

# Patellofemoral pain in athletes: clinical perspectives

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**Abstract:** Patellofemoral pain (PFP) is a very common problem in athletes who participate in jumping, cutting and pivoting sports. Several risk factors may play a part in the pathogenesis of PFP. Overuse, trauma and intrinsic risk factors are particularly important among athletes. Physical examination has a key role in PFP diagnosis. Furthermore, common risk factors should be investigated, such as hip muscle dysfunction, poor core muscle endurance, muscular tightness, excessive foot pronation and patellar malalignment. Imaging is seldom needed in special cases. Many possible interventions are recommended for PFP management. Due to the multifactorial nature of PFP, the clinical approach should be individualized, and the contribution of different factors should be considered and managed accordingly. In most cases, activity modification and rehabilitation should be tried before any surgical interventions.

**Keywords:** anterior knee pain, sport, rehabilitation, runners' knee

## Introduction

Pain in retropatellar and peripatellar regions is clinically referred to as patellofemoral pain (PFP). However, there is not a clear definition. The term patellofemoral pain syndrome (PFPS) is still a "wastebasket", which includes different entities.<sup>1</sup> It is a very common complaint in general population, particularly in young adult and adolescent athletes who participate in jumping, cutting and pivoting sports.<sup>2-4</sup> It is reported that almost 25%–30% of all injuries seen in a sports medicine clinic<sup>5,6</sup> and up to 40% of clinical visits for knee problems<sup>4,7,8</sup> are attributed to PFP. PFP accounts for 33% and 18% of all knee injuries in female and male athletes, respectively.<sup>9,10</sup> It is also one of the most common overuse injuries among different sports disciplines such as basketball,<sup>11,12</sup> volleyball<sup>13,14</sup> and running,<sup>14-17</sup> and a prevalence rate of between 13% and 26% is reported in females participating in soccer, volleyball, running, fencing and rock climbing.<sup>14</sup> Incidence of PFP among adolescent females and young adult women is 2–10 times more than in their male counterparts.<sup>10,17,18</sup> PFP symptoms may lead to limitation of sport and physical activities in 74% of patients or cause sports cessation.<sup>19-21</sup>

Current literature contradicts the hypothesis that PFP has a benign and self-limiting course; in contrast, PFP is a refractory condition which may persist for many years and is a likely contributor to long-term patellofemoral osteoarthritis, especially in cases of adolescent anterior knee pain.<sup>21-24</sup> Otherwise, some young PFP patients may have risk factors that place them at future risk for anterior cruciate ligament injury.<sup>25</sup>

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## Terminology

Despite different terms proposed to describe this condition, such as anterior knee pain or syndrome, PFP, patellofemoral pain syndrome, patellofemoral arthralgia, chondromalacia patellae, lateral patellar compression syndrome and patellar algia,<sup>26</sup> a recent consensus statement from the Fourth International Patellofemoral Pain Research Retreat recommended PFP as the preferred term. However, it does not consider how nonpainful joint conditions could be a precursor to pain development and does not include symptoms such as crepitus, and its main focus is on the “pain” aspect of the disorder.<sup>27,28</sup>

## Definition

PFP is characterized by pain in the peripatellar/retropatellar area that aggravates with at least one activity that loads the patellofemoral joint during weight bearing on a flexed knee (e.g., squatting, stair climbing, jogging/running and hopping/jumping). Additional nonessential criteria include crepitus or grinding sensation in the patellofemoral joint during knee flexion movements, tenderness on patellar facet palpation, small effusion and pain on sitting, rising on sitting or straightening the knee following sitting.<sup>27–29</sup>

## Risk factors

As an overuse injury, several risk factors may play a role in the pathogenesis of PFP. These risk factors are classified as intrinsic and extrinsic risk factors.<sup>3</sup>

Extrinsic risk factors are related to factors outside the body, such as the type and volume of sports activity, environmental conditions and the surface and equipment used. Intrinsic risk factors are attributed to individual characteristics.<sup>3</sup>

Expert consensus statements suggest biomechanical risk factors explained by anatomic location relative to the knee. These factors include proximal (upper femur, hip and trunk), local (in and around the patella and the patellofemoral joint) and distal (lower leg, foot and ankle).<sup>6,30,31</sup> These risk factors can be anatomic (increased femoral anteversion, trochlear dysplasia, patella alta and baja, excessive foot pronation and so on) or biomechanical (muscle tightness or weakness, generalized joint laxity, gait abnormalities and so on).

Some of these proposed intrinsic risk factors and clinical tests for their assessment have been shown in Table 1.

## History

Patients with PFP typically describe diffuse ill-defined pain behind, underneath or around the patella, usually with activities such as squatting, running and stair ascent or

descent.<sup>32,34,100</sup> If asked to point to the site of pain, patients may place their hands over the anterior aspect of the knee or draw a circle with their fingers around the patella (the circle sign). The symptoms are usually of gradual onset, although some of them may be acute and caused by trauma. Pain may be unilateral or bilateral and is usually described as achy, but may be sharp.<sup>32,34</sup> Sometimes, patients report stiffness or pain on prolonged sitting with the flexed knees (the theater or moviegoer sign).<sup>34</sup>

Patients may occasionally report the knee giving way or buckling. This perceived instability may be due to inhibitory effect of pain on the suitable contraction of the quadriceps, but it should be differentiated from instability originating from a patellar dislocation, subluxation or ligamentous injury of the knee.<sup>32,101</sup> Feeling of a popping or catching may be described. Locking of the joint is not characteristic of PFP and implies a meniscal tear or loose body. Occasionally, mild swelling may be present. However, it is rare to see a gross effusion seen with a traumatic knee injury.<sup>32,34</sup>

Taking history in athletes presenting with PFP may mandate some special considerations. As PFP is attributed to overuse in many cases, recent alterations in sporting activities, including any changes in the frequency, duration and intensity of training should be investigated in detail.<sup>34,100</sup> The training program also should be appraised for errors, including increasing the exercise intensity too rapidly, inadequate recovery time and extreme hill workouts.<sup>32</sup> It must be considered that PFP may present as an acute re-exacerbation of the chronic condition.<sup>100</sup>

Use of inappropriate or excessively worn footwear, recent heavy resistance training and conditioning activities (particularly squats and lunges) and running on altered surface or hills should also be considered. A history of knee traumatic injuries, including patellar subluxation or dislocation, or surgeries should be noted, as they may directly damage the articular cartilage or change the forces across the patellofemoral joint, resulting in PFP.<sup>32,34</sup>

## Physical examination

Physical examination is the foundation of PFP diagnosis,<sup>102</sup> but there is no definitive clinical test to diagnose PFP.<sup>103</sup> A variety of tests have been explained to diagnose PFP.<sup>104,105</sup> However, the common tests for PFP are not sensitive when compared with pathologic operative findings.<sup>104</sup> Lack of sensitive tests to help rule out PFPS when negative implies that PFPS may be a diagnosis of exclusion and may be best identified after ruling out other diagnoses such as tibiofemoral osteoarthritis, plica syndrome or other masquerading

**Table I** Potential intrinsic risk factors, tests for assessment and their reliability

| Potential risk factor  | Tests   | Reliability   |
|--|---|---|
| Weakness of quadriceps muscle, especially VMO <sup>29,32–35</sup>  | One-legged hop test. Test is performed by jumping and landing on the same foot with the hands behind the back and the hop distance is measured from toe. <sup>36</sup> A quotient (%) between the injured and noninjured legs is registered and defined as abnormal if the quotient is <85% <sup>37</sup>   | Good reliability <sup>36,38,39</sup>  |
| Hip muscle dysfunction (particularly, the abductors and external rotators) <sup>30,40,41</sup>                             | The Trendelenburg test (for hip abductors) to assess the ability to hold the pelvis level, while the subject performs a single-leg stance. Lateral pelvic shift or lowering of one side of the pelvis indicates weakness of hip abductors <sup>42,43</sup>  | Good sensitivity, good to excellent specificity <sup>44</sup>   |
| Poor core muscle endurance <sup>45,46</sup>  | Front plank, modified Biering–Sorensen and side bridge for anterior, posterior and lateral core muscle endurance <sup>45,47</sup>   | Good reliability <sup>47</sup>  |
| Tightness of hamstring <sup>3,48–50</sup>  | Passive knee extension test with goniometric measurement of popliteal angle. <sup>3,49</sup> Test is considered positive when a knee extension angle of >20° is measured <sup>51,52</sup>   | Excellent inter-rater and good test–retest reliability <sup>53–55</sup>   |
| Tightness of iliopsoas and quadriceps <sup>3,48,56,57</sup>  | Modified Thomas test. <sup>58,59</sup> Two angles were measured for each limb. Lengths of iliopsoas and quadriceps were determined by measuring the angles of hip and knee flexion, respectively. Inability of the opposite thigh to extend to a neutral position or drop below the horizontal constitutes a positive test for iliopsoas. The angle of knee flexion of <80° determines the quadriceps shortness | Very good to excellent inter-rater and good test–retest reliability <sup>55</sup>   |
| Tightness of iliotibial band <sup>60–62</sup>  | Ober test. <sup>61–64</sup> Positive test occurs when the leg remains in an abducted position (rests above the horizontal) <sup>65</sup>  | Excellent intra-rater and inter-rater reliability <sup>66</sup>   |
| Tightness of gastrosoleus complex <sup>32,67</sup>   | Weight-bearing lunge test. <sup>68</sup> Test is considered positive when 1) the distance between the wall and the big toe measured is <9 cm or 2) the angle made by the anterior tibia/shin to vertical is <35° <sup>69</sup>  | Excellent intra-rater and inter-rater reliability <sup>69</sup>   |
| Excessive foot pronation <sup>32,70,71</sup>   | FPI-6. <sup>72,73</sup> Scores of +6 to +9 and +9 to +12 are regarded pronated and highly pronated, respectively <sup>74</sup>  | High intra-rater and inter-rater reliability among PFPS patients <sup>73,74</sup>   |
| Limb length discrepancy <sup>75</sup>  | Gauging the distance between the anterior superior iliac spine and the medial malleolus of both legs (average of two measures). Limb length inequalities of >10 mm is considered clinically significant <sup>76</sup>   | High intra-rater and inter-rater reliability <sup>77,78</sup>   |
| Patellar malalignment <sup>34,79,80</sup>  | Patellar tilt and mediolateral glide tests. <sup>34,81,82</sup> Tilt occurs when the digit palpating one of the patellar borders is more anterior than the other. The glide is positive when the distance from the midpatella to each femoral epicondyle is not equal <sup>81</sup>   | Fair intra-rater and poor inter-rater reliability <sup>81,83</sup>  |
| Patellar hypermobility <sup>3,34</sup>   | Patellar mobility test, with the knee flexed 20°–30° and the quadriceps relaxed. <sup>84</sup> Patellar mobility of more than three quadrants suggests a hypermobile patella <sup>34</sup>  | Good intra-rater and variable inter-rater reliability <sup>84</sup>   |
| GJL <sup>3,34,85</sup>   | BHJMI, in which the range of scoring is between 0 and 9, with high scores denoting greater joint laxity   | Good to excellent reliability <sup>86–88</sup>  |
| Genu varum <sup>89</sup>   | Goniometric measurement in a standing position and barefoot, with toes placed forward and feet shoulder-width apart <sup>90</sup>   | Correlated well with the angle measured on the full-limb radiograph (gold standard) <sup>90</sup>   |
| Abnormal trochlear morphology <sup>91</sup>  | Measurement of sulcus angle in plain radiography (skyline or tangential patellar views performed in 25° of flexion; normal value 138°, SD 6°) <sup>92</sup> or evaluation of lateral trochlear inclination, medial trochlear inclination, sulcus angle and trochlear angle on the axial MRI   | Excellent intraobserver and interobserver reliability (ICCs of 0.94 and 0.92, respectively), <sup>92,93</sup> but some newer evidence recommended MRI <sup>94</sup> |
| Abnormal proprioception <sup>95,96</sup>   | Measurement of knee joint position sense using five active tests under non-weight-bearing and uni- and bilateral weight-bearing conditions <sup>95</sup>  | Good reliability <sup>97</sup>  |
| Gait abnormalities (heel strike in a less pronated position and there is roll over more on the lateral side) <sup>98</sup> | Plantar pressure measurements during walking using a foot scan pressure plate <sup>98</sup>   | Reliable (ICC: 0.75) <sup>99</sup>  |

**Abbreviations:** BHJMI, Beighton and Horan Joint Mobility Index; FPI-6, Foot Posture Index-Version 6; GJL, generalized joint laxity; ICC, Intraclass Correlation Coefficient; MRI, magnetic resonance imaging; PFPS, patellofemoral pain syndrome; SD, standard deviation; VMO, vastus medialis obliquus.

conditions.<sup>106</sup> According to the recent consensus statement from the Fourth International Patellofemoral Pain Research Retreat, anterior knee pain elicited during a squatting maneuver is the best available test, and PFP is evident in 80% of people who are positive on this test.<sup>103</sup> Several other tests proposed for PFP have limited evidence supporting their use. Tenderness on palpation of the patellar edges is another test with limited evidence and PFP is evident in 71%–75% of people with this finding.<sup>103</sup> Full range of knee motion and lack of effusion are common findings in PFP patients.<sup>28,103</sup> Patellar grinding and inhibition tests (e.g., Clarke's test) have low sensitivity and limited diagnostic accuracy for PFP.<sup>103</sup>

In another prospective study on the diagnostic value of five common tests, the authors reported three tests of vastus medialis coordination, patellar apprehension and eccentric step to have a positive ratio. It means that positive test results increase the likelihood of PFP.<sup>80,105</sup> As an important point, clinical examination of athletes engaging in high-demanding sports may necessitate more challenging and highly dynamic tests (e.g., single leg-squat or lateral step-down tests) to reveal the subtle cases of overuse injuries.

In this part, we will describe the common clinical tests used for PFP diagnosis.

### Vastus medialis coordination test

In patient's supine position, the examiner places the fist under the subject's knee and asks the patient to extend the knee slowly without pressing down or lifting away from the examiner's fist. The patient is instructed to achieve full extension (Figure 1). The test is considered positive when a lack of coordinated full extension is apparent, that is, when the patient either has difficulty smoothly achieving extension or uses the extensors or flexors of the hip to accomplish extension. A positive test may be an indicator of dysfunction of the vastus medialis obliquus muscle.<sup>105,107</sup>



**Figure 1** Vastus medialis coordination test.

### Patellar apprehension test

The patellar apprehension test, also referred to as the Fairbanks apprehension test, is performed with the patient in supine and relaxed position. The examiner uses one hand to push the patient's patella as lateral as possible, in order to obtain a lateral patellar glide. Starting with the knee flexed at 30°, the examiner grasps the leg at the ankle/heel with the other hand and performs a slow, combined flexion in the knee and hip. This lateral glide is maintained throughout the test (Figure 2). The test is considered positive when it reproduces the patient's pain or when apprehension is present.<sup>104,105,107</sup>

### Eccentric step test

For the eccentric step test, the patients perform the testing in bare feet. The step is 15 cm high or more accurately with height equal to 50% of the length of tibia. Briefly, each patient is asked to stand on the step, put hands on the hips and step down from the step as slowly and smoothly as she/he can. Patients should keep the hands on their hips throughout the test performance (Figure 3). After the patient performs the test with one leg, the procedure is repeated using the other leg. A warm-up or practice attempt is not allowed. The eccentric step test is considered positive when the patient reports knee pain during the test performance.<sup>105,108,109</sup>

### Waldron's test (Phases I and II)

To do Phase I of Waldron's test, patient lies supine and the examiner presses the patella against the femur while concurrently performing a passive knee flexion with the other hand (Figure 4A).<sup>110</sup> For Phase II, the standing patient performs a slow, full squat, again with the examiner performing a gentle compression of the patella against the femur (Figure 4B). In



**Figure 2** Patellar apprehension test.

both phases, crepitus and pain during a particular part of the range of motion are considered signs of PFP disorders.<sup>105,107</sup>

### Clarke's test (or patellofemoral grinding test)

Clarke's test is performed with the patient lying supine with both knees supported by a pad, in order to create an adequate

amount of knee flexion ( $10^{\circ}$ – $20^{\circ}$ ) and consequent articulation of the patella in the patellofemoral joint.<sup>107</sup> While the patient is relaxed, the examiner presses the patella distally (with the hand on the superior border of the patella) and then requests the patient to contract the quadriceps muscle (Figure 5).<sup>104</sup> If the patient's pain is reproduced during the test, the test will be considered positive. However, as explained before, Clarke's test is not recommended as a diagnostic test for PFP due to the lack of clarity regarding its definite mechanics of application, uncertainty regarding what represents a positive test and its poor diagnostic accuracy.<sup>26</sup>

### Standard step-down test

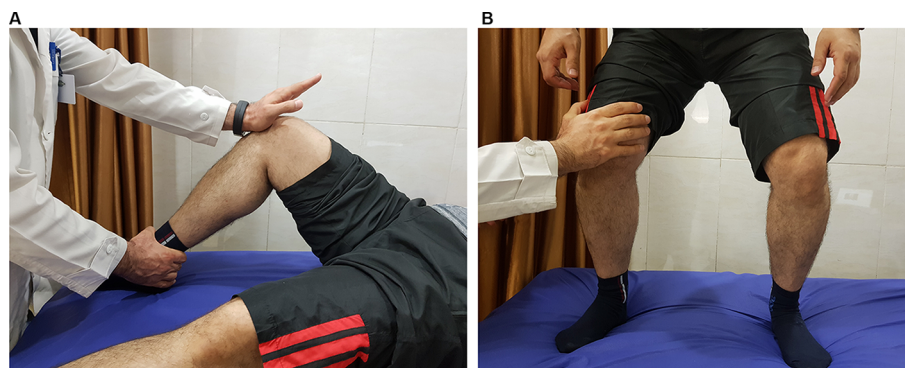
Standard step-down test is very similar to eccentric step test, except that the patient should stand with arms folded across the chest and be instructed to squat down 5–10 times consecutively in a slow and controlled manner until the heel touches the floor, maintaining their balance at a rate of approximately one squat per 2 s (Figure 6). Scoring of the deviations in the trunk, pelvis, hip and knee reveals the onset timing of the



**Figure 3** Eccentric step test.



**Figure 5** Clarke's test.



**Figure 4** Waldron's test: (A) Phase I and (B) Phase II.



**Figure 6** Standard stepdown test.

anterior gluteus medius, hip abduction torque and decreased lateral trunk strength.<sup>100</sup> Excellent inter-rater ( $k=0.80$ ) and intra-rater ( $k=0.80$ ) reliability has been reported for this test.<sup>111</sup>

### Lateral step-down test

The lateral step-down test is a modification of standard step-down test, in which the movement is in the lateral direction.<sup>112</sup> Instructions for the lateral step-down test are as follows: The patient is requested to stand with the involved leg on a 15 cm step. This will require most to bend the knee at about 60° during the test. The patient is asked to reach down and touch the opposite, non-involved heel to the ground, then return to the starting position. The patient should be rated on the criteria, including arm strategy, trunk alignment, pelvis plane, knee posture and steadiness.<sup>100</sup>

### Single-leg squat

Single-leg squat is a test of dynamic hip and quadriceps strength in the examination. This maneuver imposes higher



**Figure 7** Single-leg squat.

mechanical demands than a bilateral squat, which may induce compensatory movements such as knee valgus (Figure 7). This may partially be due to the smaller base of support and increased amounts of dynamic control that are needed in all planes during the single limb squat. Compared to controls, patients with PFP showed increased ipsilateral trunk lean, contralateral pelvic drop, hip adduction and knee abduction during a single-leg squat.<sup>100,113</sup>

As noted earlier, assessment of common intrinsic risk factors of PFP is crucial in physical examination and for planning proper rehabilitation program (Table 1). An illustrated description of the simple clinical methods to assess these common risk factors has been published.<sup>114</sup>

### Imaging

The diagnosis of PFPS is mainly clinical, and diagnostic imaging is not required for many patients. However, plain radiography may be indicated in the following cases: a history of recent trauma, dislocation or surgery, joint effusion, patients older than 50 years (to assess for patellofemoral osteoarthritis), patients who are skeletally immature (to rule out other causes such as osteochondritis dissecans, physeal injury or bone tumors), suspected cases of bipartite patella, loose bodies and occult fractures, and those who do not demonstrate improvement after several weeks of conservative

treatment. Radiography is an adjunct to history and physical examination.<sup>32,34</sup> Nevertheless, radiographic findings may not correlate well with clinical complaints, and often, the symptomatic side is difficult to differentiate from the asymptomatic side.<sup>80</sup>

The diagnosis of PFP depends primarily on the history and physical exam, but radiography is an adjunct to them. It is essential to obtain radiographs in the athlete who has apparent PFP and does not reveal improvement after several weeks of conservative treatment, or if there has been a severe malalignment or history of recent trauma.<sup>32</sup> The standard radiographic series for assessment of patellofemoral problems includes weight-bearing anterior-posterior (A-P), weight-bearing lateral, and axial or Merchant views in 20°–45° of knee flexion.<sup>32,115</sup>

Standard A-P radiograph is useful to identify accessory ossification centers, degenerative joint disease and bone tumors.<sup>32</sup> The lateral view is most valuable for the assessment of patellar height.

Axial views allow evaluation of degenerative changes in the patellofemoral joint, osteochondritis dissecans of the patella, patellar morphology, dysplasia of the trochlear groove, and accessory ossification centers and ectopic calcifications in the retinaculum.<sup>32</sup> However, some studies recommend straight lateral projection X-ray for evaluation of the trochlear configuration and subtle patellar tracking abnormalities.<sup>116</sup> Where osteoarthritis seems to dominate in the patellofemoral compartment, the radiographic features of patellofemoral osteoarthritis include joint space narrowing, subchondral sclerosis, and cysts and osteophytes at the posterior margins of the patella.<sup>115</sup>

Computed tomography and magnetic resonance imaging (MRI) are not needed for most patients with PFP. MRI is the best tool for evaluation of malalignment, trochlear dysplasia, patella tilt and articular chondral injuries.<sup>94,117,118</sup> MRI can be useful in detecting, loose bodies, patellar stress fractures and bone marrow edema, which is suggestive of patellar subluxation or dislocation.<sup>34</sup> Cartilage loss and subchondral sclerosis, edema and cystic changes at the patellar and trochlea surfaces are the main findings in patellofemoral osteoarthritis on MRI.<sup>115</sup>

## Differential diagnosis

A systematic knee and hip examination is necessary, particularly in children and adolescents, to rule out other causes of anterior knee pain. Anteromedial knee pain, particularly in adolescents, can be a consequence of plica syndrome.<sup>119</sup> Pain localized to the inferior patellar pole may suggest patellar

tendinopathy in adults engaged in jumping sports or Sinding-Larsen-Johansson disease in children. A history of acute knee trauma and joint effusion frequently identifies ligament injuries, patellar dislocations or meniscal tears. Tenderness and swelling around the tibial tuberosity in adolescents indicate Osgood-Schlatter disease. Sensations of the patellar movement or popping out may suggest patellar instability or subluxation, mainly during rotational activities.

Prolonged morning stiffness (>30 min), simultaneous involvement of several joints or tendons and joint swelling may be a presentation of systemic rheumatologic joint disease.<sup>102</sup>

## Management

Despite the high prevalence, chronicity and burden, PFP continues to be one of the most difficult musculoskeletal conditions managed by medical professionals.<sup>120</sup> It is evident that greater pain severity and longer symptom duration are indicators of poor prognosis. So, early efficient intervention may be crucial to limit the long-term effects of the condition.<sup>121</sup>

Many possible interventions are recommended by sports medicine practitioners for athletes with PFP; however, no well-established guidelines exist for management of the symptoms.<sup>122</sup>

Due to the multifactorial nature of PFP, the clinical approach should be individualized, and the contribution of different risk factors, including local, proximal (trunk and hip) and distal (foot) factors, should be considered and managed accordingly.<sup>121,123</sup> This approach may add to the treatment effects on pain and function in patients.<sup>123</sup> The physicians can use patient education leaflet during management.<sup>124</sup>

There is general agreement that nonsurgical interventions are the primary choice for PFP treatment. However, in order to select sound choices for the best management, practitioners need up-to-date, high-quality evidence.<sup>121</sup>

In this part, we aim to discuss about the most common interventions, according to the existing evidence.

## Relative rest and activity modification

In athletes in whom overuse may play a more significant role, the impact of rest will be more evident. In an acute injury, relative rest will permit the tissue to heal and the symptoms will diminish. In more chronic cases, the physiologic responses may cause daily activities to surpass the pain threshold. This situation leads to a considerable clinical challenge and needs sound patient education to avoid painful joint loading.<sup>125</sup>

## Exercise

There is consistent evidence that exercise therapy for PFP may result in clinically important reduction of pain in the short, medium and long terms; improvement in functional ability in the medium and long terms, as well as enhancing long-term recovery.<sup>126</sup> Also, it has been shown to be cost-effective and is the treatment of choice, especially in young adults.<sup>127</sup> However, the best mode of exercise therapy is unknown.<sup>128</sup>

There is inadequate information to compare the relative effects of exercise versus other conservative interventions, either unimodal (e.g., taping) or multimodal (combinations of interventions that may include different exercises).<sup>128</sup>

The low-quality existing evidence for comparisons of various exercises is not enough to draw conclusions on the relative results of supervised versus home-based exercises, open versus closed kinetic chain exercises, high- versus low-intensity exercises, hip versus knee exercises, and different variants of closed chain exercises and proprioceptive neuromuscular facilitation stretching and aerobic exercise versus classic stretching and quadriceps exercises. Combining hip and knee exercises is more successful to reduce pain and improve function in the short, medium and long terms, and this combination should be used in preference to knee exercises alone.<sup>126</sup>

There is a lack of high-quality evidence on the exercise medium (land versus water) and the duration of exercises.<sup>128</sup>

Nowadays, considerable debate exists on the specific exercises, target muscles and duration of an ideal exercise program for patients with PFP.<sup>129</sup> Both strengthening and stretching exercises are recommended in exercise therapy. Nonetheless, assessment of individual risk factors may determine the proper combination of different exercises.<sup>123</sup>

## Strengthening

A meta-analysis of randomized controlled trials (RCTs) showed that positive results were apparent with strengthening exercises, particularly knee extension, squats, stationary cycling, static quadriceps, active straight-leg raise, leg press and step-up and step-down exercises. The current evidence supports a prescription of daily exercises of two to four sets of  $\geq 10$  repetitions over a period of  $\geq 6$  weeks.<sup>130</sup>

A systematic review of conservative interventions for PFP from 2000 to 2010 deduced that both weight-bearing and non-weight-bearing quadriceps-strengthening exercises are useful for pain reduction.<sup>131</sup> Although practitioners may prefer weight-bearing exercises to increase the functional activity, the use of non-weight-bearing exercise may be equally valuable, mostly for patients with noticeable quadriceps

weakness. One important factor emphasized in recent reviews is that exercises should be pain free,<sup>131</sup> and applying heavy resistance to the quadriceps will likely perpetuate or aggravate the condition.<sup>132</sup>

Considering the biomechanical stresses at the patellofemoral joint during exercise, it is better to prescribe non-weight-bearing and weight-bearing exercises at  $90^\circ$ – $45^\circ$  and  $45^\circ$ – $0^\circ$  of knee flexion, respectively.<sup>125</sup>

Strengthening program should focus particularly on the vastus medialis oblique, hip abductors and external rotators, as well as core stability training.<sup>132,133</sup>

Although hip exercises have been recommended for the strengthening purpose (i.e., three sets of 10–15 repetitions), there is an indication that muscle endurance also needs to be increased. So, practitioners should consider higher repetitions of sets (i.e., three sets of 20–30 repetitions), in particular, for PFP patients who are involved in more demanding sports such as running and jumping.<sup>125</sup>

## Stretching

Stretching of the hamstring, quadriceps, iliopsoas, gastrocnemius and iliotibial band muscles has been studied for PFP. Theoretically, tight hamstrings, gastrocnemius or iliotibial band muscles may increase the patellofemoral joint reaction forces in full knee extension, whereas tight quadriceps or iliopsoas could cause the same in full flexion.<sup>134</sup> Lower extremity stretching alone or combined with strengthening exercises or other interventions may improve PFP symptoms in up to 60% of patients.<sup>120,122</sup> Proprioceptive neuromuscular facilitation stretching techniques such as contract-relax may be more effective than traditional static or ballistic stretching exercises.<sup>135</sup> Stretching exercises are recommended as a part of the conservative management of PFP.<sup>125</sup>

In the case of hamstring tightness, patients are trained to perform three alternating repetitions of four passive stretching exercises, and all stretching repetitions will be held for 15 s ( $12 \times 15$  s). This program will continue until the end of the 12-week program.<sup>136</sup> In patients with hip flexor tightness, the stretching comprises passive modified lunge stretches and active prone leg lifts with the knee bent. Both stretches are done for 10 repetitions each in a single daily session and each stretch held for 30 s, with up to a 30-s rest period between repetitions.<sup>114,137</sup> To address iliotibial band, common standing stretches in three positions of upright standing, overhead clasped hands and diagonally lowered arms are performed.<sup>114,138</sup> In the case of gastrocnemius tightness, static stretching in forward lunge position is advised. Patients are

taught to hold the static stretch for 60 s and complete two repetitions, for a total of 120 s of stretch during each session. Each session is performed on a daily basis over a 12-week period.<sup>114,139,140</sup>

## Patellar taping

Recent systematic reviews have represented conflicting conclusions regarding the use of patellar taping for PFP. A meta-analysis by Warden et al concluded that a clinically significant reduction in chronic knee pain happens with medially directed tape.<sup>141</sup> In contrast, a 2012 Cochrane review showed that there was no statistically or clinically significant difference in pain scores on comparing taping with no taping at the end of the treatment period.<sup>142</sup> Another study demonstrated that taping has minimal effect in management of long-term PFP symptoms; however, clinicians may use patellar taping as a short-term intervention to allow patients to perform pain-free exercise.<sup>131</sup>

A systematic review by Barton et al. concluded that tailored patellar taping immediately reduces pain with a large effect, while other techniques have only small (untailored medial patellar taping) or negligible (Kinesio Tape) effects on pain in the immediate term. The authors recommend patellar taping to control lateral patellar tilt, translation and spin, with the goal of providing at least 50% pain reduction. The proposed mechanisms for effectiveness of patellar taping include facilitation of earlier vastus medialis oblique onset and enhanced knee function capability during functional tasks.<sup>143</sup> There is minimal evidence that taping significantly adjusts patellar alignment; however, it may increase the patellofemoral contact area, leading to a decrease in pain.<sup>125</sup>

## Knee brace

Similar to taping, existing evidence has achieved conflicting conclusions about the outcomes of patellofemoral bracing. Overall, there is moderate evidence that knee braces have no additional benefit over exercise therapy on pain and function, and there is also moderate evidence for no significant difference in efficiency between knee braces and exercise therapy versus placebo knee braces and exercise therapy.<sup>144</sup> Nevertheless, some findings suggest that the Protonics knee brace may be an effective intervention for pain reduction. However, the exact mechanism for improvement is still unclear.<sup>131</sup> Another study showed that the use of a medially directed realignment brace may result in better outcomes in patients with PFP than exercise alone after 6 and 12 weeks

of treatment, but this positive effect reduced after 1 year of follow-up.<sup>145</sup>

A similar study also showed that patellar bracing may alleviate the symptoms of PFP.<sup>146</sup> Although the exact mechanisms of these positive outcomes are not obvious, they may be the result of redistributed patellar stress, increased proprioceptive input and improved neuromuscular control.<sup>131</sup> As a conclusion, patellar braces should only be used as an adjunct to other interventions; but to find a definitive answer to this clinical question, the heterogeneity of studies, the variety of braces and the quality of outcome assessment should be borne in mind.<sup>125</sup>

## Foot orthosis

There is inadequate and sometimes conflicting evidence regarding the prescription of foot orthosis as an effective intervention for PFP.<sup>125,144</sup>

A systematic review concluded that there is limited evidence for the use of prefabricated foot orthosis for short-term improvements in PFP. This review also reported that physiotherapy combined with prefabricated foot orthosis is more effective than foot orthosis alone.<sup>147</sup>

According to the 2016 consensus statement from the Fourth International Patellofemoral Pain Research Retreat, foot orthosis was recommended for short-term pain relief in patients with PFP.

However, it should be emphasized that the average pain reduction may be deemed to lack clinical significance, as a result of considerable individual variability in response.<sup>148</sup> The cardinal point is that foot orthosis may not be helpful for all patients with PFP, and identifying those most likely to benefit from foot orthosis is important. Published studies have described clinical characteristics that can be used to predict success with foot orthosis intervention, including greater midfoot mobility,<sup>149</sup> less ankle dorsiflexion and immediate improvements in PFP, when performing a single-leg squat with foot orthosis.<sup>150</sup>

## Physical modalities

Systematic reviews and RCTs have demonstrated a lack of supportive evidence for the use of physical agents such as therapeutic ultrasound, phonophoresis, iontophoresis, transcutaneous electrical nerve stimulation, medium-frequency neuromuscular electrical stimulation, low-level laser, extracorporeal shock-wave therapy, electromyographic biofeedback and massage therapies.<sup>102,125,151,152</sup> There is little justification for using these modalities alone for PFP patients.<sup>102,126</sup> However, despite the lack of clear evidence

currently, cryotherapy is still recommended as a part of the conservative treatment for PFP.<sup>125</sup>

## Pharmacotherapy

Drugs commonly used for PFP include simple analgesics such as aspirin or acetaminophen and nonsteroidal anti-inflammatory drugs (NSAIDs). A Cochrane review of drug therapy for PFP found no important differences in clinical symptoms comparing aspirin with placebo and limited evidence for the efficacy of NSAIDs for short-term pain reduction. Another Cochrane review showed that topical NSAIDs are as effective as oral NSAIDs for pain relief in chronic musculoskeletal pain.<sup>153</sup> However, NSAIDs may not be recommended due to the absence of a histologic inflammatory response in many PFP cases as well as existing concerns regarding their possible adverse effects on normal healing response of muscles and tendons. Short courses of NSAIDs may be helpful when other modalities such as exercise and analgesics have failed or pain control is necessary for performing the exercise program.<sup>125</sup>

## Surgery

Surgery is the last alternative for PFP and appears to be inadequate. This is emphasized by an RCT that showed no additional improvement in PFP symptoms and function over 9 months after surgery.<sup>121</sup> Open, arthroscopic and percutaneous techniques have been described as the surgical options. Surgery is usually reserved for refractory cases nonresponsive to conservative treatment. In cautiously selected patients, surgery may be successful, although failure rates of 20%–30% have been reported.<sup>125</sup> In some selected cases such as serious malalignment (femoral torsional deformity and so on), patella alta or lateral patellar compression syndrome, good outcomes were reported.<sup>154–156</sup>

## Other therapies

Acupuncture and dry needling have been suggested as useful interventions for PFP. Limited evidence revealed a statistically significant pain reduction in the medium term following acupuncture.<sup>125</sup> Sclerotherapy and prolotherapy injections are among other proposed interventions, although no high-quality evidence exists for their use.<sup>125</sup> There is limited evidence that injection of Botulinum toxin type A to the distal region of vastus lateralis muscle may increase the activation of vastus medialis.<sup>157</sup> Patellofemoral, knee and lumbar mobilization or manipulation has been proposed as alternatives, but are not recommended according to the current evidence.<sup>126</sup>

## Multimodal approach

According to the recent literature on PFPS and its specific treatment recommendations, multimodal approach is highly recommended to reduce pain in athletes with PFP in the short and medium terms.<sup>126</sup> Combined program is the most effective and strongly supported treatment for patients with PFP and includes strength training of weak muscles, stretching of tight muscles and adjunctive therapies such as taping, bracing and foot orthosis, if applicable.<sup>122</sup> Sports medicine practitioners should particularly assess local, proximal and distal risk factors and use individualized multimodal approach.<sup>121,132</sup> The algorithmic approach is summarized in Figure 8.

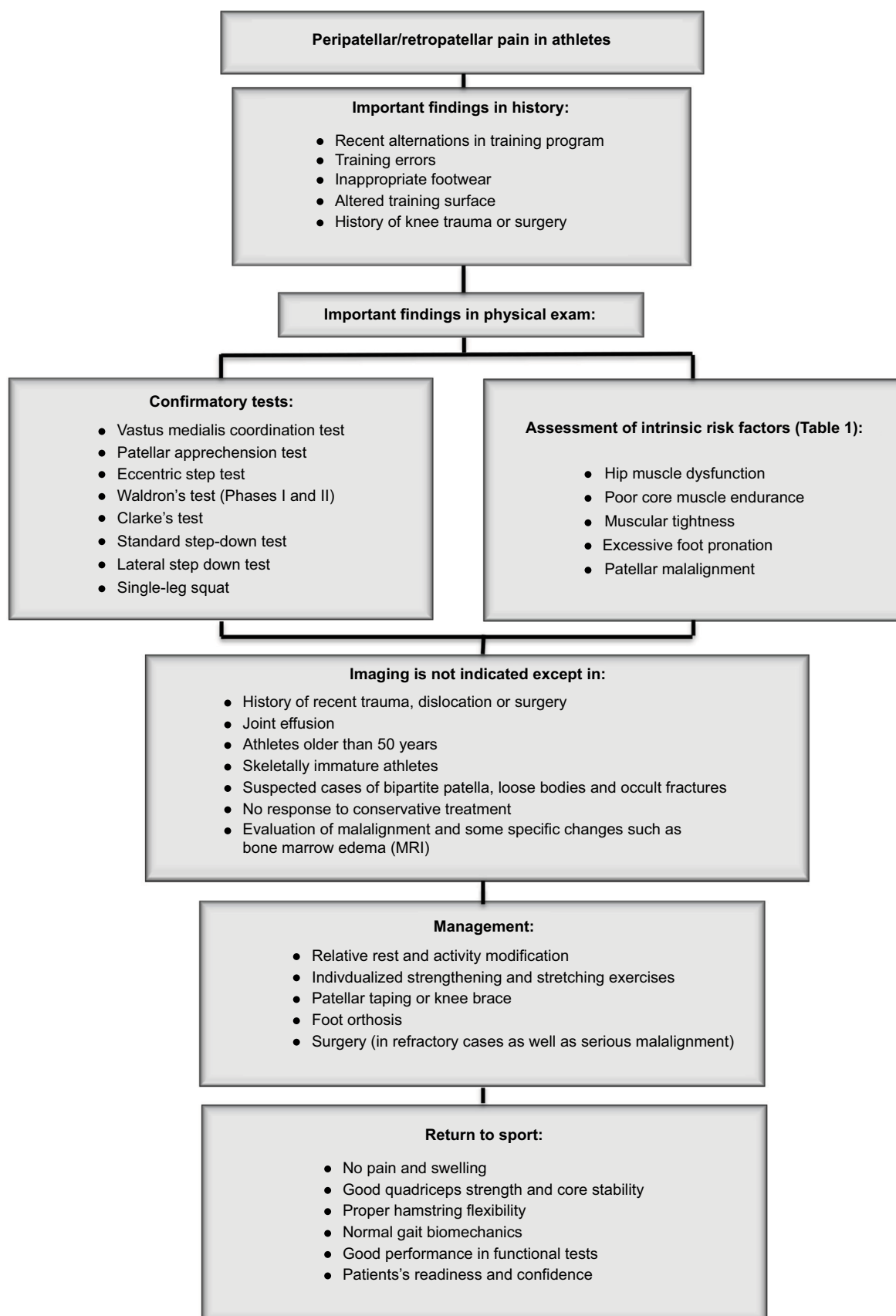
## Prognosis

A substantial proportion of individuals with PFP have an unfavorable recovery over 12 months, irrespective of the intervention. Duration of PFP >2 months is the most consistent predictor of poor long-term prognosis, along with a score of <70 on the anterior knee pain scale. Those who report higher levels of usual/resting or worst/activity-related pain should also be flagged as potentially having a poor 12-month prognosis. Sports medicine practitioners should promote education regarding the natural history and importance of early intervention for PFP, and prescribe interventions with known efficacy in reducing PFP, in order to maximize the prognosis.<sup>158</sup>

## Return to sport

Athletes may be concerned regarding the time of their return to sport. It is especially true for elite athletes who may plan to participate in important sport events. However, sports medicine practitioners should follow the objective criteria to clear the athletes for participation in sports. The athlete can return to sport when the following criteria are met:

- No swelling
- No pain in squatting and in ascending or descending stairs
- Good quadriceps strength (especially vastus medialis obliques)
- Proper hamstring flexibility
- Normal gait biomechanics
- Proper core stability strength
- Good performance in challenging functional tests (vertical jumping, anteromedial lunge, step-down, single-leg press, and balance and reach tests)
- The patient feeling that he/she is ready and has confidence in the injured knee<sup>3,125,159</sup>



**Figure 8** Practical algorithmic approach to diagnosis and treatment of patellofemoral pain in athletes.

**Abbreviation:** MRI, magnetic resonance imaging.

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The authors report no conflicts of interest in this work.

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