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Clinical and biomechanical perspectives on runner's knee: a literature-based review of patellofemoral pain syndrome

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Abstract

Introduction: This review paper aims to highlight that Patellofemoral Pain Syndrome (PFPS) is a complex and often debilitating condition, emphasizing its multifactorial nature. It discusses key risk factors, common symptoms, diagnostic challenges, and treatment strategies, while also pointing out that the diagnosis of PFPS can be difficult to establish due to the wide range of clinical presentations and overlapping conditions.

Materials and methods: A review of chosen literature in the PubMed database was conducted, using the following keywords: “ patellofemoral pain syndrome (PFPS), “runner's knee”, “knee pain”, “physical rehabilitation”

Summary: Patellofemoral Pain Syndrome (PFPS) is a common but often misunderstood condition that can lead to chronic knee pain and impaired function if not properly diagnosed and managed. Given the multifactorial nature of its causes, accurate diagnosis is critical, as symptoms can vary and overlap with other knee disorders. Early intervention through physical rehabilitation, including strengthening exercises, movement retraining, and activity modification, can significantly improve pain management and prevent long-term disability.

Conclusions: Patellofemoral Pain Syndrome (PFPS) is a complex condition requiring early diagnosis and personalized treatment. Conservative management, including physical therapy, strengthening exercises, and activity modification, is highly effective. Surgical intervention is rarely needed, reserved for severe cases. A patient-centered, evidence-based approach is key to successful long-term outcomes.

Key words: patellofemoral pain syndrome (PFPS), runner's knee, knee pain, physical rehabilitation

Introduction

Patellofemoral syndrome (PFS), often referred to as "runner's knee," describes discomfort located around or beneath the kneecap and is among the most frequent causes of knee pain [1–3]. Patients typically report diffuse pain in the front of the knee, especially during activities that place strain on the patellofemoral joint [1, 2, 4].

The exact cause of PFS remains unclear, and there is currently no universal agreement on its underlying mechanisms. A range of contributing factors has been proposed, including repetitive stress, acute injuries, improper alignment of the patella, and muscle imbalances [1, 3–7]. Some research has also indicated that psychological aspects such as poor mental health, fear, anxiety, and depression may play a role in the experience of pain associated with PFS [2, 6, 8, 9]. The condition is more commonly seen in younger individuals who are physically active [5], and

studies have found it to occur more frequently in females than in males [3, 5, 4–8,]. The incidence of anterior knee pain is relatively high, affecting approximately 22 out of every 1,000 individuals per year [9-10]. Women experience this condition more than twice as often as men [9, 11-12]. The underlying causes are varied and multifactorial, including overuse injuries of the extensor mechanism (such as tendinitis and insertional tendinosis), patellar instability, and damage to the cartilage or osteochondral structures [12].

Patellofemoral Pain Syndrome (PFPS), often referred to as "runner's knee," is not limited to runners. A systematic review and meta-analysis by Crossley et al. (2018) showed that PFPS is common in both the general population and among physically active individuals—not just runners. The annual prevalence in the general population is approximately 22.7%, with point prevalence in adolescents reaching 7.2%, and as high as 28.9% in physically active women. [13-14] Additionally, a study conducted in China on young adults (average age ~27) found a PFPS prevalence of 20.7%, regardless of sport type or activity level. [15] Another study involving U.S. Naval Academy students reported an incidence rate of 22 cases per 1,000 person-years, with women being more than twice as likely to develop PFPS compared to men. [16] Runner's knee (patellofemoral pain syndrome) has multiple causes, including biomechanical issues, muscle weakness, and joint overload—not just running. Effective diagnosis requires a broad approach, and treatment should be personalized. This article aims to describe the pathomechanism, symptoms, risk factors, and diagnostics of PFPS to improve treatment outcomes.

Pathophysiology

Patellofemoral Pain Syndrome (PFPS) is a condition characterized by pain around the patella, which worsens during activities that load the patellofemoral joint, such as squatting, running, or descending stairs. [17] The pathophysiology of PFPS is complex and multifactorial. One of the main mechanisms is abnormal alignment and tracking of the patella, leading to uneven distribution of forces on the articular cartilage surfaces, causing irritation. [18] Anatomical factors such as an increased Q-angle, trochlear dysplasia, or a high-riding patella (patella alta) may predispose to patellar tracking disorders. Muscle imbalances also play a significant role, especially weakness or delayed activation of the vastus medialis obliquus muscle relative to the vastus lateralis, which promotes lateral displacement of the patella. [19] Additionally, weakness of the hip muscles, particularly the abductors and external rotators, affects lower limb

biomechanics, increasing stress on the patellofemoral joint. [18]Repeated overload and microtrauma lead to irritation of periarticular tissues, resulting in inflammation and pain. [17] In chronic cases, peripheral and central sensitization can occur, meaning increased sensitivity of the nervous system to pain stimuli, which complicates treatment and leads to persistent symptoms. [18]

Symptoms

Patellofemoral Pain Syndrome (PFPS) typically presents as a dull, diffuse pain in the anterior part of the knee, often localized around or behind the patella—described clinically as peripatellar or retropatellar discomfort. [20-21] Patellofemoral Pain Syndrome (PFPS) typically presents as a dull, diffuse pain in the anterior part of the knee, often located around or behind the patella—described as peripatellar or retropatellar discomfort. The pain intensifies during activities that load the patellofemoral joint in flexion, such as ascending and descending stairs, squatting, running, cycling, or prolonged sitting with bent knees (commonly referred to as the "movie sign"). [22-23] In many patients, the pain develops gradually and may persist for months or even years, with no clear traumatic event linked to its onset. [24] A commonly reported symptom is crepitus, grinding, or a sensation of catching beneath the patella during knee movement. Although patients often perceive these sensations, they do not always correlate with the severity of pain or functional limitations. [25-27] Equally frequent is a feeling of instability or the knee “giving way,” which usually does not reflect true mechanical instability but rather results from pain or muscular weakness, especially of the quadriceps muscle. Unlike other knee pathologies, significant swelling or joint effusion is uncommon in PFPS; the presence of notable fluid accumulation typically suggests alternative causes of knee pain. Physical examination often reveals no obvious signs of inflammation or joint blockage — clinical signs tend to be subtle, and single diagnostic tests have limited sensitivity. However, combining several clinical tests can improve diagnostic accuracy. [27]

In addition to pain, patients commonly report sensations such as crepitus (crackling or grinding), catching, or a feeling of friction beneath or around the patella during knee movement. While these mechanical sensations are frequent complaints, studies have shown that their presence does not necessarily correlate with pain severity or functional impairment, suggesting they may be incidental or related to patellofemoral joint mechanics rather than direct pain generators. [28]

Unlike many other knee pathologies, Patellofemoral Pain Syndrome (PFPS) typically does not present with significant swelling or joint effusion. When substantial intra-articular fluid is evident, clinicians should consider alternative diagnoses such as meniscal tears, synovitis, or osteoarthritis, since minimal or absent effusion is a key differentiating feature of PFPS. [29] On physical examination, clinical signs of PFPS are often subtle and nonspecific. Individual tests—such as the patellar compression (Clarke's) test, patellar grind, and patellar tilt assessments—may reproduce pain but possess limited diagnostic sensitivity and specificity when used in isolation. [30] However, research indicates that combining multiple clinical findings into diagnostic clusters—such as pain during resisted knee extension, palpatory tenderness around the patella, and pain elicited by squatting—significantly enhances diagnostic accuracy, with sensitivity reaching approximately 95% and specificity up to 90%. Studies further emphasize that individual clinical tests alone are often unreliable; however, when these tests are grouped together, they provide much greater value for screening purposes (Kasitinon et al., 2021). Therefore, a comprehensive, cluster-based clinical assessment—which includes patient history, palpation, functional provocation tests, and resisted movements—is crucial for an accurate diagnosis of PFPS and for effectively distinguishing it from other knee pathologies. [31]

Risk Factors

The primary risk factor for developing Patellofemoral Pain Syndrome (PFPS) is poor lower limb alignment, particularly excessive femoral internal rotation and dynamic knee valgus during movement. [32] These biomechanical deviations increase lateral stress on the patellofemoral joint, disrupting normal patellar tracking and contributing to pain. Improper alignment often results from weakness or delayed activation of the hip abductors and external rotators, which play a crucial role in stabilizing the knee during dynamic activities such as running, jumping, or squatting. Another important factor is muscle imbalance within the quadriceps, especially reduced strength or coordination of the vastus medialis oblique relative to the vastus lateralis. [33-34] This imbalance can lead to lateral patellar displacement and overload of the joint surfaces. Additionally, reduced flexibility of the hamstrings and calf muscles may limit joint mobility, increasing anterior knee pressure during functional tasks. Anatomical variations such as a high Q-angle, patella alta, or shallow femoral grooves (trochlear dysplasia) also contribute to abnormal patellar motion and heightened joint stress. Individuals with flat feet or excessive foot pronation may experience altered tibial rotation and alignment, which negatively impact patellofemoral mechanics. [35] These lower chain

abnormalities can propagate upward and influence knee positioning and loading patterns. Core muscle weakness, particularly in the trunk and pelvic stabilizers, further exacerbates poor lower limb control. A weak core limits the body's ability to maintain proper postural alignment during movement, increasing the likelihood of compensatory patterns that overload the knee joint. Joint hypermobility, particularly in adolescents and females, may cause patellar instability and unpredictable tracking.[36] A history of previous lower limb injuries can also impair neuromuscular coordination, leading to chronic movement dysfunction and increased vulnerability to PFPS. Training errors represent another major external risk factor. Sudden increases in training volume, intensity, or frequency without adequate recovery can lead to repetitive overload of the patellofemoral joint. Activities involving frequent knee flexion—such as stair climbing, cycling, or deep squats—can especially aggravate symptoms when performed without proper technique or muscular support. Inadequate or worn-out footwear and hard training surfaces may further amplify joint stress.[37] Lifestyle and occupational habits, including prolonged sitting, kneeling, or stair use, may also provoke or perpetuate symptoms, especially in individuals with predisposing anatomical features. Even minor leg length discrepancies can lead to uneven joint loading and increase stress on one side of the patellofemoral complex. [38] Psychological factors are also recognized contributors to PFPS. Pain catastrophizing, low pain threshold, and fear-avoidance behavior can intensify symptom perception, hinder rehabilitation, and prolong the duration of the condition. Addressing these factors is crucial to ensure effective and sustainable treatment outcomes. [39] Finally, hormonal influences in female athletes may play a role in ligament laxity and neuromuscular control, potentially affecting joint stability during different phases of the menstrual cycle. Although not fully understood, these physiological variations may partially explain the higher incidence of PFPS in women. [40-42]

Diagnosis

The diagnosis of Patellofemoral Pain Syndrome (PFPS) presents a clinical challenge due to its multifactorial nature and symptom overlap with other knee disorders. It is primarily based on a thorough patient history and detailed physical examination, as imaging is not always necessary unless symptoms persist or suggest alternative diagnoses. [44] Patients typically report diffuse anterior or retropatellar knee pain that is aggravated by activities involving repetitive or prolonged knee flexion, such as squatting, stair climbing, running, or even sitting for extended periods with the knees bent.[45] A careful clinical interview should explore the nature and onset

of symptoms, aggravating and alleviating factors, previous injuries, training routines, and daily activities. Particular attention is paid to identifying biomechanical contributors, such as abnormal lower limb alignment or muscle weakness. During physical examination, clinicians often observe for pain provocation during functional movements—especially squatting or descending stairs—and may perform specific clinical tests such as the patellar compression test. Pain reproduced during these maneuvers supports a PFPS diagnosis and helps rule out intra-articular or ligamentous pathologies.[46-47] Observation of functional movement, particularly single-leg tasks like step-downs, may reveal dynamic valgus or femoral internal rotation—patterns strongly associated with PFPS. These altered mechanics are often the result of proximal muscle weakness, especially of the hip abductors and external rotators, which leads to impaired knee control during weight-bearing activities. [47] Muscle strength testing is crucial, especially focusing on the quadriceps, where imbalances—particularly underactivation of the vastus medialis oblique—can lead to lateral patellar maltracking. In addition, core stability and pelvic control are assessed, as deficiencies in these areas can indirectly affect knee joint mechanics and contribute to pain. [48] While clinical findings usually suffice, imaging modalities may be employed when symptoms are atypical, unresponsive to conservative treatment, or suggest structural abnormalities. Radiographs can help exclude osteoarthritis or fractures in older individuals, whereas MRI offers more detailed insights into cartilage integrity, patellar positioning, and the structure of the femoral trochlea. In some cases, ultrasound is used as a complementary tool for assessing soft tissue irritation or peripatellar inflammation.[49-50] Emerging technologies, such as real-time dynamic MRI, three-dimensional motion analysis, and surface electromyography (EMG), are expanding the understanding of patellar kinematics and neuromuscular coordination in patients with PFPS. These tools, though not routinely available in standard clinical settings, hold promise for improving diagnostic accuracy and tailoring individualized treatment strategies. [51] Ultimately, PFPS is a diagnosis of exclusion and should only be confirmed when other sources of anterior knee pain have been ruled out. The presence of peripatellar pain, reproduction of symptoms during specific tasks, and identifiable functional or biomechanical deficits together form a reliable clinical picture. Early recognition of these signs allows for timely and effective intervention, which is critical in preventing chronicity and minimizing functional limitations.[52]

Treatment

The treatment of Patellofemoral Pain Syndrome (PFPS) is largely conservative, with physical rehabilitation serving as the primary and most effective approach. [53] A well-structured

exercise program remains the cornerstone of management, aiming to address muscular imbalances and correct faulty movement patterns that contribute to joint stress. Strengthening exercises that target both the quadriceps and hip muscles—especially the hip abductors and external rotators—are consistently supported by clinical research as the most effective way to reduce pain and improve function. [54] These programs typically span six to twelve weeks and must be progressive in nature, with careful attention paid to technique and load adaptation. In athletic populations, higher-repetition regimens may be beneficial to meet endurance demands. [54-55]

Stretching is another key component of rehabilitation, particularly in individuals with tight quadriceps, hamstrings, iliotibial bands, or calf muscles. Stretching helps to alleviate soft tissue restrictions and enhance joint mobility. Techniques such as proprioceptive neuromuscular facilitation (PNF) have been shown to offer greater benefits in some cases compared to static stretching, especially when integrated into a broader rehabilitation framework. [56]

In addition to isolated muscle strengthening, incorporating functional and task-specific exercises—such as step-downs, lunges, and single-leg squats—can improve movement coordination and neuromuscular control. These exercises are particularly effective at minimizing faulty knee mechanics, such as dynamic valgus, which is a common contributor to patellofemoral joint overload. Emphasizing core and proximal hip control further supports these outcomes by stabilizing the entire kinetic chain. [57]

Adjunctive interventions like patellar taping or bracing may provide temporary relief, particularly in the early stages of rehabilitation, by modifying patellar alignment or enhancing proprioceptive feedback. Likewise, foot orthoses can be beneficial for patients with biomechanical foot issues such as overpronation, although they are considered secondary supports rather than primary treatment tools.[58-59]

Pharmacological approaches, such as non-steroidal anti-inflammatory drugs (NSAIDs), can be used for short-term symptom management but do not offer long-term improvements in function or pain. Similarly, passive therapies—including modalities like ultrasound, laser therapy, or electrical stimulation—have shown limited clinical value and are not recommended as stand-alone treatments. [60]

Surgical intervention is rarely indicated and generally reserved for chronic, treatment-resistant cases where structural abnormalities—such as severe patellar maltracking or malalignment—

are confirmed through imaging and clinical assessment. Even in such cases, evidence suggests that surgical outcomes are not consistently superior to those achieved with high-quality, individualized physiotherapy. [61-62]

An additional strategy gaining traction, especially among runners, is gait retraining. By increasing step cadence and modifying stride mechanics, patients may reduce patellofemoral joint stress and experience symptom relief. Education on proper running technique and training load is an important part of this process and may contribute to long-term success.[62]

Overall, effective treatment of PFPS requires a multifaceted and personalized approach that prioritizes active rehabilitation. Consistent participation in a targeted exercise program, combined with patient education and appropriate activity modification, remains the most evidence-based and successful method for managing this condition.[62]

Conclusion

Patellofemoral Pain Syndrome (PFPS) presents as a multifaceted condition that demands a personalized and comprehensive management strategy. Although its precise causes remain uncertain, a range of contributing factors—including biomechanical dysfunctions, anatomical variations, neuromuscular deficits, and psychological influences—have been implicated in its development and persistence. Diagnosis is primarily clinical, relying on a detailed evaluation of symptoms, movement patterns, and individual risk factors, with imaging techniques reserved for atypical presentations or cases that do not respond to initial treatments.

Conservative management remains the cornerstone of PFPS therapy, with physiotherapy-led rehabilitation programs offering the most consistent and effective outcomes. Targeted strengthening of the quadriceps and hip stabilizers, alongside stretching of tight musculature, core stabilization, and movement retraining, forms the foundation of successful treatment. Supportive interventions like taping, bracing, and orthotics may provide temporary relief but should not replace active therapeutic strategies. Medications and passive modalities offer limited benefit and should be applied with caution. Surgical treatment is considered a last resort and is generally appropriate only in patients with persistent symptoms and clear structural abnormalities.

Ultimately, the most effective management of PFPS involves a patient-focused, evidence-based approach that prioritizes education, consistent rehabilitation, and the gradual reintroduction of

physical activity. Early identification and intervention are crucial for avoiding long-term dysfunction and optimizing recovery—especially in physically active individuals. Ongoing research may further refine therapeutic approaches, enabling more precise and individualized treatment plans in the future.

Disclosure

Author's contribution

Conceptualization: Karolina Kadłubowska,
Methodology: Karolina Kadłubowska**,** Adam Sikorski,
Formal analysis:
Investigation:
Writing-rough preparation: Karolina Kadłubowska,
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