee pain. The purpose of this review is to examine the latest research on risk factors, physical examination, and treatment of patellofemoral pain to improve accuracy of diagnosis and increase use of efficacious treatment modalities.

Recent Findings The latest research suggests patellofemoral pain pathophysiology is a combination of biomechanical, behavioral, and psychological factors. Research into targeted exercise therapy and other conservative therapy modalities have shown efficacy especially when used in combination. New techniques such as blood flow restriction therapy, gait retraining, and acupuncture show promise but require further well-designed studies.

Summary Patellofemoral pain is most commonly attributed to altered stress to the patellofemoral joint from intrinsic knee factors, alterations in the kinetic chain, or errors in training. Diagnosis can be made with a thorough assessment of clinical history and risk factors, and a comprehensive physical examination. The ideal treatment is a combination of conservative treatment modalities ideally individualized to the risk factors identified in each patient. Ongoing research should continue to identify biomechanical risk factors and new treatments as well as look for more efficient ways to identify patients who are amenable to treatments.

Keywords Patellofemoral pain · Anterior knee pain · Biomechanical risk factors · Diagnosis · Management

Introduction

Patellofemoral pain is a common musculoskeletal condition characterized by vague pain in the anterior knee, typically behind the patella. It is traditionally aggravated during knee loading activities such as squats, stair climbing, and running. Despite being commonly diagnosed, its exact pathophysiology is unknown, but it is believed to be related to a combination of anatomical, biomechanical, behavioral, and psychological factors. For clinicians, successful treatment hinges on their ability to identify unique risk factors and individualize interventions to each patient. Being able to identify and implement targeted treatment of patellofemoral pain can improve patient quality of life and function [1].

Risk Factors

Biomechanical Stress

Patellofemoral pain is commonly attributed to increased cartilage stress and bone strain across the patellofemoral joint [2, 3]. This is believed to occur in activities such as squats, stair ambulation, and running which increase stress and forces by loading the patellofemoral joint. However, other studies have not been able to show a difference in mechanical stress to the cartilage or bone with deep flexion activities between patients with patellofemoral pain (PFP) and those without symptoms [4, 5]. Further studies are needed to fully evaluate if increased

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joint forces predispose one to development of PFP. Some studies found there to be decreased peak resultant forces through the knee during activities such as stair climbing in PFP patients than asymptomatic individuals. This may suggest a compensatory mechanism to minimize loading of the joint [3, 4, 6].

Quadriceps Weakness

Quadriceps weakness has been long believed to be associated with PFP especially the discrepancy in strength between the vastus medialis (VMO) and the vastus lateralis (VL). Some studies have shown isolated VMO atrophy in symptomatic patients compared with the healthy [7], but this has not been a consistent finding [8]. Additionally, in studies that have shown isolated atrophy, a causal relationship was not established [7]. Generalized quadriceps weakness has shown better evidence of its association with PFP and remains a common target for exercise therapy [9, 10].

VMO Delayed Activation

In addition to muscle size, delayed activation of VMO in comparison with the vastus lateralis has been shown to be associated with the presence of PFP in multiple studies [11–13]. The exact relationship of delayed muscle activation to PFP remains a focus of research. In 2012, Pat et al. looked at patients with and without PFP. They further subdivided them into those with patellar maltracking and those without based on patellar tilt and abnormal bisect offset. These factors were identified in patients using weight-bearing MRI. Once patients were categorized, they measured VM activation delay during jogging and running. They found no difference on average in VM activation between PFP patients with normal tracking and those pain free, but did note an association between VM activation delay in the subgroup of maltrackers [14, 15]. In 2016, Briani et al. continued the search for reasons why differences in VMO/VL have been found in some but not all PFP individuals. Briani and his team looked at EMG activation during stair climbing in women with PFP at various levels of physical activity habits and compared them with healthy women of similar exercise habits. They found the women who were most physically active to have the largest difference in VMO/VL activation times while women who moderately exercise did not have a delay or a large difference between the control group [16]. This shows activation time is associated with PFP but it also illustrates that PFP risk factors do not occur in isolation and may have unforeseen relationships to one another. Further studies are needed to understand the clinical significance of muscle activation.

Foot Overpronation

During the gait cycle, normal pronation of the subtalar joint takes place during the first portion of the gait cycle in response to lateral movement of the calcaneus creating space for the talus to move medially. As a result of inward rotation of the talus, the tibia internally rotates. Pronation of the subtalar joint is a normal part of the gait cycle. It becomes abnormal when it occurs during the wrong phase of the gait cycle or does not resupinate. This leads to excessive internal rotation of the tibia which can result in downstream compensatory internal rotation of the femur in order for the knee to reach full extension. An internally rotated femur would theoretically move the patella medially and thereby increase the Q angle and lateral forces on the patella [17, 18]. Foot overpronation has been identified as a risk factor in some prospective studies [19, 20]. Although this is a logical explanation for effect of overpronation on patellar kinematics, studies have not shown the magnitude of overpronation to be proportional to tibial or femoral rotation [21]. In addition, there is inconsistency between tibial motion and patellar kinematics as the talus overpronates and the tibia compensates with internal rotation. However, with increased tibial internal rotation, the Q-angle decreases theoretically decreasing lateral forces on the patellar [22, 23]. This may explain why some studies have not found foot overpronation alone to be related to development of PFP [24]. Further research is needed to further characterize the role of altered foot kinematics.

Hip Weakness

Just as the knee can be affected by joints distally, the hip also plays a role. Patients with PFP were found to have decreased hip strength in extension, abduction, and external rotation [25, 26]. However, this has been found retrospectively; studies looking prospectively have not found a causal relationship between hip weakness and development of PFP [27]. It is possible that hip weakness is a result rather than a cause of PFP. Despite this, it remains a central target in exercise therapy. Altered hip kinematics during dynamic tasks has been strongly linked to PFP during single leg squats and running in women with PFP [28, 29]. Female subjects with PFP have been noted to have increased hip adduction and hip internal rotation [29, 30] but these same changes were not necessarily noted in males with PFP [30]. This reinforces the importance of dynamic testing of the hip in evaluating a patient for risk factors for PFP especially in female patients.

Flexibility/Inflexibility

Soft tissue structures surrounding the knee and their flexibility play their own role in patellofemoral pain especially the lateral retinaculum. It is comprised of transverse fibers from the iliotibial band and quadriceps aponeurosis extending to the lateral aspect of the patella, forming a dense sturdy piece of tissue [31]. These fibers act on the patella as a lateral restraint preventing medial translation on the patella during movement and varus forces. However, if the lateral retinaculum is too taut, theoretically lateral forces overcome medial forces leading to patellar maltracking. When studies have looked at the association of IT band and the lateral retinaculum, they have found it to be tighter and thicker than that of patients without patellofemoral pain, contributing to altered patellar kinematics [32–36].

Just as lateral forces can be too tight, medial soft tissue structures can be too lax as a result of generalized laxity or previous trauma (patellar subluxation or dislocation). Studies are limited that show generalized laxity leading to patellar maltracking. Witzvirouw et al. conducted a prospective study looking at 282 students with follow-up at 2 years to evaluate what intrinsic risk factors may be associated with the development of PFP. Regarding laxity, they noted that a thumb to forearm flexibility and hypermobile patella were associated with the development of PFP but did not specifically highlight medial knee structures or hypermobility in other areas [37]. Also, they noted inflexibility of surrounding muscle groups such as the quadriceps and gastrocnemius to be associated with development of PFP. This confirms prospectively what some cross-sectional studies had noted which is that quad tightness was more common in PFP athletes than in their healthy counterparts [38, 39]. Further studies should continue to examine prospectively what soft tissue constraints may incline patients to develop PFP.

Training Errors and Overuse

External factors to patients may play a role in patellofemoral pain. As Dye explains, the pathophysiology of patellofemoral syndrome is one of loss of homeostasis [40]. It is argued that pain results when underlying bone and synovial tissues are overloaded. Dye suggests the source of pain can even be seen in changes to the bony architecture highlighted by positive patellar bone scans and often disappear after resolution of symptoms [41, 42]. This can be from external factors that increase stress on the patellofemoral joint (PFJ). External pressures can be anything from overuse, poor running technique, weight gain, or improper footwear. This has been an area of interest for researchers. Recent studies have looked at how the running technique changes patellofemoral joint stress and recommend a forefoot strike pattern with a shortened stride length to decrease patellofemoral joint stress [43, 44]. This is theoretically based on controlled lab measurements but may provide a basis for further studies and analysis in running athletes. Overuse as a risk factor is clear in studies that looked at new runners. New runners showed an increased risk of knee injuries including PFP when taking up the sport [45, 46] and one prospective study found increases in training greater than 30% mileage over 2 weeks made them more vulnerable to injury [47]. This can provide a basis for instructing athletes at the start of their season or when coming back from injury how to progress their training to minimize their risk of injury.

Clinical Presentation/History Taking

Patellofemoral pain is a diagnosis of exclusion and its presentation can be nonspecific. The classic patient is often young and healthy, absent other intraarticular or periarticular explanations for their pain. It often has an insidious onset and may have been present for years. It is often described vaguely as an ache behind the kneecap. It can be unilateral or bilateral. Patients often complain of at least one activity that loads the patellofemoral joint with a flexed knee such as running, squatting, or stair/hill ambulation. Pain may vary throughout a patient's run but how hill running affects their pain may be a point of interest, especially the downhill. They may describe a small knee effusion but if a large knee effusion is present (especially if no history of overuse or trauma), then other conditions should be higher on the differential, including rheumatologic causes. One should take an extensive history of physical activity including training regimen, footwear, changes to mileage, weight changes, and prior knee/ligamentous injuries.

Physical Examination

Diagnosis of PFP can be difficult and must be an integration of both clinical history and physical exam as positive signs are often vague and clinical history may not always correlate with biomechanical findings [48]. Assessing patients for potential risk factors of PFP can help guide physical exam and exclude other conditions from the differential. Start by observing the patient in a static standing position looking at knee alignment especially with concern for the genu valgum or varum. One should be sure to take time to assess the entire kinetic chain from pelvic drop to excessive dynamic adduction or internal rotation of the femur down to excessive pronation of the feet. Once patient has been assessed at rest, one should move on to functional tasks. The step-down test or single leg squat can be done quickly and easily. Ask the patient to stand on one leg with hands on their hips and bend their knee to around 60°. Observe the patient looking for hip abductor weakness, increased femoral internal rotation/adduction, and dynamic knee valgus. In a recent study, this test was shown to be more predictive of PFP than single hop test, gait, or stairs [49].

Patellar maltracking should now be observed from a seated position. The patient should be instructed to slowly extend their knee from 90° of flexion into full extension. The patella should move vertically. However, a positive "J-sign" occurs if the patella moves laterally as the knee nears full extension.

The sign can be subtle but may suggest muscle imbalances or laxity [50]. Another test to evaluate is the Q-angle which was first described by Brattstrom as a measure of the quadriceps tendency to move laterally [51]. It can be measured by the angle between a line from the anterior superior iliac spine to the middle of the patella, and a line measuring from the anterior tibial tuberosity to the middle of the patella. Theoretically, a higher Q-angle is suggestive of a tendency toward PFP [52]. However, this relationship is not consistent in the literature [37, 53]. Draper et al. measured the Q-angle with different types of goniometers and correlated it with MRI. They found long-arm goniometers to be more reliable and accurate based on MRI findings while short-arm was found to have wide clinical variability which may explain inconsistencies in implementation, but standardizing the exam such as tools and patient positioning may improve its accuracy [54].

Have the patient lie supine with the knee fully extended and palpate gently along the medial and lateral portions of the patella looking for focal areas of tenderness especially over the retinaculum. If the patient is tolerant, then one can check patellar motion including patellar mobility test, or patellar tilt test. The patellar mobility test entails checking the passive restraints of the patellar as it is gently moved from side to side. This may be suggestive of overly tight lateral structures or lax medial structures. In order to perform the patellar tilt test, the examiner will place the thumb and index finger on the medial and lateral sides of the patella and measure if one finger is more anterior. For example, if the medial finger is more anterior the patellar is consider laterally tilted. Boden et al. demonstrated that a laterally tilted patella can lead to high lateral forces on the lateral facet [55]. This was reinforced in a more recent cross-sectional study which found the patellar tilt to be most predictive of PFP patients among various functional and biomechanical measures [56]. Other tests can be attempted like patellar compression but has not been found to be sensitive or very diagnostically accurate [56]. There is no one specific abnormality or test that defines PFP. The diagnosis is made by a constellation of findings that together will change the function of the extensor mechanism, predisposing to PFP.

Management

First, there is an initial phase of treatment which involves nonspecific conservative measures that focus on mitigating pain and inflammation. This includes activity modification, short course of anti-inflammatory medications, and physical modalities to manage the acute pain. This should act as a bridge to more specific treatment of the underlying strength and mechanical deficits noted in history and clinical exam. As treatments are discussed below, bear in mind that no one treatment has been found to be solely effective, so recommendations are to incorporate multiple modalities in the treatment plan (ex. orthotics, taping, bracing, and exercises) while individualizing treatment to the specific needs of the patient [57, 58••].

Quadriceps Strengthening

Quadriceps strengthening has long been a focus of treatment for PFP. It has been shown to be effective both in isolation and when paired with other treatment modalities for the treatment of PFP [59•, 60]. While the exact mechanism remains unknown, the belief is that by strengthening the quadriceps, patellar tracking and pressure distributions improve [57]. Closed kinetic chain exercises are generally recommended as initial treatment; this is usually better tolerated by patients as stress on the PFJ is less with full knee extension because there is less patellofemoral joint contact stress and the co-contraction of muscle groups is more physiologic. As the quad strength improves and pain is better controlled, the patient can add open chain exercises which require increased PFJ stress to extend the knee from 90° to full extension [61].

Another strategy to decrease torque of the quadriceps while continuing to strengthen is blood flow restriction therapy (BFRT). This involves placing a tourniquet or adjustable bands over the extremity with about 70% pressure theoretically decreasing arterial supply to the muscle group the patient is focusing on. This is then paired with submaximal exercises to cause metabolic stress to the muscle allowing the patient to exercise muscles groups that may be typically inhibited by pain at higher loads. Under hypoxic and metabolic stress, small aerobic fibers fatigue allowing larger muscle fibers to be recruited leading to improved strength and muscle hypertrophy with low-level exercise [62]. A recent prospective study by Giles et al. noted greater improvements in pain and function for patients with PFP using quad strengthening with BFRT compared with standard quad strengthening at 8 weeks [63•]. Unfortunately, given that differences in pain score were not clinically significant and no outcome measure differences were noted at 6 months, uncertainty remains about BFRT efficacy in PFP patients. Despite showing promise, more high-quality randomized controlled trials (RCT) are needed to recommend this in PFP patients.

VMO Strengthening and Activation

The selective weakness of VMO compared with VL was discussed above. Studies have not proven exercises can selectively contract VMO improving its strength relative to VL or add specific benefit in the treatment of PFP patients [64, 65]. Some studies have focused instead on targeting activation timing of VMO relatively to the vastus lateralis. Following targeted physical therapy for vasti timing, patients showed improvements in pain and stair ambulation which correlated with improved vasti timing [66, 67]. Although generalized quad strengthening is common practice, targeted therapy to improve VMO timing has uncertain benefits clinically and continues to be an area of interest for studies.

Hip Strengthening

It remains uncertain if hip strength deficits found in PFP patients are causative or a result of PFP. Regardless, weakness in external rotators and abductors is present in PFP patients [25, 26]. Using this finding, it stands to reason that strengthening these deficits may have positive effects for PFP patients. Randomized control studies looking at hip strengthening found it to improve pain and function in patients with PFP especially women [68–71]. Results were seen with improvements in short-term pain scores and function, while one study even found improvements out to 1 year [68]. Ongoing questions remain on the relationship of hip weakness and PFP, but regardless hip strengthening exercise should remain an integral part of PFP treatment paradigm. Combined exercise therapy targeting both the hip and knee remains the intervention of choice for patellofemoral pain [58••].

Flexibility

As discussed earlier, tight lateral structures may have a contribution to patellar maltracking; it makes sense then that treatment may target inflexibility. It has been shown that persons with PFP have a tighter and thicker iliotibial band compared with pain-free controls. In vivo and cadaveric studies confirm that iliotibial band tension has a significant impact on patellar alignment and tracking, although it is not clear if this tightness and thickening is an adaption to or a cause of patellar lateral tilt [32–36]. Unfortunately, research has not shown stretching alone to be effective and deep soft tissue mobilization may be needed. Several studies have shown it to be effective for pain and function even with improvements out to 3 years when combining with strengthening and taping [72, 73]. For this reason, it is a reasonable addition to a rehabilitation prescription.

Gait Retraining

In patients who lack the physical exam findings to explain their PFP, one should consider overuse or errors in dynamic biomechanics [57]. The patient may need to be observed in their sport-specific activities to have their technique adjusted. With this idea in mind, several recent studies have looked at gait retraining therapy in PFP patients. Roper et al. conducted a RCT of 16 individuals with PFP pain and compared gait retraining from rearfoot to forefoot versus standard therapy treatment. The experimental group post intervention and at 1-month follow-up showed improvements in knee pain and alterations in biomechanics showing retraining had been successful [74•]. Unfortunately, sustained improvements in pain and gait mechanics would need to be observed further out from intervention to be considered a viable long-term treatment. In 2018, Esculier et al. compared gait retraining with exercise-only and education-only groups. The gait retraining group was noted to have increased step rate and decreased average vertical loading rate but no clinically significant differences were noted between the groups [75]. Gait retraining is difficult to implement but in order to be sure of its benefits, standardization of its use in research would help determine its efficacy. This could mean using one gait intervention at a time, focusing on one patient type at a time (i.e., rearfoot strikers), standardizing education feedback, and including long-term follow-up [76]. At this time, gait retraining shows potential but its short- and long-term benefits remain uncertain [58••]. More well-designed RCTs are needed to characterize its potential benefits for the PFP patient population.

Dry Needling/Acupuncture

While dry needling and acupuncture are common treatments used in other musculoskeletal diagnoses, their use in PFP patients has only recently been examined. In 2016, Collins et al. in a review of several non-interventional methods of treating anterior knee pain noted improvement in pain in studies looking at acupuncture versus control treatment [77]. This is encouraging but further well-designed studies reinforcing this idea are lacking. In 2017, Espi-Lopez et al. conducted a RCT which included the inclusion of dry needling into a manual therapy and exercise program then compared with those interventions alone [78]. Unfortunately, at 3-month follow-up, there was no significant difference in pain scores or function between treatment groups. At this time, there is no recommendation for dry needling or acupuncture in the treatment of PFP patients as benefit is uncertain; further well-designed RCT are needed [58••].

Psychological Factors

Patellofemoral pain was previously discussed as purely a nociceptive pain caused by overload stress to bone, cartilage, and synovial tissue [40]. However, studies have shown that patients with PFP exhibit lower pain threshold and hyperalgesia locally at the knee and other remote parts of their bodies [79–81]. This suggests PFP is not just peripheral but has a central component that is not being adequately addressed in the traditional treatment paradigm. A recent systematic review by Maclachlan et al. looked at studies on PFP which included cognitive and mental health measures. They found PFP patients to have increased levels of anxiety, depression, catastrophizing, and fear of movement, and these measures closely correlated with pain and poor function [82]. This does not address whether this is causative or a product of PFP but treatment strictly of biomechanical issues may miss the psychologic factors worsening pain and function. Ideal treatment would include physical modalities while addressing patients' beliefs toward pain, treatment expectations, and patient engagement [83].

Conclusion

Patellofemoral pain remains a diagnosis of exclusion commonly found in young healthy patients. Its exact mechanism remains shrouded in controversy but is most commonly attributed to increased or altered stress to the patellofemoral joint from intrinsic knee factors, alterations in the kinetic chain, or errors in training. Diagnosis can be made by excluding other musculoskeletal and medical problems with thorough assessment of clinical history, risk factors, and physical examination. Ideal treatment consists of a combination of conservative treatment interventions ideally individualized to the risk factors identified in each patient. Ongoing research should continue to assess the validities of these biomechanical risk factors and new treatment strategies, and look for more efficient ways to identify patients who are amenable to treatment modalities.

Compliance with Ethical Standards

Conflict of Interest Daniel Sisk declares that he has no conflict of interest.

Michael Fredericson declares he has no conflict of interest.

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

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- • Of importance
- •• Of major importance

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