Patellofemoral Rehabilitation

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Patellofemoral syndrome is one of the most common conditions encountered by orthopedic surgeons and physical therapists. These patients present with a complex syndrome of multiple findings. Many, if not all, of these findings are related to biomechanical abnormalities in the lower extremity. Secondary changes in strength and flexibility frequently occur as the result of untreated malalignment. A physical therapy evaluation encompassing an assessment of functional biomechanics, patellar alignment, flexibility, and strength is crucial in developing an exercise program designed to address the specific deficits of each individual patient. A physical therapy program of closed chain therapeutic exercise designed to correct the underlying biomechanical deficits and subsequent malalignment of the lower extremity has been effective with excellent results and low recurrence of symptoms.

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Patellofemoral syndrome (PFS) is one of the most common conditions encountered by physicians and therapists. It has been estimated to afflict 25% to 36% of the population and account for 25% of knee injuries and 10% of all injuries. Other terminology used and relevant to PFS include chondromalacia patella, runner’s knee, anterior knee pain, and retropatellar pain syndrome. PFS can significantly limit routine activities of daily living and more demanding athletic activities. Many patients with PFS present with chronic symptoms.

Many authors report successful management with conservative therapy whereas Tyler states results have been mixed. Wilk and coworkers state that PFS is one of the “most vexatious clinical challenges in rehabilitative medicine.” There have been many documented programs designed to conservatively manage PFS, with most emphasizing flexibility and quadriceps strengthening. Although Post reports high success for patients in the short term, longer-term recurrence of symptoms appear to be questionable.

Most health care providers agree that treatment is best initiated nonoperatively, which usually involves activity modification and a course of physical therapy. The therapy program should directly address the causes of common objective findings rather than focus on the symptoms themselves. In my experience, most findings are the result of biomechanical deficiencies as opposed to random findings with no underlying cause. The treatment program outlined in this chapter has produced excellent results with minimal recurrence over the course of 2 decades.

Anatomy

Please refer to articles earlier in this issue of the journal for a thorough review of the anatomy. However, 2 structures that have significant clinical relevance in the treatment of PFS deserve further discussion: the vastus medialis obliquus (VMO) and distal iliotibial band (ITB)/lateral retinaculum. The distal ITB blends together with the lateral retinaculum to form a direct attachment to the lateral aspect of the patella. Tightness of this structure will lead to a lateralized patella with a concomitant lateral tilt. This tightness induced malposition leads to a stretch weakness of the VMO caused by biomechanical inefficiency secondary to excessive length. It is important to note that the VMO attaches to the superomedial corner of the patella at an oblique angle. Studies have shown the VMO to have no extension moment and, therefore, it cannot be stimulated in the sagittal plane. Its primary function is dynamic medial stabilization especially in terminal extension as the patella loses its bony support.

A review of lower-extremity biomechanics is necessary to understand the basis of the etiology of these conditions and...
the therapy program designed to address the causes of the symptoms. The biomechanics will be reviewed from distal to proximal as the ground reaction force is the origin of stress ascending the loaded limb. The loading response of gait will be the reference as pain most commonly occurs at this time. Squats and stair climbing are simply variations of the same load.

Loading response occurs from the moment of impact at heel strike until just after foot flat. The purpose of this phase is for the foot to accommodate to the supporting surface and for the limb to accept the load of body weight. To accommodate this load, the hindfoot everts and the forefoot inverts. This movement creates a more parallel alignment of the planes of the hindfoot and forefoot allowing for more supple structure. Eversion of the hindfoot allows the navicular to drop inferomedially. The ankle dorsiflexes, and the tibia rotates medially as it follows the navicular. The internal rotation of the tibia induces the internal rotation of the femur. Knee flexion is occurring as the knee assumes a valgus position. Hip flexion, adduction, and internal rotation also occur as the reaction force travels up the chain. The pelvis subsequently protracts and rotates anteriorly.11,12

In 20-plus years of clinical experience, I have consistently observed that many, if not all, of these motions are excessive in the pathological state. Excessive foot pronation occurs as the hindfoot continues to evert past neutral in the quest to have the first ray arrive firmly on the ground. This compensation is usually the result of a varus deformity of the forefoot. The compensatory force then triggers excessive motions further up the kinetic chain. All or most of the aforementioned motions increase in their magnitude producing many possible pathologies, especially patellofemoral malalignment. This compensatory pronation is responsible for many of the “causes” of PFS found in the literature, such as ITB and lateral retinaculum tightness, VMO weakness, and lateralized patella.3,5,7 Looking up the kinetic chain, it becomes apparent that the malalignment is a medialization of the femoral groove as opposed to lateralization of the patella. Long-term malalignment of the lower extremity leads to tightness of the ITB, lateral retinaculum, hip flexors and adductors, among others. Not addressing restrictions in the flexibility of these tissues will inhibit a clinician’s ability to achieve proper realignment of the lower extremity and patellofemoral joint.

Physical Examination

Common findings associated with PFS noted in the literature include excessive foot pronation, lateral patellar tilt and glide, tightness of the ITB and lateral retinaculum, compromised patellar mobility, atrophy and weakness of the VMO, as well as other weaknesses in the involved lower extremity.3,5,7 It has been my experience that biomechanical deficiencies are the underlying cause of many of these findings.

Biomechanics

An assessment of a patient with PFS begins with a biomechanical evaluation of the lower extremity. I believe that lower extremity malalignment is the main cause of many of the findings associated with PFS. A biomechanical examination begins with an assessment of foot alignment as the ground reaction force initiates all compensations in the loaded limb. Foot alignment offers a predictive value of other findings as one progresses proximally up the kinetic chain. Assessment of foot alignment should be performed with the limb in the open chain with the foot maintained in subtalar neutral, which is the position of maximum congruence of the talonavicular joint. Subsequently, the foot also should be evaluated in the closed chain to assess the associated compensations. Neutral alignment in this position presents with the forefoot perpendicular to the hindfoot and the hindfoot aligned parallel to the distal leg.11,12 Most patients with PFS will present with a varus deformity of the forefoot, where the forefoot is inverted in relation to the hindfoot. During loading response, this varus position forces the subtalar joint into greater eversion as the forefoot seeks contact between the first ray and the ground for stability. This movement will present as a valgus position of the calcaneus in standing.

This compensatory pronation will allow the navicular to excessively drop inferomedially, with the talus following suit. This inferomedial motion of the talus forces the tibia to rotate internally while subsequently flexing the knee and inducing a valgus force at the knee. Internal rotation of the femur positions the femoral condyles and femoral groove medially. The hip exhibits increased flexion, adduction and internal rotation while the ipsilateral pelvis protracts and rotates anteriorly.

Although this series of events occurs during a normal loading response, these motions are excessive in the overpronator because of the excessive eversion occurring at the subtalar joint. However, these excesses will not present symmetrically. The joint or joints that display the greatest deviation from normal will typically be the location of the symptoms. In this case, malalignment of the foot and hip create the greatest effect on the knee as it receives the excessive force ascending from the foot and decreased control descending from the hip.

Observation

The most common physical examination finding on observation is atrophy of the VMO. The VMO loses much of its mechanical advantage and efficiency due to its excessive length. This length is the result of lateralization of the patella which also causes painful tension on the medial structures. Patients also frequently present with femoral anteversion. Femoral anteversion, an increase in the angulation of the femoral neck as it attaches to the femoral shaft, displaces the femoral groove in a medial direction as it produces internal rotation of the limb. This, combined with excessive foot pronation, creates a significant medial rotation of the femur.

ITB/Lateral Retinaculum Tightness

Malalignment of the lower extremity allows tightening of the ITB as it is chronically shortened because of the positions of the pelvis, hip, and knee as listed previously. ITB tightness
typically occurs concurrently with tightness of the lateral retinaculum as they are intertwined.

ITB tightness is typically measured with the Ober test. The test is performed as follows: the patient is positioned on his or her side, the test limb is abducted and extended into slight extension, the limb is then lowered while the pelvis is stabilized, as discussed by Fredericson in his reference to Punieillo. A positive result is indicated when the test limb is unable to descend below the horizontal.

There is a variation to the standard Ober test, which has been successfully used in our clinic. The knee on the test leg is maintained in 30° of flexion as opposed to 90° or full extension. This is the isometric point where the ITB is neither a flexor nor extensor of the knee and therefore allows for a more accurate assessment of maximum length.

Patellar Alignment

Tightness of the lateral retinaculum leads to a patella that is laterally displaced and tilted in relation to the femoral groove. It is this malposition that leads to excessive compression on the lateral facet and traction of the medial retinaculum. Assesement is made by locating the center point of the patella. This point is then measured to the medial and lateral epicondyles. The center point should be equidistant to each epicondyle. The test can be performed in either full extension or in 30° of knee flexion with the partially flexed position tensioning the medial and lateral restraints. As this test takes minimal time, thoroughness frequently dictates that both conditions be measured. Lateral tilt is measured by assessing the difference in the vertical height of the medial and lateral patella borders with the patient resting supine. This test can also be performed quickly in both full extension and 30° of flexion.

Patellar Mobility

Mobility testing typically reveals hypomobility in the medial direction and hypermobility in the lateral. Medial hypomobility is the result of tightness of the lateral structures. Hypermobility in the lateral direction usually indicates insufficiency of the medial restraints. Assessment is performed with the patient resting in supine and the knee flexed to 30°. The patella is then displaced in the medial and lateral directions to assess the distance traveled. The patella should be able to glide one half of its width in either direction.

It is important to note and control patellar tilt while performing the mobility test. It is common for tightness of the lateral structures to increase the lateral tilt of the patella while allowing the medial glide to appear normal. If this is observed, place gentle downward pressure on the medial border of the patella to minimize lateral tilt as you displace the patella medially. This step allows for a more accurate assessment of the tightness of the lateral restraints.

Muscular Strength

Because of the typical chronic nature of these conditions, patients present with significant weakness of multiple muscle groups. The combination of these weaknesses usually exacerbates the biomechanical deficiencies of the lower extremity thereby making it more difficult for the patient to maintain an alignment that is symptom-free.

Our strength assessment, distally, typically reveals weakness of the tibialis posterior and peroneus longus, which control the frontal and transverse planes of the foot, respectively. The inability of these muscles to control these motions at the foot allows for the dropping of the navicular and compensatory pronation to proceed uncontrolled. The weakness of the peroneus longus is more of an issue later in stance because it is unable to properly depress the first ray in mid- to late stance. The implication is either delayed or absent supination of the foot. This prevents or restricts the femur from rotating externally thereby sustaining the medial alignment of the femoral groove. This frequently causes the symptoms to have greater duration and to carry into later phases of gait.

Eccentric control of the quadriceps is quite weak because it has usually been limited by pain. The patient displays occasional difficulty ascending stairs but frequently is unable to control descending stairs. Descending stairs is also significantly limited by pain. Marked weakness of the VMO is evident as it displays a poor ability to restrain the patella from displacing laterally. It suffers greatly from poor leverage due to its excessive length as the femur maintains a medially rotated posture in weight bearing.

Weakness of the hip abductors and external rotators results in poor control of the frontal and transverse planes, respectively. This weakness is evident by the excessive adduction and internal rotation of the hip. Increased valgus and rotational stress at the knee is increased as the femur is allowed to excessively adduct and rotate medially. This finding is supported by the work of Ireland and Powers. Although not the cause of this malalignment, greater strength and eccentric control can minimize the excessive force placed on the patella.

I advocate testing strength in the closed chain because of its tri-planar nature. Manual muscle tests are limited in that they assess the muscle in only one plane of motion and do not accurately assess the muscles function. Closed chain tests should be designed to simulate the muscles function during loaded functional activities. The specificity of the tests allows them to be ideal exercises in which to enhance the functional ability of that muscle while applying a more normal stimulus for strengthening.

Rehabilitation

Physical therapy has been effective as a conservative approach to managing PFS. However, long-term success is questionable because recurrence rates are fairly high. I have treated many patients who have received physical therapy elsewhere with mixed results only to have the same symptoms recur at a later time. If the therapy is not directed at the causes, then symptoms are likely to recur at some time. My treatment program will address the biomechanical causes of patellofemoral malalignment.

Restoration of normal biomechanics of the lower extremity should be the cornerstone of physical therapy. Therapeutic
Exercises designed to improve the strength, function, and efficiency of biomechanical deficiencies will greatly improve the alignment of the patella, enhance the patient’s function, and greatly reduce the risk of future recurrence.

These exercises will be performed in the closed chain to better simulate normal function and to enhance proprioceptive feedback of the neuromuscular system. This feedback is crucial as it provides a stimulus to the muscles that is consistent with what they will encounter during normal function. Balance is also a key component to daily function that is greatly enhanced when exercises are performed in the closed chain. The eccentric component of each exercise is typically emphasized as this will directly address the patient’s inability to control excessive motions against the force of gravity.

Exercises performed early in the program are more focused on specific joints and motions while more advanced exercises combine multiple motions to better integrate the movement enhancements into function. Repetitions and speed are increased as the patient progresses to better simulate functional speeds and to emphasize muscular endurance. All exercises, even in the early stages, are performed with more speed than is typical. Loading response of the limb occurs too quickly to expect slow training to carry over to function.

Although restoration and enhancement of normal biomechanics remains the major emphasis of the program, flexibility will be a key component. Biomechanical deficits allow for chronic shortening of contractile structures which foster long term tightening. This inflexibility inhibits the ability of the exercise program to restore normal alignment and needs to be addressed immediately.

**Flexibility**

It is accepted that tightness of the ITB is a common finding. It frequently occurs concurrently with tightness of the lateral retinaculum and together they induce a lateral pull on the patella. Lower-extremity malalignment has allowed this tightening to occur yet it is this tightness of the ITB which can limit the ability of the limb to be realigned. An Ober stretch in sidelying is recommended to patients to be performed for three to five minutes. An ITB stretch performed in standing is also prescribed (Fig. 1). Sensory feedback is difficult as the patient does not experience the same sensation as with a muscular stretch, therefore technique is crucial. Great care is obviously taken to provide careful instruction regarding positioning.

Mobilization in the medial direction is performed to improve the flexibility of the lateral retinaculum. This is always performed with the knee in 20° to 30° of flexion and can be performed when the patient is either supine or lying on his or her side. As noted previously, care is taken to prevent an increase in lateral tilt while performing the medial glide as this reduces the stretch on the lateral retinaculum.

**Figure 1** Standing ITB stretch. (Color version of figure is available online.)

**Figure 2** Posterior tibialis strengthening via supination lift onto 1” riser. (Color version of figure is available online.)
The gastrocnemius and soleus are frequently overlooked with regards to stretching. Tightness of these muscles can increase pronation during mid and late stance as the restriction in dorsiflexion forces the midfoot into greater sagittal plane motion. This allows the navicular to continue dropping at a time when it should be elevating. This process prolongs the pronation phase and inhibits or even prevents supination of the foot. In turn, lateral rotation of the limb is either diminished or absent resulting in prolonged lateral displacement of the patella. It is important to include the soleus as it is stretched infrequently, even by active patients.

**Biomechanics**

There will be several motions that will be emphasized in the rehabilitation process. Improving foot and hip control in the frontal and transverse planes will be paramount to the long-term success of patients with PFS. The VMO will be activated in the transverse plane at the knee while motion in the sagittal plane will be enhanced for general quadriceps strengthening and overall daily function. We will begin with emphasizing the foot and ankle as the knee might be too symptomatic to tolerate exercise. This approach allows us to make significant progress toward improving the mechanics of the lower extremity without increasing the patient’s pain. I do not believe artificial stabilizers such as tape or braces should be used in order for the patient to successfully complete exercises. If this is required, I prefer to choose exercises that are appropriate for the patient’s current level of ability and tolerance.

**Foot**

Control of the foot in the frontal plane will emphasize eccentric control from the posterior tibialis. Although a concentric component to the exercises exists, the eccentric phase is what we will target most. The foot is placed with its lateral border supported on a one inch riser. The patient then supinates the foot to lift its medial border off the ground to a position slightly above the horizontal. The medial border of the foot is then lowered, with control, back to the ground. Careful instruction is provided to minimize compensation because of weakness (Fig. 2).

Transverse plane motion is controlled by the peroneus longus as it supports the midfoot and depresses the first ray. This occurs as you move through midstance and prevents prolonged pronation. This is the stimulus for the foot to begin supinating, which will rotate the lower extremity externally. This is recreated by having the patient sway anterior over the supporting leg. This eccentric dorsiflexion moment triggers a contraction of all musculature posterior to the malleolus thereby activating the peroneus longus. This stimulus also triggers activity in the posterior tibialis. The two work in concert to elevate the midfoot, further contributing to supination of the foot (Fig. 3).

![Figure 3](https://example.com/figure3.png)

**Figure 3** Peroneus longus strengthening via sagittal sway. (Color version of figure is available online.)

![Figure 4](https://example.com/figure4.png)

**Figure 4** Standing hip adduction. (Color version of figure is available online.)
Hip

The abductors and external rotators of the hip are also trained at this time to control adduction and internal rotation respectively. Again, this is done in the closed chain and in a position attempting to simulate its normal function by recreating its natural stimulus.

Strengthening of the abductors helps to minimize hip abduction during loading response and decreases the valgus moment at the knee. This training is performed with the patient in a modified stance where the involved extremity is bearing most of their weight and the contralateral limb is in a toe touch position. The patient then sways the pelvis to the ipsilateral side while maintaining a level pelvic and shoulder girdle. This forces the ipsilateral abductor to eccentrically control the lateral pelvic sway. I believe this closely simulates the abductor activity of midstance (Fig. 4).

Resistive tubing is also used to perform hip abduction in standing with the involved side acting as the support leg. This insure that the abductor on the involved leg will be controlling the motion of the pelvis in a closed chain. It is important to instruct the patient to minimize movement of the upper body and support from the upper extremities beyond basic balance assistance (Fig. 5).

Transverse plane training is achieved by inducing an ipsilateral rotation of the pelvis, which produces internal rotation of the hip. This is done by having the patient assume the same modified stance and reaching with the contralateral upper extremity 45° to the ipsilateral side. The external rotators have to control this motion eccentrically in order for the patient to maintain balance. Emphasis is placed on the amount of hip rotation and control. Both of these exercises are progressed by increasing the distance traveled and should at least be equal to the uninvolved side (Fig. 6).

Steps

The patient should perform step ups to an eight inch height for stair climbing training and general lower extremity strengthening. The height limit is usually consistent with standard step height. Descending stairs is usually much more problematic and therefore step downs will be initiated at a later time when the patient displays improved lower-extremity alignment and control. They should also be able to perform the step up exercise for several sets without symptoms. Anterior step downs directly simulate descending stairs and provide excellent eccentric control training for the quadriceps. They are quite taxing and should be prescribed with care to avoid a recurrence of symptoms. Medial step downs are performed off the side of a step or stool and provide for quicker concentric and eccentric contractions of the complete lower extremity in all planes with a high balance and proprioceptive demand.

Leg Press

Unilateral leg presses are very effective in providing total leg strength and to reinforce alignment. The patient is allowed to
go from 0 to 90° if there is no pain present. The foot is placed in the center of the patient’s pelvis to increase transverse plane motion at the knee to stimulate contraction of the VMO. Light resistance is used with greater repetitions and speed to avoid excessive compressive forces on the patella (Fig. 7).

**VMO**

The VMO is primarily activated in the transverse plane at the knee. This rotation is easily induced by adducting the limb toward or past the midline. Proper foot and hip control need to be achieved before this to prevent overloading the already weakened VMO. VMO training is performed with higher repetitions and with greater speeds to maximize its reaction time and muscular endurance.

The VMO originates from the adductor magnus tendon and studies have indicated VMO activity with hip adduction.15 The patient can perform and tolerate standing hip adduction utilizing resistive tubing with the stance leg again being the involved leg. The patient stands on the involved leg with the knee flexed to 20° to provide the patella with some boney stability. The patient then adducts the contralateral limb against the resistance of the tubing (Fig 8). Minimal, if any, upper-extremity assistance is provided to maximize balance demands thereby enhancing fine motor control of the foot. Other VMO exercises, which are more integrative and advanced, are the medial balance and reach (Fig. 9) and anteromedial crossover lunges (Fig. 10).
Another exercise that effectively stimulates the VMO utilizes the elastic resistance of the Pro Fitter to increase demands in the transverse plane (Fig. 11). Most exercises require little equipment and space and can therefore be performed in almost any location. This, hopefully, makes it quite easy for the patient to be compliant with a home exercise program.

**Conclusion**

Patients with PFS offer a complex and difficult clinical challenge. They present with a variety of clinical signs that, despite their complexity, frequently can be linked to a common cause when the lower extremity is assessed as a kinetic chain. Biomechanical analysis will frequently reveal significant deficits that have allowed secondary changes to occur that subsequently contribute to the syndrome. Restoring near normal biomechanics, strength and flexibility will usually result in a favorable functional outcome with minimal recurrence over the long term. My exercise-based rehabilitation program, with its emphasis on eccentric muscular control in the closed chain, is quite efficient and effective at restoration of proper mechanics.

**References**