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The current management of patients with patellofemoral pain from the physical therapist's perspective

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Abstract

Patellofemoral pain (PFP) is a common diagnosis that includes an amalgam of conditions that are typically non-traumatic in origin and result in peripatellar and/or retropatellar knee pain. The purpose of this review is to provide an overview of the physical therapist's management, including the evaluation and treatment, of the patient with PFP. A thorough history is critical for appropriately diagnosing and optimally managing PFP; the history should include the date of symptom onset, mechanism of injury and/or antecedent events, location and quality of pain, exacerbating and alleviating symptoms, relevant past medical history, occupational demands, recreational activities, footwear, and patient goals. Physical examination should identify the patient's specific impairments, assessing range of motion (ROM), muscle length, effusion, resisted isometrics, strength, balance and postural control, special tests, movement quality, palpation, function, and patient reported outcome measures. Objective assessments should guide treatment, progression, and clinical decision-making. The rehabilitation program should be individually tailored, addressing the patient's specific impairments and functional limitations and achieving the patient's goals. Exercise therapy, including hip, knee, and core strengthening as well as stretching and aerobic exercise, are central to the successful management of PFP. Other complimentary treatments may include patellofemoral and tibiofemoral joint mobilizations, patellofemoral taping, neuromuscular training, and gait retraining. Appropriate progression of interventions should consider objective evaluations (e.g., effusion, soreness rules), systematic increases in loading, and the chronicity of symptoms. Although short-term changes or reductions in movement often are necessary in a protective capacity, the persistence of altered movement is a key characteristic of chronic pain, which may be managed in part through emphasis on function over symptoms, graded exposure, patient education, and perhaps referral. PFP etiology is largely movement related and a comprehensive conservative treatment using movement can be successful.

Keywords

Patellofemoral joint; patellofemoral pain (PFP); rehabilitation; physical therapy

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Patellofemoral pain (PFP) is exceedingly common. Annual prevalence for PFP approaches 23% in the general population and is approximately 29% among adolescents, with female athletes being at particularly high risk (1). Participation in recreationally running or military training, both of which may lead to high patellofemoral joint contact forces (2), is associated with an especially high incidence of PFP (1). Persistent symptoms are common and 57% of individuals with PFP report unfavorable outcomes five to eight years after their initial diagnosis (3). As such, it is important for individuals with PFP to receive optimal rehabilitation with the goal of achieving positive short- and long-term outcomes and preventing the transition from a transient, acute episode into a recurrent, chronic problem.

The purpose of this review is to provide an overview of the physical therapist's management, including the evaluation and treatment, of the patient with PFP. We begin with a brief overview of symptom onset, then discuss the importance of considering the complexities of the painful experience when rehabilitating individuals with PFP, particularly among those with episodic or recalcitrant symptoms. We then present our rehabilitation approach for a systematic physical therapy examination including a thorough subjective history and objective clinical, functional, and patient-reported outcome measures. Finally, we present a comprehensive treatment approach that draws heavily from recently published literature and clinical trials.

Symptom onset

PFP, or anterior knee pain, is an amalgam of conditions that are typically non-traumatic in origin and result in peripatellar and/or retropatellar knee pain. A number of structures in and around the patellofemoral and tibiofemoral joints, such as the synovium or infrapatellar fat pad, may individually or collectively contribute to PFP (4). The patellofemoral articular cartilage itself, however, is not painful when probed directly sans anesthesia (5), likely due to its lack of free nerve endings (6). While a variety of factors may also contribute to symptom onset, disruption of tissue homeostasis via acute injury or repetitive overloading (i.e., high-frequency moderate loading or an isolated very high loading event) may exceed tissue homeostasis, or the envelope of function, for a given structure(s) and lead to pathology and pain (7,8). Conservative management may initially promote relative rest and avoidance of activities that exacerbate the patient's pain while attempting to limit loss of muscle strength, ROM, or function. PFP, however, often persists for months or even years (3,9), requiring a more complex rehabilitation approach.

The complex pain experience

Throughout the successful management of PFP and especially when symptoms are chronic in nature, rehabilitation specialists must appreciate the complexity of the pain experience (10). In his 2016 Maley Lecture, physical therapist and pain science researcher Steven George, PT, PhD, calls for a shift in physical therapist education, research, and clinical practice from the traditional direct link among pain, nociception, and injury to a more inclusive biopsychosocial model that incorporates pain with movement (10). Healthcare professionals must consider not only the patient's underlying knee pathology (e.g., structural abnormalities, muscle dysfunction) but also the patient's psychological distress and pain neurophysiology when evaluating the clinical pain experience (11). In chronic musculoskeletal conditions, as can often become the case with PFP, symptoms may outlive their usefulness; although no clear definition exists, chronic pain is generally described as pain that lasts "beyond the body's usual healing time" and is typically three months or greater (12). Clinicians must recognize the difference between acute (protective) pain and chronic pain, which may limit function and inhibit progress. Encouraging regular movement and exercise within the pain-free envelope of function (7) and, when appropriate, such as in the chronic case, even beyond the pain-free range, may be necessary to optimize function in patients with PFP. In such cases, graded exposure (13) may help maximize function even in the absence of full symptom resolution.

Conscientious monitoring and progression of interventions and other activities throughout rehabilitation is thus essential to achieving optimal outcomes. The remainder of this review article will delineate strategies for conducting a thorough evaluation and creating an appropriate, progressive, and individualized treatment approach for PFP.

Evaluation

History

A thorough history is critical for appropriately diagnosing (14) and optimally managing PFP (15). While one may accurately identify the relatively young, active woman with atraumatic onset of anterior knee pain as the most likely candidate, men and women of all activity levels across a wide age range may develop PFP (16). The rehabilitation specialist should ask the patient to identify the date of symptom onset, mechanism of injury and/or antecedent events, location and quality of pain, exacerbating and alleviating symptoms, relevant past medical history including prior lower extremity and low back symptoms, diagnostic imaging, occupational demands, recreational activities, footwear including use of orthotics, and patient goals (Table 1). Pertinent past medical history may include not only previous knee symptoms but also ankle, hip, and lumbar pain, as radiculopathy from the spine to the knee is possible. Referred knee pain may be present due to hip pathology, such as osteoarthritis or predominantly pediatric conditions like slipped capital femoral epiphysis (17,18), thus subjective questioning and physical examination should consider the hip, particularly when the practitioner is unable to provoke the patient's symptoms during a thorough, targeted knee evaluation. Gradual and even insidious onset of anterior knee pain are common in PFP whereas acute onset of knee pain secondary to a traumatic event merits further evaluation of the integrity of the knee ligaments, tendons, menisci, and bone. Clinicians should refer their patients to an appropriate specialist if they suspect serious pathology (e.g., fracture or osteomyelitis) or non-musculoskeletal origin (e.g., cancer or infection) due to the presence of red flags (i.e., fever, unremitting night pain, or increased temperature and swelling around the knee; or, among adolescents or children, a leg length discrepancy, limp, and limited hip ROM possibly indicative of Perthes disease or a slipped capital femoral epiphysis) (16). Physician referral is also warranted in the case of unremitting or worsening symptoms despite appropriate physical therapy and activity modification.

Clinical examination

Physical examination should incorporate a variety of measures including ROM, muscle length, effusion, resisted isometrics, strength, balance and postural control, movement quality assessments, special tests, palpation, functional evaluation, and patient reported outcome measures. Objective assessments should guide treatment, progression, and clinical decision-making. An individualized rehabilitation program that addresses the patient's specific impairments and functional limitations is regarded as best practice (9).

ROM and muscle length testing—ROM of the knee as well as the ankle and hip should be assessed. The physical therapist should evaluate at a minimum both active and passive ROM measurements of tibiofemoral flexion and extension, talocrural dorsiflexion, and femoroacetabular extension, internal and external rotation, and flexion; other motions (e.g., hip abduction and adduction) or joints (e.g., subtalar eversion and inversion and lumbar flexion and extension) may also be considered.

Muscle length testing is also an important consideration as soft tissue tightness (i.e., limited flexibility) is prevalent in individuals with PFP and may contribute to symptoms (19). Evaluation of the rectus femoris, hip flexors (1- and 2-joint muscles), tensor fascia lata and iliotibial band, hamstrings, gastrocnemius, and soleus should be performed.

Effusion—Knee joint effusion can easily be evaluated using the stroke test (Table 2). The stroke test is a reliable grading scale that assesses the presence of intracapsular swelling (20). While effusion is not often present, mild effusion can occur among individuals with PFP; significant effusion is likely indicative of more serious pathology (e.g., ligament rupture, meniscus tear, fracture) and merits further evaluation. Effusion monitoring may help determine appropriate clinical progression (21,22). Increased effusion can indicate when rehabilitation has exceeded the patient's current envelope of function (7,23) and thus rehabilitation exercises or activity should be reduced or not progressed further. Tracking or asking the patient about outside activities is critical in determining whether or not the prescribed exercises or home exercise program contributed to an exacerbation of effusion and/or other symptoms or whether other factors are more likely culpable. For example, asking a student about activities such as walking around school or campus or attending a party may be pertinent. The use of activity trackers to monitor movement outside of therapy is becoming increasingly possible and should be considered as a more accurate way to quantify activity and joint loading (24).

Resisted isometrics—Resisted isometrics at various angles of knee flexion may be used during the early portions of the clinical examination to determine what type of structure(s) is most likely involved. A finding of "strong and painful" with resisted isometric knee extension is most likely to support the diagnosis of PFP, although weakness is also possible, particularly in the acute phase (pain-mediated) or in long-standing, chronic cases. The clinician should evaluate resisted isometrics at multiple angles of knee flexion to see if there is a range that is more or less painful for the individual patient. The clinician may use these findings to inform subsequent strength evaluations as well as treatment, selecting ranges of motion that are least provocative to the patient to improve muscle strength and activation while avoiding exacerbation of symptoms.

Strength—Strength assessments should evaluate not only the muscles crossing the knee joint but also the surrounding hip and ankle musculature. Knee extensor and hip extensor, abductor, and external rotator muscle strength and activation are of utmost importance given their roles in dynamically controlling hip and knee motion and the association of PFP with weakness of these muscles (25–29), although cause and effect are unknown (28). Interestingly, Kindel and Challis found that patients with PFP have weaker hip extensors and poorer neuromuscular control with the knee flexed but not extended compared to healthy controls (30), suggesting knee position may be important when evaluating hip musculature. A thorough evaluation should also strength of the core muscles, knee flexors, ankle plantarflexors and dorsiflexors, and hip flexors, internal rotators, and adductors.

Given the strength of the lower extremity muscles, clinicians should evaluate lower extremity muscle, particularly quadriceps, strength using an electromechanical dynamometer when possible. When an electromechanical dynamometer is not available, one-rep max testing on knee extension machine for quadriceps strength or handheld dynamometer secured with a strap are acceptable alternatives, although they overestimate strength of the involved quadriceps (31). Electrical burst superimposition may be used to evaluate quadriceps muscle activation (i.e., inhibition) (32), but requires relatively expensive equipment that is unavailable to many clinicians (Figure 1). In contrast to the usual order, we recommend that clinicians test the (most) involved limb first to determine the angle of knee flexion that is pain-free or least provocative; the clinician can subsequently evaluate the contralateral limb in the same position. Clinicians may also use patellar taping (see below) to facilitate strength evaluation, enabling some patients to complete testing with less or no pain. While we most often use a limb symmetry index [i.e., involved limb strength/ uninvolved limb strength × 100 (%)] for comparison, PFP is often a bilateral condition thus clinicians should interpret limb symmetry indexes with caution. Additional evaluation using manual muscle testing of the hip and knee muscles may provide additional insight, especially in the case of bilateral weakness.

Balance and postural control—Balance and postural control may be impaired in patients with PFP compared to healthy controls (33–35) during a variety of tasks including dynamic standing balance (33), postural stability during a stepping up and down task (34), and stair climbing (35). Static balance during single leg stance is also impaired on the involved compared to uninvolved limb among women with PFP (36). Fatigue of the hip abductors and to a lesser degree the knee extensors is associated with greater balance instability during dynamic standing balance (33). Patients with PFP may also exhibit especially poor postural control with their eyes closed (37). In light of these findings, it is important to assess both static balance with eyes opened and closed as well as dynamic balance on both the (most) involved and contralateral limb. To assess static balance, we evaluate single leg stance, which can be progressed in difficulty by having the patient stand on an unstable surface such as a foam pad; document the time to error and/or number of errors in a given time (e.g., 30 seconds). Dynamic balance may be assessed using the reliable Star Excursion Balance Test (38,39).

Movement assessments—Clinicians should consider a variety of movement quality assessments concordant with the patient's complaints and activity limitations given that aberrant mechanics and neuromuscular activation patterns are often present in individuals with PFP (23,26,40–44). The position of dynamic knee valgus, characterized by hip adduction and internal rotation, may be associated with PFP (23,40,44,45), thus clinicians should pay particular attention for these aberrant mechanics. Clinicians should consider evaluating multi-joint lower extremity movements including but not limited to double and single leg squatting, drop jump landing, hopping, walking, stair ascent and descent, and running. Identification of movement impairments may guide not only targeted strengthening but also and perhaps more importantly neuromuscular activation exercises and movement retraining (23,40,46,47).

Step test—We recommend using a modification of the previously described step test (Figure 2). The step test involves standing on a 15 centimeter block with hands on hips and using the involved limb to "slowly" and "smoothly" eccentrically lower the body until the contralateral heel touches the floor (48). A positive result is reproduction of the patient's PFP; a positive finding is prevalent in 74% (57 of 77) of individuals with PFP (49) and has a modest positive likelihood ratio of 2.34 (48). In the authors' clinical experience, we modify the test by recording the angle at which pain first occurs and asking the patient to rate the pain on an 11-point numeric pain rating scale. If the test is positive, we often evaluate the patient again on the modified step test after applying patellar taping (described below) to determine whether or not patellar taping provides immediate relief of symptoms and may therefore be beneficial in facilitating increased function in the short-term.

Palpation—Individuals with PFP often have pain in or around the patella that may be reproduced with palpation. Clinicians should also palpate other nearby structures, such as the patellar and quadriceps tendons, to rule out other sources of anterior knee pain. For example, reproduction of pain with palpation of the patellar tendon may indicate patellar tendinopathy; pain at the distal pole of the patella in adolescents may indicate Sinding-Larsen-Johansson Syndrome (50); and swelling and point tenderness around the tibial tuberosity in adolescents may indicate Osgood-Schlatter Disease (16,50).

Functional testing—Functional testing may evaluate tasks that are important to the patient and are currently limited. Examples of functional testing include the stair climb test, sit to stand test, and 6-minute walk test. Performance as well as symptoms should be documented.

Objective measures for evaluation, treatment progression, and clinical decision-making—Evaluation, treatment progression, and clinical decision-making like discharge and return-to-sport clearance should be based as much as possible on objective measures while simultaneously considering the patient's needs and goals. As mentioned above, an increase in or the presence of new effusion indicates that the activity has exceeded the current envelope of function and should not be progressed further. Clinicians may also use the soreness rules (Table 3), initially developed by Fees *et al.* (51) and later adapted to the lower extremity by Adams *et al.* (21), to monitor appropriate progression of activities. (While avoiding pain and symptom exacerbation is critical during the early management of acute PFP, clinicians may set a threshold of acceptable symptoms (e.g., 5/10 on numeric pain rating scale) for individuals with chronic PFP, focusing on increasing function rather than complete avoidance of symptoms). Successful completion of a running progression (Table 4) (21) should be pre-requisite to initiating higher level activities.

Valid and reliable patient reported outcome measures should be completed at initial evaluation and periodically throughout rehabilitation to monitor progress and inform rehabilitation. The Visual Analog Scale for usual pain or worst pain and the Kujala Anterior Knee Pain Scale (52) are reliable, valid, and responsive in individuals with PFP (53); the Kujala Anterior Knee Pains Scale is also valid and reliable in adolescent female athletes with anterior knee pain (54).

Throughout the rehabilitation process, the clinicians must appreciate the impact of psychological factors (e.g., kinesiophobia) (55) and other factors (e.g., stress, sleep) on pain, particularly when a patient reports a transient increase in symptoms. Anxiety, depression, catastrophizing, and kinesiophobia may be present in individuals with PFP and correlate with higher pain ratings and reduced physical function (56); appropriate referral or consultation may be beneficial. Stress levels (57) and sleep duration (58) also influence pain; for example, too much (>9 hours) or too little (<6 hours) sleep the previous night is associated with greater pain the following day (58). Asking and educating patients about these factors is important when determining whether to progress, maintain, or reduce interventions.

Treatment

Patients with PFP present with a wide variety of underlying pathophysiology and associated impairments (25,47). It is thus imperative to individually assess each patient to identify and subsequently address his or her impairments, functional limitations, and activity restrictions. Management of PFP should consist of an individualized (47), multi-modal approach with exercise therapy as the hallmark of the plan (9,16,26,59–61).

Exercise therapy: strengthening, stretching, and aerobic exercise

According to the 2016 consensus statement from the International Patellofemoral Pain Research Committee, exercise therapy is the “treatment of choice” for individuals with PFP (9). High-quality evidence supports exercise therapy to improve pain and function in the short-, medium-, and long-term; exercise was the only intervention that received such a high recommendation (9). Exercise therapy should include both hip and knee strengthening (9,27,62,63) using both open (non-weight-bearing) and closed (weight-bearing) kinetic chain exercises (9,62). Open kinetic chain exercises include straight leg raises (progress by adding ankle weights), short arc quadriceps strengthening, knee extensions, side-lying hip abduction straight leg raise, and clamshells. Closed kinetic chain exercises include wall sits, double- and single-leg squats, lateral step-downs, and leg press. Strengthening of the core

(47,64) and ankle musculature should be included if the patient exhibits deficits or imbalances in these areas.

Appropriate selection of open and closed chain strengthening exercises should consider the patellofemoral joint contact forces in each mode. Steinkamp *et al.* found that comparison of patellofemoral joint contact forces during closed (i.e., body weight squat) and open (i.e., 9 kg weighted boot) kinetic chain exercises resulted in relatively less patellofemoral contact force in the closed kinetic chain condition in less than 48° knee flexion and relatively less patellofemoral contact force in the open kinetic chain condition in more than 48° knee flexion (65). Similar findings have been more recently produced by Powers *et al.,* who added that patellofemoral joint contact force was less during quadriceps strengthening using a constant resistance knee extension machine compared to squatting at angles greater than approximately 45° (66). Therefore, particularly during the early stages of rehabilitation, patients may benefit from performing open kinetic chain exercises in deeper ranges of knee flexion (e.g., 50°–90°) and closed kinetic chain exercises in shallower ranges (e.g., 0°–45°) (66).

Throughout the rehabilitation process, clinicians should design appropriate exercises that maximize muscle strength while minimizing symptom exacerbation, using the soreness rules (Table 3) to guide progression. A recent study by van Rossom and colleagues provides peak and mean patellofemoral joint contact forces during gait plus nine functional exercises and may serve as a guide for appropriately and gradually progressing loading during rehabilitation (67). While initially during the acute stage of rehabilitation a clinician may strive to perform only exercises that are pain-free, the goal of completely eliminating movement-related pain in the chronic condition may be not only unrealistic but also a disservice to the patient's recovery (10). In such cases, setting an acceptable threshold of symptoms based on the patient's presentation may be appropriate.

Stretching is another important component of rehabilitation, as individuals with PFP often have limited ROM, particularly around the hip (19) and knee and perhaps also the ankle (25). Treatments should address the specific ROM and muscle length restrictions identified during the evaluation and may include the quadriceps, hip flexors, hamstrings, tensor fascia lata/iliotibial band, gastrocnemius, and/or soleus.

Joint mobilizations

Joint mobilizations may be effective in improving pain and function among individuals with PFP when joint mobilizations are directed at the knee (i.e., patellofemoral and tibiofemoral joint) and combined with a comprehensive treatment approach including exercise (59). A case study by Lantz *et al.* highlights the potential benefit of tibiofemoral mobilizations in an individual with chronic PFP (68).

Patellofemoral taping

Conflicting evidence exists regarding the efficacy of patellofemoral taping (60,69–72). We recommend using taping in conjunction with a multi-modal, comprehensive treatment plan if taping alleviates pain during exercises in rehabilitation and/or functional activities. Clinicians should evaluate the immediate effectiveness of patellofemoral taping within an individual by assessing a functional task pre- and post-taping that is specific to that patient's symptoms; if pain is alleviated then taping may help the patient complete functional activities and exercises which may in turn facilitate recovery. While we recommend first evaluating medial patellar glide therapeutic taping (73), placebo taping plus exercise may be similarly beneficial to therapeutic tension taping plus exercise (60). The use of patellar taping in isolation is not recommended (9,16,60,61,69,70,73).

Neuromuscular electrical stimulation (NMES)

A 2017 Cochrane Review by Martimbianco *et al.* found limited, low-quality regarding the effect of NMES for the treatment of PFP (74). The review concluded that very low-quality evidence suggests NMES reduces pain at the end of treatment (3 to 12 weeks) but the improvement may not be clinically relevant given the small magnitude of change (1.63 out of 10 on the visual analog scale). The authors found even less support for NMES on strength or function, concluding that "insufficient and inconclusive evidence" exists for the effect of NMES on treating individuals with PFP (74). While one pilot study has found no statistically significant differences between 38 athletes (19 per group) who completed physiotherapy or physiotherapy plus electrical stimulation, limitations including study design, follow-up, and stimulation parameters limit its applicability (75). Given the dose response relationship between electrical stimulation intensity and quadriceps femoris muscle torque (76), we recommend using higher NMES intensity levels to facilitate muscular strength and activation development. A 2010 systematic review on NMES on quadriceps strength in individuals after anterior cruciate ligament reconstruction found that NMES combined with exercise is more effective than exercise alone at improving quadriceps muscle strength (77). We therefore recommend using NMES in conjunction with a comprehensive rehabilitation program in individuals who have PFP and deficits in quadriceps strength and/or activation. We recommend the following parameters: 10.2 cm × 12.7 cm pads on the vastus medialis and proximal vastus lateralis muscles; 15 electrically elicited, isometric contractions of the quadriceps at about 65° knee flexion (or the most comfortable position for the patient), 75 bursts per second; 10" on, 50" off, 2" ramp; and the maximum tolerated intensity that elicits at least 50% maximum volitional isometric contraction (21,76).

Neuromuscular training

Neuromuscular activation deficits are common in individuals with PFP, especially in the hip abductors and external rotators, knee extensors, and core musculature (23,26,40,44,45). Evaluating movements during functional tasks (described above) is essential to identifying and treating neuromuscular activation deficits. Strengthening alone seldom changes mechanics (78), thus task-specific movement retraining is likely necessary (23,40,79,80). Use of resistance tubing bands may promote activity of specific muscle groups; for example, using resistance tubing bands around the knees during a squat may facility hip abduction and external rotation. NMES may facilitate neuromuscular training, as improvements in kinematics and muscle activity have been observed in a small group (N=15) of women with PFP (46).

Running mechanics and gait retraining in patients with patellofemoral pain have received significant attention likely due in part to the high incidence of PFP among runners (1). Running mechanics are often altered in individuals with PFP and young women may be especially prone to altered mechanics such as excessive hip adduction and internal rotation leading to dynamic knee valgus (23,41–43,81). Gait retraining may be considered in individuals with PFP who have aberrant running mechanics and should address the specific deficits in the individual (43). Sagittal plane trunk mechanics (82) and footwear (as described by the Minimalist Index) (83) are related to patellofemoral joint stress during running, thus should also be considered during gait analysis and running retraining; forward trunk lean (82) and more minimalist shoes (83) are associated with reduced patellofemoral joint stress. A systematic review by Agresta and Brown found the use of real-time auditory and visual feedback in conjunction with therapeutic exercise to be effective in improving lower extremity kinematics in runners with patellofemoral, although no single method of feedback was deemed superior (84).

Activity modification and gradual loading

During the acute phase, activity modification characterized by relative rest is likely appropriate to allow healing to occur. Reintegration of loading, however, must be implemented and should be done in a systematic way to gradually increase and restore the envelope of function. Chen *et al.* evaluated patellofemoral joint reaction forces using an MRI-informed subject-specific three-dimensional model, finding that, among the four tasks evaluated, patellofemoral joint reaction forces were highest during running [58.2 N/kg-body weight (bwt)], followed by stair ascent (33.9 N/kg-bwt), stair descent (27.9 N/kg-bwt), and walking (10.1 N/kg-bwt) (2). In light of these findings, it may be inappropriate for an individual with acute PFP to run if stair descent is painful, although individual evaluation and clinical judgment should be considered. Recently, van Rossom *et al.* added to Chen's findings by evaluating peak and mean patellofemoral joint contact forces during ten functional tasks; peak patellofemoral joint contact forces were lowest during gait and progressively higher in sit down, stand up, squat, forward lunge, stair ascent, stair descent, single leg hop weight acceptance phase, sideward lunge, and single leg hop push-off phase (67).

Other interventions

Numerous other interventions have been proposed as adjuvants or stand-alone treatments for individuals with PFP and may be considered as part of a comprehensive plan of care if impairments warrant or symptoms have been intractable to the more evidence-based approaches outlined above. Foot orthotics may be beneficial in reducing pain and improving function (16). Dry needling does not appear to provide any additional benefit when added to a multimodal treatment approach including manual therapy and strengthening exercise compared to manual therapy and strengthening exercise alone (85).

Appropriate progression and discharge

Rehabilitation should be progressive and rooted in objective clinical findings. Monitoring effusion and soreness should occur throughout rehabilitation and guide progression. Use of gradual, return-to-activity training protocols, such as the running progression (Table 4) (21), may facilitate appropriate progression and aid clinical decision-making.

Discharge from physical therapy should occur when the patient has achieved his or her goals and is equipped to transition to self-management or management by an athletic trainer, strength and conditioning coach, or personal trainer if available. Patient education is thus critical at this time-point and throughout the rehabilitation process; the patient should know what exercises to perform and how to progress activity while adhering to basic principles such as the soreness rules. Although research on return-to-sport criteria in patients with PFP is lacking, we recommend athletes achieve limb symmetry index scores of 90% of greater for quadriceps strength and all four hop tests (single, crossover, triple, and 6 meter timed) (86) prior to resuming full participation; limb symmetry indexes, however, have limitations (87) particularly in individuals with bilateral involvement thus should be interpreted with caution.

Conclusions

Early, appropriate rehabilitation may be critical to preventing poor outcomes (88) and optimizing function for individuals with PFP. We strongly recommend exercise therapy, including hip and knee strengthening and stretching, to improve short-, medium-, and long-term outcomes in individuals with PFP (9,16,26,27). A multimodal, individually tailored rehabilitation program should be designed to target the patient's specific impairments and functional limitations identified during the evaluation (47). Treatments may include open- and closed-chain exercises, strengthening, stretching, aerobic exercise, patellofemoral and tibiofemoral mobilizations, patellar taping, high-intensity NMES, neuromuscular training, and gait retraining. Although short-term changes or reductions in movement often are necessary in a protective capacity, the persistence of altered movement is a key characteristic of chronic pain. PFP etiology is largely movement related and a comprehensive conservative treatment using movement can be successful.

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Figure 1.

Quadriceps strength may be evaluated isometrically using an electromechanical dynamometer during with an electrical burst superimposition technique (32) to assess muscle activation. Clinicians may evaluate the (most) involved limb first to determine the angle of knee flexion that is pain-free or least provocative and subsequently evaluate the contralateral limb at the same angle of knee flexion for comparison. Patellar taping may be used to alleviate pain.

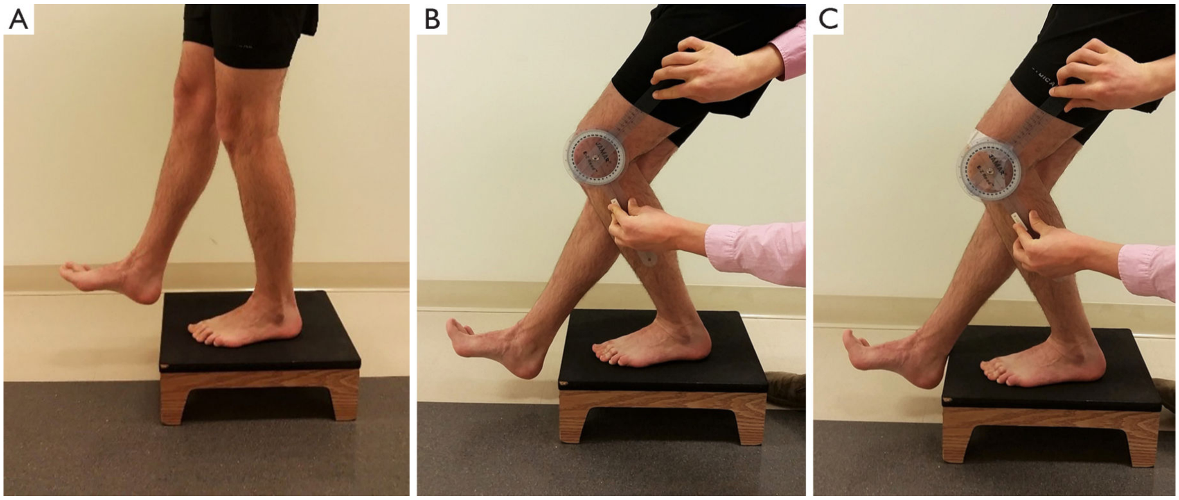

Figure 2.
The patients stand on the involved limb on a 15-cm box (A) to begin the modified step test. We document the angle at which the patient experiences pain and the patient's numeric pain rating both before (B) and after (C) applying patellar taping.

Table 1

A thorough patient history should include the following questions

Questions	Notes
Date of onset	
Mechanism of injury (traumatic vs. atraumatic):	If traumatic, consider and evaluate thoroughly for alternative diagnoses including ligament sprain, meniscus tear, fracture, etc.
If atraumatic, sudden or gradual onset? What factors led to symptoms (i.e., any changes in activity level, exercise, footwear, stress levels, sleep habits, diet or body mass)?	
If traumatic, describe event in detail including presence of swelling and time to swelling onset	
Chief complaint (location and quality of pain):	
Exacerbating factors (e.g., stair descent, squatting)?	
Alleviating factors (e.g., ice, heat, rest, stretching)?	
Are other symptom(s) present?	If true giving way episodes are present, consider ligament exam; if locking is present, consider meniscus involvement
If yes, any giving way/buckling, locking/clicking/popping/crepitus, stiffness?	
Diagnostic tests and imaging	
Relevant past medical history (e.g., previous lower extremity injury, previous back pain with or without radiculopathy)	If history of back pain or unable to elicit symptoms during targeted knee evaluation, perform lumbar and spinal radiculopathy examination
	Consider also the hip joint as a source of knee pain, particularly in the child (17,18) or older adult
Has the patient received any prior treatment? If so, describe in detail	
What are the patient's occupational demands?	
What recreational activities does the patient typically engage in? Are these activities limited? If so, how?	
Describe footwear and orthotic use	Examine footwear and orthotics for wear and irregularities
Goals for rehabilitation	

Table 2

Clinicians should monitor knee effusion throughout rehabilitation using the reliable stroke test (20) (*Effusion Grading Scale of the Knee Joint Based on the Stroke Test*)

Grade	Test result
Zero	No wave produced on down stroke
Trace	Small wave on medial side with down stroke
1 +	Larger bulge on medial side with down stroke
2+	Effusion spontaneously returns to medial side after upstroke (no down stroke necessary)
3+	So much fluid that it is not possible to move the effusion out of the medial aspect of the knee

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Table 3

The soreness rules provide clinicians with a guideline to monitor symptoms and evaluate progression throughout rehabilitation (21,51) (*Soreness rules*)

Criterion	Action
Soreness during warm-up that continues	2 days off, drop down 1 level
Soreness during warm-up that goes away	Stay at level that led to soreness
Soreness during warm-up that goes away but redevelops during session	2 days off, drop down 1 level
Soreness the day after lifting (not muscle soreness)	1 day off, do not advance program to the next level
No soreness	Advance 1 level per week or as instructed by healthcare professional

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Table 4

A running progression may facilitate gradual resumption of loading; progression should occur only in the absence of increased effusion or pain and on nonconsecutive days (*Running progression*[*])

Level	Treadmill	Track
Level 1	0.1-mi walk/0.1-mi jog, repeat 10 times	Jog straights/walk curves (2 mi)
Level 2	Alternate 0.1-mi walk/0.2-mi jog (2 mi)	Jog straights/jog 1 curve every other lap (2 mi)
Level 3	Alternate 0.1-mi walk/0.3-mi jog (2 mi)	Jog straights/jog 1 curve every lap (2 mi)
Level 4	Alternate 0.1-mi walk/0.4-mi jog (2 mi)	Jog 1.75 laps/walk curve (2 mi)
Level 5	Jog full 2 mi	Jog all laps (2 mi)
Level 6	Increase workout to 2.5 mi	Increase workout to 2.5 mi
Level 7	Increase workout to 3 mi	Increase workout to 3 mi
Level 8	Alternate between running/jogging every 0.25 mi	Increase speed on straights/jog curves

[*] progress to the next level when the patient is able to perform activity for 2 mi without increased effusion or pain. Perform no more than 4 times in 1 week and no more frequently than every other day. Do not progress more than 2 levels in a 7-day period. Conversion: 1 mi =1.6 km. Reproduced with permission from Tara Manal, PT, DPT, FAPTA, University of Delaware Physical Therapy Clinic.