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Patellofemoral pain syndrome – a review of causes, diagnosis and management

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ABSTRACT

Introduction: Patellofemoral pain syndrome (PFPS) is a common cause of anterior knee pain, especially in young and physically active individuals. It is characterized by diffuse pain in the retropatella or peripatella region, which is exacerbated by activities that load the knee joint in flexion, such as squatting, running or descending stairs. Despite the lack of unequivocal structural changes, PFPS can lead to chronic pain and limited knee function. The complex etiology, including biomechanical, anatomical and environmental disorders, makes the diagnosis and treatment of this condition a significant clinical challenge.

Aim of the study: The purpose of this study is to review the current data on the pathophysiology, diagnostics (including clinical and imaging) and therapeutic strategies used in the treatment of PFPS. Particular attention is paid to the prognosis and factors preventing recurrence of symptoms.

Materials and methods: A review of the scientific literature from the last 10 years was conducted using the PubMed, Scopus and Google Scholar databases. Publications in English and Polish regarding the diagnosis, conservative and surgical treatment, imaging and

prevention of PFPS recurrence were included. Articles without peer reviews, with limited sample size and those with unavailable full texts were excluded.
State of knowledge: PFPS is a disease entity of diverse etiology, in which biomechanical abnormalities play a significant role (e.g. increased Q angle, dynamic knee valgus, weakness of VMO and hip abductors). Diagnosis is mainly based on physical examination, but imaging studies (USG, MRI) are also increasingly used. Conservative treatment is the first-line procedure and includes physiotherapy, patient education, taping and selection of orthoses. In cases refractory to conservative therapy, surgical treatment is considered, such as tibial tuberosity osteotomy or MPFL reconstruction. The prognosis is uncertain – symptoms may recur even after several years, therefore prevention of recurrence through continued exercise and correction of movement patterns is crucial.
Conclusion: Effective treatment of PFPS requires a multifaceted approach, based on an individual assessment of the patient's biomechanics and motor function. A combination of exercise therapy, education and – in justified cases – surgical treatment gives the best clinical results. Future studies should focus on standardization of diagnostics and therapeutic interventions and long-term evaluation of treatment effectiveness and prevention of recurrences.
Keywords: Patellofemoral pain syndrome, PFPS, anterior knee pain, diagnostics, conservative treatment, surgical treatment, biomechanics, prognosis, recurrences.

1. Introduction

Patellofemoral pain syndrome (PFPS) is one of the most common causes of anterior knee pain, especially in young and physically active people [1], [2]. It manifests itself with diffuse pain in the patella area, which intensifies during activities that load the knee joint in flexion, such as descending stairs, squatting or prolonged sitting [3].

The incidence of PFPS is estimated at about 22.7% in the general population [4]. Despite its high prevalence, the etiology and risk factors remain poorly understood, mainly due to the limited number of prospective studies and the homogeneity of the analyzed populations [4], [5]. PFPS may be an early stage of the development of patellofemoral joint osteoarthritis, which emphasizes the importance of early diagnosis and treatment [6], [7].

The diagnosis is mainly based on the clinical picture. Imaging is not necessary unless there is a suspicion of other pathologies [3]. Treatment includes rest, short-term use of NSAIDs, and physiotherapy aimed at strengthening the lower limb and trunk muscles [8].

Kinesiotaping may provide short-term relief, but the evidence is insufficient to recommend its routine use [8].

The aim of this study is to review the current data on the etiology, diagnosis, and management of PFPS.

2. Study objective

The aim of this study is to analyze the current state of knowledge on patellofemoral pain syndrome (PFPS), including its epidemiology, pathophysiology, and risk factors. Particular emphasis is placed on biomechanical, anatomical, and environmental determinants of the development of PFPS, which affect the clinical course and treatment efficacy. In addition, contemporary diagnostic methods, both clinical and imaging, as well as current therapeutic strategies – conservative and surgical, are discussed. The aim of the study is also to present data on the prognosis and prevention of PFPS recurrence, as well as to indicate potential directions for further research and clinical practice to improve the quality of treatment and long-term therapeutic outcomes.

3. Materials and methods

To prepare this review, a systematic search of electronic databases was conducted: PubMed, Scopus, Web of Science and Google Scholar. Original research articles and literature reviews published between 2013 and 2024 on patellofemoral pain syndrome (PFPS) were included. Publications in English and Polish that covered pathophysiology, diagnostics (clinical and imaging), conservative and surgical treatment, as well as prognosis and relapse prevention were included in the analysis. Studies with small sample sizes, works without full text available online and publications that were not peer-reviewed were excluded.

4. State of knowledge

4.1 Etiopathogenesis and risk factors

Identification of biomechanical factors associated with patellofemoral pain (PFP) is crucial for both effective treatment and prevention of this condition. Although the exact mechanisms of PFP pathogenesis have not yet been fully explained, the main factor responsible is considered to be increased load on the patellofemoral joint. At the same time, it is believed that certain characteristics of lower limb movement that cause an increase in this load play an important role in the development of PFP [9], [10]. Particular attention is paid to biomechanical disorders of the knee, including altered kinematics and kinetics in three planes:

sagittal, frontal and transverse [10]. Factors contributing to increased load on the patellofemoral joint include increased knee flexion, valgus and external rotation, which contribute to increased forces acting in the posterior and lateral direction [10].

An important element in the pathogenesis of patellofemoral pain syndrome (PFPS) is considered to be patella maltracking, i.e. abnormal lateral displacement of the patella, which intensifies during joint loading, for example during squats. Stimulation of nerve endings located in the ligaments, Hoffa's fat pad, and the synovial membrane surrounding the patella may additionally contribute to the development of PFPS symptoms [11].

Risk factors for the development of PFPS include female gender and activities such as running, squatting, or climbing and descending stairs [12], [13]. A systematic review of the literature also showed that quadriceps weakness is associated with a significant increase in the risk of PFPS, probably due to its role in stabilizing the patella [13]. Additionally, other causes of patellar instability, such as knee sprains, may also predispose to the development of this syndrome [14].

Another mechanism that plays a role in PFPS is dynamic knee valgus, characterized by medial collapse of the knee due to excessive valgus, internal or external rotation, or both. Such biomechanics increase lateral forces acting on the patella, which promotes its abnormal path of movement. Dynamic knee valgus is more common in female athletes, which may explain the higher incidence of PFPS in this group [15]. Furthermore, foot disorders such as excessive rearfoot supination and pronated foot lead to internal rotation of the tibia, which in turn may exacerbate the phenomenon of dynamic knee valgus [16].

4.2 Clinical presentation

Patellar femoral pain (PFP) is one of the most common musculoskeletal complaints, characterized by an insidious onset and pain of an ambiguous nature, located in the anterior knee region – behind or around the patella [17]. Symptoms may appear gradually, although sometimes they develop rapidly. Typically, pain increases during activities requiring a flexed knee, such as squatting, prolonged sitting, climbing or descending stairs, running (especially uphill) or jumping [18].

Despite numerous hypotheses regarding pathoanatomical causes – such as cartilage softening or structural disorders of the joint – these associations remain poorly documented and do not show a strong correlation with clinical symptoms. Therefore, the diagnosis of PFP is based mainly on the clinical picture and exclusion of other possible causes of knee pain [19], [20].

The clinical picture typically concerns young, active adults who experience increasing pain in the anterior compartment of the knee. Patients often report a feeling of friction during movement, as well as bilateral pain, although usually dominant on one side. The pain intensifies with movements that put strain on the knee, especially when climbing stairs or squatting. Subjective symptoms are also characteristic – such as “knee giving way” or “slipping”, which result from impaired muscle control and inhibition of the quadriceps femoris muscle [21]. The location of the pain can be difficult to pinpoint precisely; patients often wrap their hand around the patella – the so-called circle sign [22]. Another characteristic symptom is the so-called “movie-theatre sign”, consisting of a feeling of locking or stiffness of the knee after a long period of sitting with the limbs bent [23]. During a physical examination, various deformities may be revealed that contribute to incorrect positioning of the lower limb, which increase the risk of developing PFPS. The classic so-called The “unfavorable alignment syndrome” includes a combination of features such as anteversion or internal rotation of the femur, cross-eyed patellae (inward), valgus knees, external rotation and varus of the proximal tibia, and flattening of the longitudinal arch of the foot (flat foot). Atrophy of the distal vastus medialis (VMO) is also often seen [21].

Because of the wide differential diagnosis of knee pain, a thorough physical examination should be performed in every patient reporting symptoms in the anterior part of the joint. Although the main emphasis is on the limb affected by the pain, assessment of the contralateral limb is also important – patellofemoral pain syndrome (PFPS) is often bilateral.

Typically, pain is located along the medial or lateral edges of the patella [22]. These structures are best palpated with the patient lying supine or sitting with the knee in extension and the quadriceps relaxed. This arrangement allows for the assessment of patellar displacement in all directions: medial, lateral, superior and inferior.

Meta-analyses have shown that pain during squatting is the most sensitive symptom in the physical examination of patients with PFPS, while a positive result of the patellar tilt test has the highest positive probability of confirming the diagnosis [24].

The patellar tilt test, described by Grelsamer and McConnell, is used to assess the position of the patella in the transverse plane and identify any disturbances in its axis. The test is performed in the supine position, with the knee in full extension and the quadriceps muscle fully relaxed [25].

To perform the test, the examiner places the thumb and index finger on the lateral and medial edges of the patella, comparing their height in relation to the frontal plane. Both edges of the patella should be at a similar level. If the finger assessing the medial edge is more

anterior than the finger at the lateral edge, this indicates a lateral tilt of the patella. Similarly, if the lateral border protrudes more anteriorly, this suggests medial tilt [26].

This test allows for the assessment of the tension of the soft tissue structures surrounding the patella and can be particularly useful in detecting excessive tension in the iliotibial band or weakness of the medial muscle complex (including the vastus medialis, VMO). It has been shown that a positive result of the patellar tilt test may correlate with the presence of pain symptoms and increased lateral force acting on the patella [25].

In clinical practice, the Clarke test (patellar grind test) is also used, in which the examiner stabilizes the patella by exerting distal pressure, and the patient contracts the quadriceps muscle. The occurrence of pain or a symptom of restlessness may indicate dysfunction. However, this test has limited reliability, may provoke pain even in healthy individuals, and should not be used as the sole diagnostic tool. Isolated patella crepitus also does not constitute a basis for the diagnosis of PFPS.

Muscle weakness is an important component of the pathophysiology of patellofemoral pain syndrome (PFPS). Numerous studies have shown that patients with PFPS often present with reduced quadriceps strength, which is considered to be one of the main predisposing factors for the development of this condition [27]. In addition, weakness of the muscles responsible for hip abduction and external rotation is also commonly observed [28].

Recent reports confirm these relationships. In a study conducted by Nunes et al., muscle strength was assessed in 32 physically active individuals, including 16 diagnosed with PFPS and 16 in the control group. The authors observed statistically significant deficits in isometric strength during hip abduction and extension in individuals with PFPS compared to participants without symptoms of the syndrome [29]. These results emphasize the importance of assessing and strengthening the pelvic girdle muscles in the therapeutic management of patients with patellofemoral pain.

In biomechanical assessment, it is worth considering the Q angle, determined between the femoral and tibial axis. Its average value is approximately 14° in men and 17° in women. An increased Q angle generates an increased lateral force acting on the patella, which may contribute to its incorrect tracking and the development of PFS.

The Q angle, first defined by Brattström [30], is a measure of the tendency of the patella to move laterally during quadriceps contraction. An increase in the Q angle is associated with a greater force pulling the patella outward, which may predispose to the development of patellofemoral pain syndrome (PFPS) [26].

This angle is defined as the angle between the line connecting the anterosuperior iliac spine (ASIS) to the center of the patella and a line running from the center of the patella to the tibial tuberosity. The importance of this parameter is emphasized by the fact that tibial tuberosity lateralization can affect the biomechanics of the patellofemoral joint. Despite the development of imaging techniques, the Q angle measurement remains the only clinical method to assess the degree of tuberosity lateralization without the need for expensive additional tests [31].

Smith et al. [32] proposed the introduction of a standardized measurement protocol, which aimed to increase the accuracy and repeatability of the study. This protocol, described in detail by Merchant et al. [31], assumes the subject is in a supine position with the lower limbs in full extension and the quadriceps relaxed. The patellas should be in a neutral position, pointing upwards. The person performing the measurement marks the centre of the tibial tuberosity and then uses a long-arm goniometer, in accordance with the previous recommendations of Draper et al. [33], who demonstrated greater accuracy of such instruments compared to short-arm goniometers. During the measurement, the subject holds one of the goniometer arms at the ASIS, while the examiner places the goniometer axis in the centre of the patella, taking care to centre it in relation to the femoral trochlea. The other arm of the goniometer measures the angle, which allows for precise determination of the degree of lateral deviation of the axis of force action of the quadriceps muscle on the patella [26].

It is also worth assessing gait and footwear, which may indicate biomechanical abnormalities affecting patellofemoral joint function. Gait examination may reveal excessive foot pronation, knee valgus or compensatory antialgesia pattern, which promotes overload. In turn, assessment of shoe wear – especially excessive abrasion on the medial side – may suggest incorrect lower limb axis and unfavourable force transfer.

It should be remembered that symptoms such as effusion, erythema or increased temperature of the knee joint are not typical of PFPS and should prompt further diagnostics for other diseases, e.g. arthritis, structural injury or rheumatic diseases [16].

4.3 Diagnostics

Imaging studies, particularly magnetic resonance imaging (MRI) and ultrasonography (USG), combined with clinical assessment, show high diagnostic value in diagnosing patellofemoral pain syndrome (PFPS).

A study by Schoots EJM et al. (2013) [34] demonstrated the presence of structural changes in the lateral patellar retinaculum (retinaculum laterale) using USG. Increased

thickness and neovascularization were found, visualized using color Doppler ultrasound in patients with PFPS.

Jan et al. analyzed the vastus medialis muscle (VMO) sonographically in patients with PFPS and healthy individuals. A significantly lower level of attachment, fiber angle and VMO volume were demonstrated in the study group [35]. Similarly, Siev-Ner et al. in a study of 67 young dancers (54% of whom were diagnosed with PFPS) noted a significantly higher incidence of intra-articular effusions among patients with this syndrome [36].

In the study by Kizilkayi et al., the thickness of the quadriceps tendon and patellar tendon was assessed in patients with PFPS. A quadriceps tendon thickness of ≥ 0.54 cm was characterized by 80% sensitivity and 71% specificity in diagnosing PFPS, while a patellar tendon thickness of ≥ 0.35 cm achieved a sensitivity of 66.7% and specificity of 67.7% [37].

Abnormal position of the patella in relation to the intercondylar groove of the femur has also been repeatedly confirmed in studies based on magnetic resonance imaging [38]. In recent years, Lok Yin Ada Kwan [39] demonstrated the usefulness of US in assessing the position of the patella relative to the femoral condyle. The obtained results were characterized by high reliability, which suggests that this method can be routinely used in clinical practice to assess lateral patellar displacement.

Radiography, computed tomography (CT) and magnetic resonance imaging (MRI) play an important role not only in confirming PFPS, but also in differentiating it from other pathologies, such as lateral meniscus injuries, extensor tendon ruptures, tumor-like changes (e.g. giant cell tumor of the tendon sheath) or synovial fold syndrome [40]. Despite the wide use of these techniques, no single diagnostic “gold standard” has been established [41].

However, ultrasonography remains a promising diagnostic tool due to its availability, low cost, and ability to assess peripatellar soft tissue structures such as the retinaculum, hyaline cartilage, and their relationship to the patella. An example is the study by Lapègue et al. [42], who proposed a simple, clinically applicable protocol for the assessment of the patellofemoral joint by ultrasound, including three criteria: trochlear angle, TT–TG distance, and the presence of trochlear dysplasia.

4.4 Therapeutic treatment

The aim of treating patellofemoral pain syndrome (PFPS) is to eliminate the causes underlying the patient's symptoms, restore dynamic muscle balance, and correct impaired kinematics and positioning of the patellofemoral joint. Therapy is divided into conservative and surgical treatment, with conservative treatment, conducted for 3–6 months, being

recommended as the first-line treatment in the initial stages of the disease. Failure of non-surgical therapy may be an indication for surgical intervention [21].

Conservative treatment

In the case of pharmacotherapy, a short course of non-steroidal anti-inflammatory drugs (NSAIDs) is recommended. A randomized, double-blind study showed that a seven-day course of naproxen was associated with a statistically significant reduction in pain compared to placebo. However, there is no clear evidence confirming the efficacy of longer use of NSAIDs in this disease entity [43].

Patients with PFPS often have reduced hip abduction and external rotation strength and reduced peak knee extension moment [21]. For this reason, the basis of conservative treatment is the optimization of lower limb biomechanics through functional training, improvement of soft tissue flexibility, gait pattern correction and motor re-education using appropriate exercise techniques. Effective pain control is essential for effective rehabilitation [44].

Strengthening the quadriceps femoris, especially the vastus medialis (VMO), is a recognized and commonly used approach in PFPS rehabilitation. It has been documented that targeted training of this muscle group can not only reduce pain, but also improve knee function and prevent symptom recurrence [45], [46]. It is recommended that strength and stretching exercises be performed three times a week for at least 6–8 weeks [47].

Additional adjunctive techniques include patellar taping (e.g. McConnell's method), which aims to improve patella alignment by controlling patellar tilt, translation, and rotation. The use of this technique can result in inferior and lateral displacement of the patella, resulting in a more favorable distribution of forces in the joint [48], [49]. In cases with confirmed maltracking, the use of patellar stabilizing orthoses may be indicated as an adjunct to the rehabilitation program and quadriceps strengthening exercises.

On the other hand, physical modalities such as cryotherapy, ultrasound, phonophoresis, iontophoresis, and transcutaneous neuromuscular stimulation have not shown clear benefits in the treatment of PFPS and are not recommended as stand-alone treatments [50].

Available data suggest that young patients, those of shorter stature, and patients with unilateral symptoms may respond better to conservative treatment [51].

Surgical treatment

Most authors emphasize that surgical treatment of PFPS is reserved exclusively for selected cases and is rarely the first choice of therapy. Surgery is considered only in patients

who have exhausted conservative treatment options and whose symptoms persist despite properly performed rehabilitation. Additionally, surgical qualification requires the presence of one or more documented abnormalities, such as: pathological Q angle, increased TT–TG distance (tibial tuberosity–trochlear groove), tension of the lateral patellar retinaculum or damage to the articular cartilage [21].

Initial intraoperative assessment is often performed using arthroscopy, which allows direct visualization of the joint, assessment and debridement of cartilage damage, resection of pathological synovial folds and exclusion of other coexisting intra-articular pathologies.

One of the most commonly used surgical procedures in PFPS is the release of the lateral patellar retinaculum, indicated only in the case of significant tension and symptomatic lateral compression syndrome. Although technically a relatively simple procedure, it is rarely performed as an isolated procedure due to limited long-term efficacy [52].

Tibial tuberosity realignment (e.g. Elmslie-Trillat osteotomy or tuberosity shift) is the preferred technique in cases of significant lateral patellofemoral joint overload and the presence of anatomical abnormalities such as increased TT–TG distance. This procedure is most often performed in skeletally mature patients [21].

In cases of chronic medial instability resulting from medial patellofemoral ligament (MPFL) insufficiency, its reconstruction is possible. This procedure is performed using various techniques using autografts (e.g. gracilis tendon, semitendinosus tendon) or allografts. Despite the growing popularity of this procedure, many controversies remain regarding the choice of graft, its fixation, anatomical location, and appropriate tension. The graft can be secured to the patella using sutures, anchors, or bone tunnels, but this procedure is associated with a risk of complications [21].

According to a recent systematic review, the complication rate after MPFL reconstruction is as high as 26.1%. The most common complications include patellar fractures, postoperative instability, limited knee flexion, and chronic pain [53].

4.5 Prognosis and prevention of relapse

The prognosis of patellofemoral pain syndrome (PFPS) is varied and largely depends on the duration of symptoms, their severity, the treatment used, and individual factors such as biomechanics or psychosocial characteristics of the patient. Although PFPS is often considered a self-limiting condition, many studies indicate that it can be chronic or recurrent.

In a 7-year follow-up study (Rathleff et al., 2019), as many as 57% of patients continued to report pain symptoms despite previous improvement after conservative treatment. Moreover, symptoms such as pain when going down stairs or during prolonged sitting (the so-called kinematic sign) persisted in the majority of the study participants, despite the lack of significant structural changes in imaging studies [54]. The work of Hoogeboom et al. showed that the factors negatively influencing the prognosis are high pain level at the beginning of the treatment, long-term symptoms and the presence of general pain (e.g. fibromyalgia) [55]. People with low self-efficacy, especially men, showed worse results after 12 months of therapy [55].

Meta-analytical data indicate that as many as 40–90% of patients may experience pain recurrences in the period of 2–5 years after the end of treatment, especially if they do not maintain recommendations regarding physical activity and muscle strengthening [4]. The most common recurring symptoms are anterior knee pain when climbing stairs, running and sitting for long periods [4].

In order to prevent recurrences, it is crucial to implement an individual preventive program. It should include:

- regular exercises to strengthen the quadriceps and hip abductors [56],
- correction of biomechanical abnormalities (e.g. dynamic knee valgus) [57],
- patient education on proper movement patterns and joint loading [47],
- and maintaining physical activity in accordance with the principles of progression [58].

Preventive interventions for young athletes – such as knee stabilization programs (e.g. FIFA 11+) – have been shown to reduce the frequency of relapses and improve neuromuscular control [59].

5. Conclusions

Patellofemoral pain syndrome (PFPS) is one of the most common sources of anterior knee pain in young and physically active people. Although this entity is not associated with structural changes in imaging studies, it can significantly affect the quality of life of patients and lead to chronic symptoms. The key aspect in diagnostics is a thorough clinical assessment, supported if necessary by imaging studies such as ultrasound or magnetic resonance imaging.

The etiology of PFPS is complex and multifactorial, including biomechanical, anatomical and environmental disorders. A special role is attributed to abnormalities in the functioning of the muscles that stabilize the knee and deviations of the lower limb axis, such

as dynamic valgus, increased Q angle or abnormal patella movement (maltracking). Weakness of the hip abductor muscles and the vastus medialis muscle adversely affects the stabilization of the patellofemoral joint and should be included in functional diagnostics.

Therapeutic treatment should be individually selected and include primarily conservative treatment – targeted physiotherapy, strengthening of weakened muscle groups, gait re-education, activity modification and pain control. In cases resistant to conservative treatment, surgical interventions may be considered, although they are reserved for strictly defined indications.

The prognosis for PFPS is varied – symptoms may persist for years in a significant proportion of patients, and relapses are frequent. Therefore, an important element of long-term treatment is prevention: continued strengthening exercises, correction of biomechanics and education of the patient in the field of correct movement pattern. Early intervention and a comprehensive therapeutic approach increase the chances of lasting improvement and reduce the risk of chronicity of the syndrome.

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