# Patellofemoral Pain: Is There a Role for Orthoses?

## CASE SCENARIO

A 28-year-old woman presents with right anterior knee pain of 3 months' duration that occurs while she is running. To improve her overall fitness, she has been running 3 to 4 times per week (average, 12 to 15 miles per week) for the past 5 years. Before the onset of her knee pain, she had been gradually increasing the frequency of her training sessions and was running up to 4 to 5 times per week (average, 20 to 25 miles per week) in preparation for her first marathon. She has no history of knee injury or knee trauma. Her symptoms are exacerbated by running on hills (especially running downhill), performing squat exercises, and (most recently) traveling up or down stairs. The physical examination reveals a standing alignment notable for mild genu varum and pes planus. The patient experiences pain and medial knee collapse when performing a single leg squat. Bilateral mild heel valgus and moderate forefoot varus are noted. Her Q-angle is 20° on the right and 18° on the left. There is no evidence of knee effusion, swelling, or increased warmth. A 2+ medial and 3+ lateral patellar glide without evidence of patellar apprehension are noted. Palpation reveals tenderness of the medial patellar facet and lateral retinaculum that is not appreciated on the asymptomatic left side. Lower extremity flexibility is within normal limits and is symmetrical for the hamstrings, rectus femoris, psoas, and gastroc-soleus musculature. The Ober test reveals mild bilateral iliotibial band tightness. The results of a neurologic examination are within normal limits, except for the 5−/5 strength of the right hip abductors when the patient is tested while lying on her side. Radiographs (standing anteroposterior, lateral, and notch views) reveal no degenerative changes or osteochondral defects. There was evidence of mild lateral patellar tilt on the Merchant view. Previous treatment, which resulted in only mild relief, included 8 visits for physical therapy focusing on quadriceps strengthening, hamstring flexibility, and wall squats. A 4-week course of antiinflammatory medication also did not alleviate the patient's pain. Her overall presentation is consistent with the diagnosis of patellofemoral pain. Her primary care provider has referred her to you to determine whether orthotics or any other therapeutic options are feasible and likely to be effective. Which further assessment and treatment do you now recommend?


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## Christopher Powers, PhD, PT, Responds

Patellofemoral pain (PFP) is the most common overuse injury in persons who are physically active [1]. Despite its high incidence, the treatment of PFP continues to be a controversial issue. When faced with a patient with PFP, the clinician has many treatment options from which to choose, and selecting the right approach is often an arduous task. The question posed by this particular case is whether use of foot orthoses is indicated in a runner with a 3-month history of PFP. As with many interventions for PFP, orthoses often are prescribed without a justifiable biomechanical rationale and knowledge as to whether such an approach will be effective in alleviating symptoms. The use of orthoses as a treatment for PFP is an inexact science at best and often becomes an exercise in trial and error. As in the current case, orthoses often are considered as a "last-ditch effort" when traditional interventions have failed.

The patient described in this case exemplifies the dilemma facing clinicians who encounter PFP on a regular basis—

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pronounced pain and the absence of clinical and/or radiographic findings that explain the cause of symptoms. With that being said, it is commonly accepted that the etiology of PFP is multifactorial, with contributing factors being defined by 3 general categories: (1) local joint impairments (ie, abnormal patella tracking, tightness of lateral structures, etc); (2) altered lower extremity biomechanics (ie, motion impairments at the hip and/or foot and ankle); and (3) overuse (ie, excessive activity, training errors, etc.) [2]. The fact that there is no obvious evidence of a local joint impairment, combined with the patient's self-report of pain with dynamic activity, suggests that there may be an underlying biomechanical problem contributing to her symptoms. This premise is supported by the observation that the patient exhibits "medial collapse" of the lower extremity and concurrent pain during a single limb squat. Finally, the increase in her training volume in preparation for her marathon also suggests an element of overuse.

It is now recognized that the patellofemoral joint can be influenced by the segmental interactions of the lower extremity. Abnormal motion(s) of the tibia and femur in the transverse and frontal planes can have a substantial effect on patellofemoral joint mechanics and therefore PFP. More specifically, it has been proposed that abnormal lower extremity motion can affect the "dynamic Q-angle" and the lateral forces acting on the patella [3]. The 3 lower limb motions that can influence the dynamic Q-angle are tibial rotation, femoral rotation, and dynamic knee valgus [3].

The decision to prescribe a foot orthosis for PFP should be determined by sound biomechanical theory and careful examination of the patient's gait and/or running pattern. As a result of the intimate relationship between the rearfoot and the tibia, abnormal pronation has been linked to several lower extremity conditions, including patellofemoral joint dysfunction. When relating excessive pronation to various clinical entities, an assumption is made that abnormal pronation results in excessive tibial internal rotation and that this motion places a rotatory strain on soft tissues of the lower extremity. Although this may be the case with respect to the tibiofemoral joint, the same assumption does not hold true for the patellofemoral joint. In fact, excessive tibia internal rotation caused by foot pronation would actually decrease the dynamic Q-angle and the lateral forces acting on the patella [3].

This discrepancy was noted by Tiberio [4], who described a set of circumstances by which excessive pronation could affect the patellofemoral joint. Tiberio [4] states that to achieve knee extension in midstance, the tibia must externally rotate relative to the femur to ensure adequate motion for the screw-home mechanism at the knee. To compensate for this lack of tibial external rotation (because of the failure of the foot to resupinate), the femur would have to internally rotate on the tibia such that the tibia is in a position of relative external rotation [4]. Compensatory internal rotation of the femur would therefore permit the necessary screw-home mechanics to allow for knee extension in midstance. In this scenario, excessive internal rotation of the femur would move the patella medially with respect to the anterior superior iliac spine, thereby increasing the dynamic Q-angle and the lateral component of the quadriceps muscle vector [3]. Furthermore, excessive femoral internal rotation has been shown to be the primary contributor to altered patellofemoral joint kinematics in weight bearing (as opposed to patella motion) [5,6]. Therefore, there appears to be a viable rationale by which excessive pronation could influence the patellofemoral joint; however, such motion ultimately would have to influence the femur.

Apart from controlling motion, foot orthoses also are prescribed to assist the foot in attenuating ground reaction forces; if the forces at impact can be minimized, loading at the knee also may be reduced. However, it bears mentioning that because of its vertical orientation, the patellofemoral joint is not subjected to the same impact forces as the tibiofemoral joint. Although improving shock absorption at the foot would be expected to minimize impact loading at the tibiofemoral joint, use of an orthosis would not be expected to have a significant influence on patellofemoral joint compression.

On the basis of the aforementioned information, it could be argued an orthosis could be justified for this patient; however, it would be only under a specific set of circumstances, ie, the presence of abnormal pronation and corresponding internal rotation of the tibia and femur. If excessive pronation was evident in this patient, but without a corresponding increase in tibia and femur rotation, then it could be argued that an orthotic intervention may be of little benefit from a biomechanical standpoint. Indeed, Reischl and colleagues [7] have reported that the magnitude of foot pronation does not predict the magnitude of tibia or femur rotation. As such, patients need be evaluated on an individual basis to determine whether abnormal foot mechanics are contributing to a kinematic pattern that could explain the presence of patellofemoral symptoms.

It also should be recognized that the presence of abnormal foot pronation, tibia rotation, and femur rotation in a particular patient does not rule out proximal influences as a contributing factor. Recent studies of hip function in female patients with PFP have reported that this population exhibits reduced hip muscle strength and excessive hip internal rotation [8,9]. For example, Souza and Powers [9] reported that women with PFP had excessive degrees of peak hip internal rotation during running compared with pain-free control subjects (8.3° vs 0.3°). These authors also reported that isotonic hip extension endurance was a significant predictor of peak hip rotation during running, suggesting that impaired hip muscle performance may underlie the abnormal hip kinematics thought to contribute to PFP.

Another factor to consider in this case is whether or not a foot orthosis has the ability to change lower extremity mechanics in a meaningful way. Biomechanical studies have reported that medial-wedged foot orthoses have minimal influence (1°-2°) on knee kinematics in the frontal and transverse planes [10,11]. In a recent study, Jenkins et al [12] reported that the use of an over-the-counter foot orthotic caused a secondary decrease in hip internal rotation. Interestingly, the use of a custom orthosis only resulted in a 1° decrease in hip internal rotation in this study. Whether the small changes in lower limb kinematics afforded by a foot orthosis would result in meaningful decreases in patellofemoral joint loading remains to be seen.

In addition to the scant biomechanical evidence to support the use of foot orthoses as a treatment for PFP, clinical evidence also is lacking. Apart from one small clinical trial with 10 subjects [13] and a case series with no control group [14], there is limited evidence to support use of a foot orthotic as a treatment for PFP. A clinical trial evaluating the use of foot orthoses in the treatment of PFP (n = 179) reported that the use of orthoses was no better than physical therapy [15]. The combined use of foot orthoses and physical therapy was found to be no better than physical therapy or the orthotic intervention alone.

In summary, the decision to prescribe an orthosis for the patient described in this Point/Counterpoint should be approached with considerable caution. This opinion is determined via 3 main points: (1) the link between abnormal foot pronation and patellofemoral joint dysfunction is somewhat tenuous; (2) it is questionable whether a foot orthosis has the potential to change lower limb mechanics and, therefore, patellofemoral joint loading in a meaningful way; and (3) there is limited clinical evidence supporting the use of an orthosis as a treatment option for PFP. Although it is certainly plausible that certain patients may respond favorably to foot orthoses, care should be taken in overgeneralizing this assumption to the PFP population as a whole. Future research should be directed toward identifying which patients respond best to a foot orthotic intervention.

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## Gary Berke MS, CP, and Mark Clary, CO, Respond

The treatment of patellofemoral pain (PFP) like that described in this case is subject to controversy, much of which is related to difficulty in determining the cause of discomfort. Prevalent etiologic theories surround mechanical causes, that is, increased Q-angles, tibial rotation, femoral alignment problems, foot alignment issues, and patella alignment. With that said, most experts agree that the cause is multifactorial and therefore treatment must also address the patient's pain in various ways. A careful evaluation of the foot and ankle, knee, patella, and hip must precede the selection of the appropriate pathway to healing. Our job as orthotists is to discuss the role of the foot and ankle with regard to alignment-related PFP and to determine the benefit of foot orthoses in the treatment regimen.

A review of the literature produced evidence of the variable effectiveness of foot orthoses in the treatment of PFP. A recent consensus conference on that disorder yielded several studies in which the use of foot orthoses resulted in good or excellent results in the treatment of PFP [1-5]. Other investigators have also shown a positive therapeutic effect of foot orthoses in patients with PFP [6-10]. The results of several investigations suggested that altering ground reaction forces

around the foot by modifying the material used to make an orthosis or shoe can significantly affect the forces around the knee [11-13]. However, comprehensive systematic reviews on this topic are limited [14,15].

The question then becomes "Why is the use of foot orthoses so controversial if many studies in the literature show that their use is beneficial in cases of PFP?" First, experts have agreed that the mechanism of action imparted by a foot orthosis on PFP is not clearly understood. Although the alteration of the Q-angle is relatively straightforward in patients with that disorder, the effect of an orthotic device on tibial and femoral rotation (as well as the role of rotation in PFP patients) is less clear. In addition, several findings in the current literature [4] may explain some of the differences in study outcomes. In only one of the studies reviewed [4] (which included all of the literature used in consensus conferences and in systematic reviews) did a trained, experienced clinical orthotist evaluate subjects for and provide foot orthoses. The authors of another study [1] suggested that prefabricated orthoses could be provided by therapists with 6 or fewer hours of training by the manufacturer and that "comfort" should be the primary determinant of efficacy. Even that study demonstrated the positive results of treating PFP patients with foot orthoses, the therapeutic effects of which were nevertheless likened to the results of physical therapy.

We suggest that the varying results of studies on orthoses for PFP in the existing literature are determined by differences in the following: (1) the training and clinical experience of those providing foot orthoses for the treatment of knee disorders; (2) orthotic materials (eg, rigid, semirigid, firm, soft, prefabricated, custom) and methodologies; (3) orthotic evaluation; and (4) the prevalent assumption that the design of foot orthoses, the materials used, the length of the orthosis, and the evaluation of the foot may be inconsequential to the efficacy of treatment. Studies in the literature have also failed to consider the type of shoe used with respect to style, overall use, and interaction with the orthosis. Furthermore, no defined protocol for orthoses has been established with regard to the following variables: the duration of use required throughout the day, the weaning process, or the duration (weeks or months) of use. Each of those factors itself can cause a significant variation in treatment outcome.

Because the patient described in this report has been complaining of pain for 3 months, has participated in a physical therapy program for a significant period of time, has taken medication, and exhibits notable lower extremity alignment issues, we suggest that a custom full-length foot orthosis would be a reasonable recommendation supported by the available evidence. Runners and others with a high activity level present additional therapeutic challenges regarding the wearing of a custom foot orthosis—challenges that are not imposed by patients whose activity level is relatively lower.

Characteristics of the materials used in the orthosis must be considered because of the dynamic repetitive nature of the activity and the increased ground reaction forces. It is interesting that the patient described had been running for 5 years without symptoms, but after she increased her mileage, problems surfaced. Instead of rigid materials, firm materials that absorb shock should be considered for use in an orthosis, which must provide medial longitudinal arch support without hindering the natural pronation mechanism of the foot. Hindfoot valgus can be addressed with a medial heel wedge, and the forefoot must be supported with medial posting because of the rigid deformity; otherwise, the rigid forefoot will continue to "drive" the hindfoot into valgus. According to Davis and Mann [16], the relationship of the forefoot to the hindfoot is critical for surgical alteration in that a fixed varus or valgus forefoot deformity does not permit the foot to become plantigrade after the hindfoot has been placed in a neutral position. Orthoses must also be configured to fit properly inside the shoe and to reinforce each other to achieve the desired ground reaction forces at the plantar surface of the foot.

Because pronation is a triplanar deformity, it is important to consider the effects of a foot orthosis in the transverse plane, and in this case, how it might address the medial collapse of the knee during a single leg squat. Researchers such as Cheung et al [17] examined the assumption that foot orthoses can be used to control excessive foot pronation in the stance phase of gait, thus reducing internal tibial rotation and improving lower limb biomechanics. Although in the clinical setting it may be possible to observe an improvement in the frontal plane alignment of a lower extremity, transverse plane alignment is more difficult to quantify. The question of whether the discomfort results from lower extremity rotations distal or proximal to the knee joint (or a combination of both) then arises. In the presentation of this young female runner, it would seem reasonable to address both, because she exhibits distal malalignment of the heel and forefoot in addition to mild tightness and weakness proximally.

One of the confounding factors that must also be considered in this case is the varus knee position at rest. The effect of foot alignment on PFP is unclear, as is the effect (on the knee) of the correction of foot alignment with increased medial support. If the alignment of the knee is in the correct anatomic position, then an increase in the medial longitudinal arch and medial heel posting may exert a negative effect on the medial compartment of the knee and should be closely evaluated before correction of the foot.

In summary, the diagnosis of PFP is multifactorial and exclusionary. Conservative management should include physical therapy and the use of foot orthoses in patients with foot and ankle malalignment should be considered. It is clear, especially in the fields of orthotics and prosthetics, that standardized clinical measures of foot alignment and function are needed; these will improve the clinician's confidence

in recommending foot orthoses to patients who present with PFP. It is our hope that in the next few years, we will be better able to classify alignment issues of the foot and ankle, that our understanding of the causes of PFP will improve, and that a well-designed study in which well-trained, experienced clinical orthotists using appropriate materials and design will determine the true efficacy of foot orthoses in the treatment of this complicated disorder. Because much of the current research has concentrated on the rearfoot, future studies that clarify the mechanisms of the midfoot and forefoot as they relate to more proximal structures of the lower extremity will be useful. In addition, detailed descriptions of foot orthotic materials, modifications, and wearing time, as well as recommendations for the shoes that should be worn by patients with PFP, should be part of the study methodology.

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## Michael Fredericson, MD, Senior Editor Commentary

PFP, which accounts for 25% to 33% of the knee injuries diagnosed in sports medicine clinics, is a frequent complaint among running athletes [1,2]. It is estimated that approximately 2.5 million runners will be diagnosed with PFP in a given year [3]. Although treatment for that disorder may be successful in the short term, long-term results are less promising. Limited function persists in many people with PFP, even after a full treatment program. Studies have shown that 73% of treated PFP patients experienced pain 5 years after their initial presentation [4] and that 25% of such patients reported symptoms up to 20 years later [5].

The case presented in this report shows that the cause of PFP is multifactorial, and it underscores the need for multiple treatment approaches. Although scientific evidence indicates a link between PFP and patellar alignment and mechanics, foot mechanics, and hip strength, most clinicians do not follow a clear clinical decision-making algorithm in determining which treatment is best for each patient [3].

Many clinicians have prescribed orthoses to treat those with PFP, and that therapy has produced positive clinical outcomes; thus, orthoses are a reasonable option to consider in such patients. However, as our discussants have indicated, the mechanism of action of foot orthoses in patients with PFP is unclear; thus, predicting which patients will benefit from that treatment is difficult. Delayed or prolonged peak rearfoot eversion has been reported during walking [6] and running [7] in patients with PFP; however, that finding has not been consistent in all studies [3]. In addition, those patients with PFP have been reported to strike the ground with increased rearfoot eversion during walking [8] and running [9], which can be associated with increased knee flexion and abduction [10], both of which are associated with increased loading of the patellofemoral joint. As suggested by the recent consensus statement from the international patellofemoral research group, we need to continue to develop valid and reliable standardized clinical measures of foot

alignment and function [3]. These measures will greatly assist with decision making when the prescription of foot orthoses is considered for patients with PFP.

Evidence also suggests that patients with PFP exhibit altered hip kinematics. Results from dynamic magnetic resonance imaging studies [11,12] have shown that excessive femoral internal rotation increases lateral patella tracking and patellofemoral joint stress. Women with PFP exhibit hip abduction and external rotation weakness and greater hip adduction than that found in healthy women [13]; this finding correlates with prospective evidence that runners in whom PFP develops demonstrate increased hip adduction and internal rotation [3,14]. However, like the case presented in this report, most studies on PFP have focused on female subjects; more studies involving men with this disorder are needed. If the mechanics of PFP differs in men and women, then therapeutic interventions may need to be gender specific [3].

Although the patient described in our case report had already tried quadriceps and presumably vastus medialis obliquus strengthening, it does not that appear that vastus medialis obliquus timing was compared with vastus lateralis (VL) timing. Multiple studies have demonstrated the prevalence of vastus medialis (VM) activation delay in subjects with patellofemoral pain [15,16] and the efficacy of rehabilitation protocols in improving VM activation timing and reducing pain [17]. However, several authors [18,19] have reported no differences in VL and VM activation timing in subjects with or without PFP. Our Stanford research group has developed a comprehensive method, determined with patellar tracking measures, for classifying patellofemoral pain subjects [20]. By using this classification, we discovered a significant association between VM activation delay and patellar tracking measures in subjects with patellofemoral pain who were classified as maltrackers; this finding suggests that there is a subset of patients who will demonstrate greater clinical success in response to a VM retraining program.

My own experience in studying PFP suggests that we still have much to learn in terms of optimal treatment strategies for specific patients. This treatment requires a collaborative effort among engineers, biomechanists, and clinicians and is the model we are following in the Stanford patellofemoral research group. In addition, clinical prediction rules must be established to determine which patients will respond best to each intervention [3]. A cluster of signs and symptoms (a clinical prediction rule) must be defined to help identify patients whose PFP results from abnormal patellar bony and structural abnormalities, altered hip neuromechanics, foot mechanics, quadriceps imbalance and timing discrepancies, or soft-tissue restrictions. Like the subject of our case report, patients who are classified in more than one subgroup will require a combination of interventions to achieve optimal results.

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