Patellofemoral-pain syndrome (PFPS) is the most prevalent knee disorder among adolescent and young-adult athletes. Despite its prevalence, PFPS remains one of the most problematic musculoskeletal disorders for sports-medicine practitioners to manage. Conservative rehabilitation strategies including exercise therapy, taping, bracing, foot orthoses, biofeedback, physical modalities, and activity modifications have been advocated to reduce PFPS symptoms and to restore premorbid functional status. Although these treatment options are quite plausible, many sports-medicine practitioners rely on anecdotal evidence to support these interventions. An effective strategy for managing the care of patients with PFPS is to establish a plan of care based on the strongest evidence available. This approach is known as evidence-based practice.

Evidence-Based Practice

What is evidence-based practice? Sackett is credited with coining the terms evidence-based medicine and evidence-based practice. Evidence-based practice (EBP) is defined as a method of integrating individual clinical expertise with the best available evidence from clinically relevant research to make decisions about the care of individual patients. An important premise of EBP is that clinical decision making should not be based on either clinical experience or research evidence in isolation of the other component. It has been reported by several investigators that the process of EBP consists of the following five steps: (1) defining the question, (2) searching the literature, (3) evaluating the evidence, (4) applying the results to the patient, and (5) evaluating the outcome of EBP.

A couple of key terms such as level of evidence and critical appraisal must be considered in order to understand the process of EBP. Confidence in making a clinical decision regarding an intervention depends strongly on the supporting evidence for that intervention. Sports-medicine practitioners often refer to the level of evidence as an indication of the type and quality of evidence found in the literature. The levels of evidence consist of the following types: systematic reviews, randomized controlled trials, cohort studies, case-control studies or case reports, and expert opinions. The evidence available to support a clinical procedure can be given a grade of recommendation based on Grades A thru D. Evidence that is consistently supported by systematic reviews of randomized controlled trials is designated by the recommendation Grade A. Grade B evidence represents a consistent level of findings among cohort studies or systematic reviews of
The VMO allows the muscle to function primarily as a medial stabilizer of the patella during terminal knee extension. The concepts of VMO and VL motor-activation differences and muscle-strength differences have prompted many sports-medicine practitioners to establish VMO-isolation exercises as the cornerstone of PFPS rehabilitation. Current evidence indicates that there is considerable doubt that the VMO can be selectively isolated.

In a systematic review of PFPS rehabilitation, Lohman et al. concluded from the reviews of numerous studies that the VMO is not selectively isolated during traditional quadriceps isometrics or during leg raises with various thigh positions. In addition, they concluded that there is limited evidence in the current literature that demonstrates significant differences in activation timing of the vasti muscles in patients with PFPS. Witvrouw et al. supported these findings in a prospective investigation of 60 patients with PFPS. Patients were randomized into a 5-week OKC exercise group or a CKC exercise group. Reflex-response times of the VMO and VL were assessed with electromyography (EMG). The investigators found no significant alterations in reflex-response times of the VMO and VL in either group despite significantly decreased knee pain.

In an investigation of VMO motor activity on patellar kinematics, Powers employed the methodology of kinematic magnetic-resonance imaging and EMG to assess 23 women with nontraumatic PFPS while they performed OKC knee extension. The investigators found no difference in the VL:VMO motor-activity ratio between PFPS patients and controls. Also, the VL:VMO ratio was not predictive of patellar motion at any point in the range of knee flexion for the participants. Although there is evidence indicating that the VMO cannot be selectively isolated, sports-medicine practitioners should appreciate the importance of quadriceps strengthening as a whole for patients with PFPS. Evidence for this clinical guideline is supported by a 7-year prospective follow-up study by Natri et al., who found that restoration of quadriceps strength is important for successful long-term outcomes in patients with PFPS.

The quality of evidence relative to VMO/VL selective activation and timing differences supports a recommendation Grade B. The literature does not consistently support selective activation of the VMO or VMO/VL timing differences at terminal knee extension. There appears to be little evidence to support isolation of the vasti muscles with specific exercises.

**Strength Training**

Conservative treatment of patients with PFPS has focused mostly on the effects of therapeutic exercise. Traditionally, quadriceps strengthening has been the primary objective for PFPS rehabilitation. Despite the widespread use of quadriceps strengthening among sports-medicine practitioners, many questions surround the efficacy of this intervention in the rehabilitation of athletes with PFPS. These clinical questions include the following: Can the vastus medialis obliquus (VMO) be selectively activated from the vastus lateralis (VL)? Are there specific exercises that isolate the VMO? Does closed kinetic chain (CKC) strengthening provide better clinical outcomes than open kinetic chain (OKC) strengthening in patients with PFPS?

**Vastus Medialis Obliquus Isolation**

It has been theorized that the anatomical location of the VMO allows the muscle to function primarily as a
Sports-medicine practitioners should focus on restoring quadriceps strength as a whole in patellofemoral rehabilitation.

**Closed Kinetic Chain Versus Open Kinetic Chain**

Another clinical controversy surrounding the management of patients with PFPS involves using CKC and OKC strengthening exercises during rehabilitation. Traditionally, short- and long-arc OKC leg-extension exercises, isometric contractions, and straight-leg raises have been used to strengthen the quadriceps muscles. Recently, CKC strengthening exercises such as wall sips, leg presses, and step-ups have been advocated because of their purported ability to replicate functional movements while minimizing patellofemoral-joint stresses at terminal knee extension. Whether one mode of strengthening offers a significant advantage in the rehabilitation of patients with PFPS is a major question for sports-medicine practitioners.

In a prospective, randomized study, Witvrouw et al. evaluated the efficacy of OKC exercises versus CKC exercises. They randomized 60 patients (20 men and 40 women) into a 5-week OKC-exercise-only group or a 5-week CKC-exercise-only group. The investigators used the following assessments to compare groups at a 5-week and a 3-month follow-up: a Kujala standardized scoring scale, a visual analog scale, a unilateral squat test, a step test, a triple-jump test, isokinetic quadriceps- and hamstring-muscle-strength tests, and muscle-length measurements. Overall, they found that both forms of exercise led to a significant decrease in pain and an increase in functional performance as measured by the Kujala scale. When the outcomes of functional tests were specifically assessed, however, the CKC group demonstrated a significantly increased performance level.

In a systematic review, Selfe used an extensive search strategy to retrieve 168 articles (67 reviews and 101 primary studies) on the patellofemoral joint. From the search, the investigator concluded that CKC training might be more effective than joint-isolation exercises in restoring function. Because functional activity is composed of both OKC and CKC components, however, it is recommended that sports-medicine practitioners use each mode of exercise in the rehabilitation of patients with PFPS.

In another systematic review, Bolgla and Malone used the Medline, CINAHL, and SPORThDiscus databases from 1985 to 2004 to evaluate the effectiveness of exercise in participants with PFPS. The literature seems to support the notion that patients can benefit from both OKC and CKC exercises when performed in a pain-free range of motion. Bolgla and Malone advise that OKC exercises be performed between 40° and 90° flexion and CKC exercises be performed between 0° and 45° to reduce patellofemoral stresses.

The evidence relevant to CKC and OKC strengthening exercises for management of PFPS supports a recommendation Grade B. Results of these studies reveal that there are no significant differences in long-term subjective outcome measures between isolated CKC strengthening and isolated OKC strengthening. CKC strengthening appears to produce greater improvements in functional activities than OKC strengthening does. Sports-medicine practitioners should use both methods of strengthening in rehabilitation of patients with PFPS.

**Hip Strengthening**

Currently, clinicians hypothesize that the etiology of PFPS might be associated with a decrease in hip and pelvic control. Hence, the rehabilitation of patients with PFPS should include proximal-stabilization exercises. Proximal stabilization should specifically target the hip abductors and hip external rotators. Theoretically, strengthening the lateral hip muscles in order to control femoral internal rotation and femoral adduction could reduce stress at the patellofemoral joint by providing an increased trochlear-contact surface for articulation with the patella during functional activities.

This theoretical approach to PFPS rehabilitation is supported by a cross-sectional study conducted by Ireland et al. who assessed isometric hip-abductor and external-rotator strength in 15 female participants and 15 age-matched female control participants using handheld dynamometry. The investigators found that participants with PFPS demonstrated 26% less hip-abductor strength and 36% less hip external-rotator strength than their control counterparts. The strength deficits found in this study are similar to those reported by Van Wilgen et al., who used handheld dynamometry to assess strength in patients with unilateral non-specific chronic pain.

Brindle et al. provide some potential support for the hypothesis that hip control is important in the rehabilitation of patients with PFPS. They assessed lower extremity EMG activity and kinematics in 16 parti-
pants (12 women and 4 men) with generalized anterior knee pain and 12 age-matched controls (7 women and 5 men) during stair negotiation. They concluded that the anterior-knee-pain group demonstrated a delayed onset and a shorter duration of gluteus medius motor activity during the ascent and descent phases of stair negotiation.\(^{22}\) Delayed onsets and shorter durations of gluteus medius activity are neuromuscular alterations that might be part of a movement dysfunction in patients with PFPS. Nonetheless, these alterations in EMG activity cannot be interpreted as direct changes in muscle strength.\(^{24}\)

Mascal et al.\(^{21}\) used a case-report study design to investigate the effects of a 14-week hip-, pelvis-, and trunk-muscle-training program on 2 patients with PFPS. Each patient participated in a non-weight-bearing exercise phase (Weeks 0–6), a weight-bearing exercise phase (Weeks 6–10), and a functional-training phase (Weeks 10–14). The results of the study revealed that both individuals experienced a significant reduction in patellofemoral pain. In addition, both improved their gluteus medius and gluteus maximus force production by 50\% or more.\(^{21}\) Although this study revealed favorable results for hip strengthening, the limitations inherent to case-study designs prevent clinicians from generalizing the results to a larger population of patients with PFPS.

The quality of evidence supporting the efficacy of hip strengthening in patellofemoral rehabilitation is limited. The current evidence only supports a recommendation Grade D. The theory of associated hip abductor and hip external-rotator weakness with PFPS is not supported by sufficient evidence in the literature. Additional studies are needed before clinical guidelines can be established regarding the role of hip strengthening in patellofemoral rehabilitation. Nonetheless, this appears to be a promising area in patellofemoral research.

**Neuromuscular Control**

It has been postulated that abnormal proprioception might be associated with the etiology or sequelae of PFPS.\(^{25,26}\) Abnormal proprioception could lead to movement dysfunctions that produce abnormal stresses on the tissue adjacent to the patellofemoral joint.\(^{25}\) Traditionally, proprioception has been measured by passive angle reproduction, active angle reproduction, and threshold for detection of passive movement.\(^{26}\)

Baker et al.\(^{25}\) assessed knee-joint position sense in 20 participants (15 women and 5 men) with PFPS and 20 control participants. Experimental methods included non-weight-bearing and weight-bearing (unilateral and bilateral) joint-angle-reproduction tests. The investigators reported the following results: Proprioception was less accurate and less consistent in the knees with PFPS for both conditions, and proprioception was less accurate in the asymptomatic knees of the unilateral PFPS participants than in the knees of the control participants.\(^{25}\)

Powers\(^{19}\) theorized that altered kinematics of the lower extremity might lead to dysfunctions of the patellofemoral joint. It has been hypothesized that abnormal control in the transverse and frontal planes causes excessive knee valgus and a dynamic malalignment of the patellofemoral joint.\(^{19,27}\) Scant support for this theory can be found in investigations by Hewett et al.,\(^{28}\) who, in a cross-sectional controlled laboratory study, performed three-dimensional kinematic analysis of 81 healthy male and 100 healthy female preadolescent and adolescent athletes. After being instrumented with retroreflective markers, each participant performed a box-drop vertical jump while reaching for a basketball rebound. Compared with males, females demonstrated significantly greater knee abduction in the pubertal-stage groups. In addition, females demonstrated a side-to-side difference in knee-valgus angle at landing in the postpubertal stage of development. These differences were not evident between genders in the prepubertal stage of development. The investigators concluded that after the pubertal growth spurt, females might have decreased neuromuscular control of the knees when performing sports maneuvers such as landing from a jump. Decreased neuromuscular control might increase their risk of serious knee injuries.

Investigations relating to the role of proprioception and neuromuscular-control training are limited. Overall, the quality of the current evidence only supports a recommendation Grade D. The role of proprioception deficits in patients with PFPS is inconclusive. There is scant evidence to support the theory that dynamic neuromuscular training is beneficial for the rehabilitation of patients with PFPS. No clinical guidelines can be made given the paucity of literature.

**Conclusion**

This evidence-based review of conservative rehabilitation for athletes with PFPS assessed the efficacy of
strength and neuromuscular-control training. This article supports the use of quadriceps-strengthening exercises for successful long-term outcomes, but the evidence to support the use of hip strengthening in the rehabilitation of patients with PFPS is weak. The evidence supports the use of CKC and OKC strengthening exercises to reduce symptoms and to improve functional status in athletes with PFPS. There is no conclusive data that support the use of proprioception and neuromuscular training in patients with PFPS. Future studies should investigate the efficacy of hip strengthening and neuromuscular training on outcomes in patients with PFPS.

References


Adrick Harrison is a doctoral student in the rehabilitation sciences program at the University of Kentucky. He is also a sports physical therapist and research assistant in the Sports Medicine Biodynamics Center at Cincinnati Children’s Hospital Medical Center.