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General

Adolescent patellofemoral pain syndrome: reappraisal of pathophysiology and implications for clinical management

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Background

Adolescent patellofemoral pain syndrome (APFS) is the most common cause of knee pain in this population. Despite its high prevalence, it remains frequently underestimated and is often considered a benign and self-limiting condition. However, persistent symptoms, significant psychosocial burden, and limited long-term efficacy of conventional treatments challenge this traditional view and call for an updated understanding of its underlying mechanisms and management.

Main body

This narrative review is based on a structured literature search conducted in PubMed and Google Scholar, with studies selected according to predefined relevance criteria. APFS typically develops around puberty and predominantly affects physically active adolescents, particularly females. Clinical presentation is characterized by activity-related anterior knee pain and pain during prolonged sitting. Diagnosis remains primarily clinical, although it should incorporate assessment of biomechanical, functional, and psychosocial factors. While standard imaging is usually unremarkable, advanced magnetic resonance imaging techniques have revealed early structural and biochemical cartilage alterations. Current evidence supports a multifactorial model of pain involving both peripheral nociceptive sources and central sensitization mechanisms, further supported by neuroimaging studies. Psychosocial factors, including kinesiophobia, reduced participation in physical activity, and impaired quality of life, play a key role in symptom persistence. Standard management based on education, load management, and rehabilitation yields suboptimal outcomes in a substantial proportion of adolescents. Emerging approaches include psychologically informed interventions, digital adherence strategies, and adjunctive therapies such as intra-articular hyaluronic acid.

Conclusion

APFS should no longer be regarded as a benign condition. A shift toward earlier, multimodal, and individualized management is warranted, integrating physical, psychological, and educational components. Improved understanding of central pain mechanisms and the development of adjunctive therapeutic strategies may contribute to better outcomes and prevention of chronicity.

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INTRODUCTION

Anterior knee pain in children and adolescents encompasses a broad spectrum of clinical entities with overlapping features, which explains the diversity of terminology used in everyday practice, including patellar syndrome, patellofemoral chondropathy, and chondromalacia patellae. Within this heterogeneous group, adolescent patellofemoral pain syndrome (APFS) must be clearly distinguished from other frequent causes of anterior knee pain at this age, particularly Osgood–Schlatter disease and Sinding–Larsen–Johansson syndrome, in order to avoid misdiagnosis and inappropriate management.

From an epidemiological perspective, APFS is the leading cause of knee pain in adolescents, with an estimated prevalence of 6–7%.[1] The condition typically begins around the age of 11 years, coinciding with the pubertal growth spurt, and may persist until the end of adolescence or even into adulthood. A marked female predominance has been consistently reported, with a female-to-male ratio of approximately 2.3:1. In specific populations exposed to high mechanical loads, such as young female basketball players, prevalence may reach up to 16%, highlighting the major role of repetitive stress and sports-related factors.[1]

The etiology is largely dominated by overuse. Approximately two-thirds of adolescents with APFS report regular and intensive sports participation, often involving repetitive loading of the patellofemoral joint. However, it is noteworthy that one-third of patients present without any clearly identifiable triggering factor, suggesting that additional constitutional or biomechanical determinants may be involved.

Although APFS is often described as a benign and self-limiting condition, this assumption deserves critical reconsideration. Longitudinal data indicate that approximately 25% of patients remain symptomatic after adolescence, and a potential association with the later development of patellofemoral osteoarthritis has been suggested.[2] These observations challenge the traditional perception of APFS and support the need for a more proactive and comprehensive approach.

The aim of this narrative review is to provide a comprehensive and clinically oriented synthesis of current knowledge on APFS, with a focus on emerging concepts in pathophysiology and management.

STUDY SELECTION PROCESS

Due to the heterogeneity of the available literature and the conceptual nature of the topic, a formal systematic review methodology was not employed. All identified records were initially screened based on their titles and abstracts, which were obtained from the PubMed and Google Scholar databases. Articles were considered for inclusion if their content was deemed relevant according to predefined eligibility criteria. These articles involved participants aged 10 to 18 years who suffered from APFS and reported on the evaluation of diagnosis and assessment tools or conservative or minimally invasive strategies with a level of evidence of III or higher. Studies evaluating surgical management were excluded. Full-text versions of potentially eligible studies were then retrieved and assessed in detail. Each article was reviewed in its entirety to confirm its suitability. Any uncertainties regarding inclusion were resolved through discussion among the authors until consensus was achieved. Additionally, we manually examined the reference lists of all included articles to identify further relevant studies that may not have been captured through the initial database search.

CLINICAL PRESENTATION

The clinical presentation of APFS is dominated by anterior knee pain, typically described as diffuse and peripatellar. Pain localization is often imprecise, which may contribute to diagnostic uncertainty. Bilateral involvement is common, occurring in approximately 75% of cases, although symptoms are frequently asymmetric, with one knee being more symptomatic.

Pain is characteristically mechanical. It is exacerbated by activities that increase patellofemoral joint loading, including stair climbing, running, jumping, and squatting. Activities involving sustained knee flexion, such as prolonged sitting, frequently provoke symptoms, a phenomenon classically referred to as the “Movie sign.” Conversely, pain usually improves with rest, particularly when load is reduced.

Symptom onset is most often insidious and progressive. In approximately two-thirds of cases, it occurs in the context of sports overuse, often without a clearly defined acute event. In some cases, minor trauma may be reported, although a causal relationship is not always evident. Importantly, in nearly one-third of adolescents, no precipitating factor can be identified.[1]

A major clinical issue is the delay in diagnosis. Symptoms are frequently trivialized, both by patients and healthcare providers, and are often attributed to so-called “growing pains.” This delay, which may extend over several months or even years, contributes to chronicity, the development of kinesiophobia, and progressive functional impairment.

Functional impact can be objectively assessed using validated outcome measures such as the Kujala Anterior Knee Pain Scale (F-AKPS).[3] This instrument ranges from 0 to 100, with lower scores indicating greater disability. A threshold of 70 is generally considered to reflect moderate impairment, and the minimal clinically important difference is estimated between 7 and 14 points (Table 1).

PHYSICAL EXAMINATION

Clinical examination plays a central role in the diagnosis of APFS. It typically includes assessment of classical patellofemoral signs, such as tenderness on palpation of the patellar facets, the patellar compression (Zohlen) test,[4] and evaluation of patellar mobility using the patellar glide test.[5] However the clinical diagnosis remains a challenge due to the low isolated reliability of traditional maneuvers.

Table 1.

Item	Clinical Feature	Scoring Options	Points
1	**Limp**	(a) None (b) Slight or periodical (c) Constant	5 3 0
2	**Support**	(a) Full support without pain (b) Painful (c) Weight bearing impossible	5 3 0
3	**Walking**	(a) Unlimited (b) More than 2 km (c) 1-2 km (d) Unable	5 3 2 0
4	**Stairs**	(a) No difficulty (b) Slight pain when descending (c) Pain both when descending and ascending (d) Unable	10 8 5 0
5	**Squatting**	(a) No difficulty (b) Repeated squatting painful (c) Painful each time (d) Possible with partial weight bearing (e) Unable	5 4 3 2 0
6	**Running**	(a) No difficulty (b) Pain after more than 2 km (c) Slight pain from start (d) Severe pain (e) Unable	10 8 6 3 0
7	**Jumping**	(a) No difficulty (b) Slight difficulty (c) Constant pain (d) Unable	10 7 2 0
8	**Prolonged sitting with knees flexed**	(a) No difficulty (b) Pain after exercise (c) Constant pain (d) Pain forces to extend knees temporarily (e) Unable	10 8 6 4 0
9	**Pain**	(a) None (b) Slight and occasional (c) Interferes with sleep (d) Occasionally severe (e) Constant and severe	10 8 6 3 0
10	**Swelling**	(a) None (b) After severe exertion (c) After daily activities (d) Every evening (e) Constant	10 8 6 4 0
11	**Abnormal painful patellar movements (Subluxations)**	(a) None (b) Occasionally in sports activities (c) Occasionally in daily activities (d) At least one documented dislocation (e) More than two dislocations	10 6 4 2 0
12	**Atrophy of thigh**	(a) None (b) Slight (c) Severe	5 3 0
13	**Flexion deficiency**	(a) None (b) Slight (c) Severe	5 3 0
	TOTAL SCORE		**/ 100**

While the Zohlen sign (also referred to as Clarke's test) and the patellar glide test are frequently used in clinical practice to assess cartilage irritation and patellar mobility recent guidelines emphasize a cluster-based approach including functional tasks like squatting or stair ambulation.[6]

Particular attention should be paid to dynamic assessment. The 45-second anterior knee pain provocation test, consisting of a single-leg squat maintained at approximately 60° of knee flexion, has been described as particularly sensitive in adolescents.[7] This test allows not only

confirmation of pain but also evaluation of the speed of onset and tolerance to sustained load, which may provide additional clinical information.

The examination should also systematically include identification of predisposing factors. These include static factors such as genu valgum and patella alta, as well as generalized joint hypermobility. Dynamic and biomechanical factors, including altered lower limb alignment or movement patterns, should also be considered, as they may contribute to increased patellofemoral stress.

IMAGING: FROM APPARENT NORMALITY TO EARLY ABNORMALITIES

By definition, idiopathic APFS is typically associated with normal findings on standard radiographs. Conventional imaging, including weight-bearing anteroposterior, lateral, and axial patellar views, is nevertheless recommended to exclude alternative diagnoses and to identify anatomical variants that may predispose to patellofemoral overload, such as trochlear dysplasia or patella alta.

However, the concept of strictly normal imaging must be reconsidered in light of recent data. Several studies have demonstrated that subtle structural or biochemical abnormalities may be present despite normal radiographs. Advanced MRI techniques, particularly T2 mapping, have provided important insights into early cartilage changes. For example, studies in adolescent athletes exposed to high levels of repetitive loading have demonstrated increased T2 relaxation times in patellar cartilage, suggesting early alterations in cartilage composition not detectable on conventional sequences.[8]

In addition, MRI studies in pediatric populations with overuse-related knee pain have reported a substantial prevalence of subclinical abnormalities, including patellar chondromalacia (27%), cartilage fissures (19%), and bone marrow edema.[9] Other studies have identified subtle morphological differences in patellar and trochlear geometry in symptomatic adolescents compared with controls, even in the absence of overt dysplasia.[10]

Taken together, these findings suggest that APFS may involve early structural or biochemical changes and should not be considered purely functional. This has important implications for both diagnosis and management.

PAIN MECHANISMS: A MULTIFACTORIAL AND MULTIDIMENSIONAL MODEL

The mechanisms underlying pain in APFS remain incompletely understood and are likely multifactorial.[1] Several peripheral structures within the patellofemoral joint are richly innervated and may contribute to nociception, including subchondral bone, synovium, the infrapatellar fat pad (Hoffa's fat pad), and the medial and lateral retinacula.

Among these, subchondral bone has been proposed as a particularly relevant source of pain. Increased metabolic activity within the patellofemoral joint has been reported in patients with patellofemoral pain, and differences in cartilage thickness—particularly in females—may result in greater transmission of mechanical stress to subchondral bone.[1]

Beyond peripheral mechanisms, increasing attention has been paid to the role of central sensitization. Several studies have demonstrated features consistent with altered pain processing in patients with patellofemoral pain.[11-13] Supporting the theory of central pain modulation, a study by Rodrigues et al.[14] demonstrated the efficacy of anodic transcranial direct current stimulation in 28 women with PFPS. Compared to the placebo group, participants receiving active stimulation showed significant gains in quadriceps strength and a marked reduction in pain (VAS and clinical testing) at the 8- and 12-week follow-ups. These results suggest that targeting central nervous system excitability can directly influence peripheral clinical outcomes.Functional MRI studies have provided further evidence, revealing changes in brain connectivity patterns involving regions associated with sensorimotor integration, emotional processing, and pain modulation.[15] These alterations appear to be linked to pain perception and may be influenced by cognitive and emotional factors such as catastrophizing. More broadly, they support the concept that APFS should be understood within a multidimensional framework integrating peripheral, central, and psychological mechanisms.

PSYCHOSOCIAL IMPACT: A CENTRAL COMPONENT OF THE DISEASE

The psychosocial impact of APFS is considerable and is increasingly recognized as a major determinant of outcome. Adolescents affected by APFS are often highly engaged in sports, and the onset of pain frequently leads to a reduction or cessation of physical activity. This may result in physical deconditioning, weight gain, and reduced participation in social and recreational activities.

Psychological consequences are common and include decreased self-confidence, anxiety, and depressive symptoms. Kinesiophobia and avoidance behaviors are particularly prevalent and tend to increase with symptom duration. These factors contribute to a vicious cycle in which fear of pain leads to reduced activity, further deconditioning, and persistence of symptoms. Quantitative data illustrate the magnitude of this burden. A substantial proportion of adolescents report daily or constant awareness of their knee pain, reduced confidence in their knee function, and significant limitations in daily activities.[16] These findings highlight the importance of addressing psychosocial dimensions as an integral part of management.

CURRENT MANAGEMENT AND ITS LIMITATIONS

In such a complex landscape, the immediate priority should be swift analgesia to interrupt the transition to chronic pain. Paradoxically, standard care still prioritizes mechanical interventions, such as sports cessation and rehabilitation, despite their inherent lag time in providing clinical efficacy.

REHABILITATION

Current management of PFPS, particularly in adolescents, is primarily based on patient education and load management.[17] Rehabilitation follows a structured progression where the initial phase focuses on symptom control through the implementation of an 'Activity Ladder'. This tool allows patients to maintain physical activity by adjusting the volume and intensity based on pain response, rather than resorting to complete rest.

As emphasized by Rathleff's work, education regarding pain mechanisms and load adaptation is crucial to improve long-term adherence. The subsequent phases introduce progressive strengthening, but with the clinical understanding that in this population, muscular deficits may be a consequence of pain-induced inhibition rather than the primary etiology.[18] This phased approach ensures that functional exercises, such as squats and lunges, are reintroduced only when the patient has successfully climbed the initial rungs of the activity ladder without symptom flare-ups.

Despite this structured approach, outcomes remain disappointing. Only approximately one-third of adolescents experience significant improvement at one year, and up to 50% remain symptomatic at two years.[1] Unlike adult populations, many adolescents may not respond adequately to current rehabilitation strategies, possibly due to a different pathophysiology. In this age group, strengthening exercises are frequently insufficient for pain relief, as hip and knee weakness may be the result—rather than the cause—of the condition.[18,19]

Several other factors may explain these limitations. Delayed diagnosis is a major issue, with adolescents often presenting after prolonged symptom duration. It has been shown that time it takes to receive treatment after symptoms first appear is much longer for children and adolescents than for adults, as it averages six months for seven out of 10 adults, compared with three years for adolescents.[1]

Adherence to rehabilitation is another critical factor: Rathleff et al have shown that compliance is frequently suboptimal, with many adolescents failing to complete prescribed programs.[1] Finally, the limited consideration of psychosocial factors in traditional rehabilitation programs likely contributes to poor outcomes.

STOPPING SPORT

While the sport responsible for the onset of SFPA should be discontinued during the first two months of rehabilitation, school sports activities should be adapted to the level of pain, but maintained as far as possible in order to avoid avoidance behavior, kinesiophobia and their consequences (muscle loss, weight gain, isolation).

ADJUNCTIVE STRATEGIES

A range of adjunctive interventions is commonly used, including foot orthoses, patellar taping, and bracing. However, the level of evidence supporting these approaches is generally low, particularly in pediatric populations. Results are inconsistent, with some studies reporting modest benefits and others showing no significant effect or still in progress.[20-24]

These interventions may provide short-term symptomatic relief in selected patients but do not appear to substantially modify the long-term course of the disease.

TOWARD A MULTIMODAL AND PROACTIVE APPROACH

PSYCHOLOGICALLY INFORMED INTERVENTIONS AND ADHERENCE STRATEGIES

Given the importance of psychosocial factors, there is growing interest in interventions that explicitly address these dimensions. Psychologically informed approaches aim to modify maladaptive beliefs, reduce fear of movement, and improve coping strategies.

Recent randomized studies have shown that educational interventions incorporating psychological content can lead to greater improvements in both pain and psychological outcomes compared with purely biomechanical education.[25] In parallel, digital health tools, including mobile applications, have been developed to support adherence and facilitate communication between adolescents, parents, and healthcare providers.[26] These approaches represent promising avenues to improve engagement and outcomes in this population.

Emerging evidence suggests that chronic pain may involve alterations in emotional and cognitive processing. In this context, psychologically oriented interventions, including approaches such as eye movement desensitization and reprocessing (EMDR), have been explored in other chronic pain conditions.[27] Their potential relevance in adolescent patellofemoral pain remains to be established and warrants further investigation.

INTRA-ARTICULAR HYALURONIC ACID

Intra-articular hyaluronic acid (HA) has been widely used for more than three decades in the management of knee osteoarthritis.[28] Its use in APFS is based on several considerations, including its favorable safety profile,[29] ease of administration, and prolonged duration of action. Its main advantages include minimal reliance on patient adherence, which is a major limitation of exercise-based interventions, and expected sustained clinical benefit, typically lasting between 6 and 12 months. The main limitations are related to the intra-articular route of administration and the delayed onset of action, usually observed after 4 to 8 weeks.

A retrospective series including 16 adolescent sportswomen (22 knees) who had failed rehabilitation provides preliminary evidence supporting this approach.[30] Patients had a mean age of 13.4 years and had experienced symptoms for an average of 20 months. All had discontinued at least one sport due to pain. Treatment consisted of intra-articular injection of cross-linked hyaluronic acid. Tolerance was reported as excellent in all cases. Clinical efficacy,

as assessed by patients and families, was rated as excellent (complete resolution of symptoms) in 56% of cases, good in 25%, moderate in 13%, and poor in 6%. Improvement occurred within 4 to 6 weeks in responders. Importantly, return to sport was achieved in 75% of adolescents, and all competitive athletes were able to resume competition. Intra-articular hyaluronic acid may represent a potential adjunctive option in selected adolescents with persistent symptoms despite well-conducted rehabilitation. These preliminary data suggest a possible clinical benefit, although evidence remains limited and further well-designed prospective studies are required to confirm its efficacy and define its place in management for preventing the transition to chronic symptoms.

CONCLUSION

Adolescent patellofemoral pain syndrome should no longer be considered a benign and self-limiting condition. A substantial proportion of patients experience persistent symptoms, with significant physical, psychological, and social consequences. Advances in imaging and pain science have led to a better understanding of the underlying mechanisms, highlighting the contribution of both peripheral and central factors. At the same time, the limitations of current management strategies, particularly when applied in isolation, have become increasingly apparent. These observations support a shift toward earlier, more proactive, and multimodal management strategies integrating physical, psychological, and educational components. In this context, emerging therapies such as intra-articular hyaluronic acid may play a role as adjunctive treatments in selected patients.

Future research should focus on identifying predictors of chronicity, optimizing adherence strategies, and evaluating innovative therapeutic approaches in well-designed prospective trials.

CLINICAL TRIAL NUMBER

Not applicable.

AUTHORS' CONTRIBUTIONS

Thierry Conrozier: Conceptualization, Methodology, Formal analysis, Writing original draft. Anne Lohse: Supervision, Writing original draft

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AVAILABILITY OF DATA AND MATERIALS

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

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CONSENT FOR PUBLICATION

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