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PROPRIOCEPTION AS A KEY COMPONENT OF REHABILITATION IN PATELLOFEMORAL PAIN SYNDROME: A NARRATIVE REVIEW

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ABSTRACT

Patellofemoral pain syndrome (PFPS) is a common musculoskeletal condition characterized by anterior or retropatellar knee pain and functional limitations during activities such as squatting, stair negotiation, running and prolonged sitting. Although strengthening remains the foundation of rehabilitation, altered proprioception and neuromuscular control may contribute to impaired movement and dynamic stability. Proprioception provides sensory information regarding joint position and movement and is essential for coordinated neuromuscular responses. Evidence indicates that individuals with patellofemoral pain may demonstrate impaired knee joint-position sense and altered sensorimotor performance. Proprioceptive and neuromuscular training may therefore complement conventional hip- and knee-focused exercise by improving movement control, balance and functional performance. This narrative review summarizes the role of proprioception in PFPS, its relationship with neuromuscular control, dynamic balance, pain and function, and its clinical relevance to rehabilitation. Current evidence supports proprioception as an important component of multimodal PFPS rehabilitation, although the independent effects and optimal dosage of proprioceptive training require further investigation.

KEYWORDS

Patellofemoral pain; Proprioception; Neuromuscular control; Rehabilitation

INTRODUCTION

Patellofemoral pain (PFP), commonly referred to as patellofemoral pain syndrome (PFPS), is one of the most prevalent musculoskeletal conditions affecting adolescents and young adults. It presents primarily as anterior or retropatellar knee pain aggravated by activities that load the patellofemoral joint, including squatting, stair climbing, running, jumping and prolonged sitting (Crossley et al., 2016; Willy et al., 2019). PFPS is increasingly understood as a multifactorial disorder involving muscular, biomechanical, sensorimotor and psychological factors rather than a single structural abnormality (Crossley et al., 2016).

Exercise therapy, particularly combined hip- and knee-focused strengthening, is the cornerstone of conservative rehabilitation (Crossley et al., 2016; Willy et al., 2019). However, muscular strength alone may not ensure appropriate movement control. Functional activities require continuous integration of sensory information with motor responses to regulate joint position and stability. Proprioception is a major component of this sensorimotor system and provides information regarding body position, movement and force through receptors located in muscles, tendons, joints and skin (Lephart et al., 1997).

Evidence indicates that individuals with PFPS may demonstrate impaired knee joint-position sense compared with healthy individuals (Baker et al., 2002). Such deficits may affect neuromuscular control and dynamic balance during functional activities. Recent evidence further suggests that neuromuscular training can reduce pain and improve physical function in individuals with PFP (Maleki et al., 2026). Therefore, proprioception represents an important rehabilitation target within comprehensive PFPS management.

Proprioception and it's Neurophysiological Role

Proprioception is the ability to perceive the position and movement of body segments without relying exclusively on visual information. It includes joint-position sense, kinesthesia and force perception (Lephart et al., 1997). Muscle spindles detect changes in muscle length, Golgi tendon organs provide information concerning muscular tension, and joint and cutaneous receptors provide additional information regarding movement and mechanical loading.

Proprioceptive information is continuously transmitted to the central nervous system and integrated with visual and vestibular information to generate appropriate motor responses. This process can be represented as:

Sensory input → Central integration → Motor response → Functional movement → New sensory feedback

This feedback mechanism is particularly important during single-leg activities, stair descent, squatting and running, where rapid adjustments in lower-limb position and muscular activation are required.

Proprioceptive Deficits in PFPS

Evidence suggests that proprioceptive impairment may occur in individuals with PFPS. Baker et al. (2002) reported abnormal knee joint-position sense in individuals with patellofemoral pain, demonstrating greater repositioning errors compared with healthy participants. These findings indicate that PFPS may involve alterations in the sensory regulation of knee movement.

Subsequent research has also investigated the association between proprioceptive function and lower-extremity performance. Coelho et al. (2021) reported altered knee proprioceptive function in individuals with PFP and examined its relationship with physical performance. These findings support the clinical relevance of assessing sensorimotor function in patients with PFPS.

Proprioceptive deficits may influence the ability to maintain optimal lower-limb alignment during dynamic activities. During a single-leg squat, for example, the individual must simultaneously control hip, knee and ankle position. Accurate sensory information is therefore required to regulate muscular activity and maintain stability.

However, proprioceptive impairment should not be considered the sole cause of PFPS. It is more appropriately regarded as one component of the multifactorial impairment profile of the condition (Crossley et al., 2016; Willy et al., 2019).

Proprioception, Neuromuscular Control and Dynamic Balance

Neuromuscular control describes the ability to appropriately coordinate muscle activation and movement according to task demands. Proprioceptive information provides essential sensory input for this process.

Altered neuromuscular characteristics have been reported in individuals with PFPS, including changes in quadriceps and proximal muscle function. Such alterations may affect lower-limb movement control during functional activities.

Dynamic balance represents a functional manifestation of sensorimotor integration. It requires the interaction of proprioceptive, visual and vestibular information with coordinated muscular responses. Individuals with PFPS may demonstrate impaired functional movement and balance, particularly during single-leg tasks.

The Y-Balance Test can be used to assess dynamic balance during multidirectional single-leg reaching. Although it is not a direct measure of proprioception, performance requires proprioceptive information, postural control, strength and coordination. Consequently, combining direct proprioceptive assessment with the Y-Balance Test may provide a more comprehensive evaluation of sensorimotor function.

Proprioceptive Training in PFPS Rehabilitation

Proprioceptive training aims to improve joint-position awareness, movement accuracy and sensorimotor control. Exercises may include weight shifting, single-leg stance, balance activities, joint-position reproduction, multidirectional reaching, step-down exercises and

progressive functional tasks.

A systematic review of proprioceptive training reported improvements in proprioceptive and motor performance following active proprioceptive interventions, although considerable variation existed between protocols (Winter et al., 2022).

In PFPS, proprioceptive training should complement rather than replace strengthening. Hip- and knee-focused strengthening remains strongly recommended by clinical practice guidelines (Willy et al., 2019). Proprioceptive training may provide an additional stimulus by improving the ability to use muscular strength during coordinated functional movement.

A practical progression is:
Sensory awareness → Static balance → Dynamic balance → Functional movement → Advanced/sport-specific control
Progression should be based on movement quality, symptom response, balance performance and successful completion of previous tasks.

Evidence for Neuromuscular Training

Recent evidence provides increasing support for neuromuscular approaches in PFPS. Maleki et al. (2026) conducted a systematic review and meta-analysis of 17 randomized controlled trials involving 871 individuals with PFP. Neuromuscular training significantly reduced pain and improved physical function compared with control interventions. The findings suggest that neuromuscular approaches addressing control, proprioception and dynamic stability may provide additional benefits within comprehensive rehabilitation.

Raju et al. (2024) also investigated proprioceptive training compared with hip abductor and external rotator strengthening in individuals with PFPS. Their randomized controlled trial demonstrated the potential of proprioceptive training to improve pain and functional outcomes. However, evidence remains insufficient to establish proprioceptive training as superior to conventional strengthening.

The available literature therefore supports an integrated approach combining strengthening, proprioceptive training, neuromuscular control and functional exercise rather than relying on any single intervention.

Assessment and Technology-Assisted Rehabilitation

Proprioception may be assessed using joint-position sense, kinesthesia, force reproduction and technology-based sensorimotor measures. Joint-position sense is commonly assessed by determining the difference between a target knee angle and the angle reproduced by the participant (Baker et al., 2002).

Dynamic balance can be evaluated using functional measures such as the Y-Balance Test. Technology-assisted balance systems may additionally provide real-time visual feedback and objective performance scores. Such systems can allow progressive manipulation of task difficulty and may improve standardization in clinical research.

For PFPS research, combining a direct proprioceptive measure with measures of pain, functional status and dynamic balance may provide a multidimensional assessment of rehabilitation effectiveness.

Research Gaps and Clinical Implications

Despite growing interest in proprioceptive rehabilitation, important research gaps remain. Definitions and assessment methods for proprioception vary considerably between studies, while intervention dosage, frequency and progression criteria are not standardized. Furthermore, relatively few PFPS studies simultaneously assess proprioception, pain, functional status and dynamic balance.

It remains unclear whether improvements in proprioceptive accuracy directly mediate reductions in pain or primarily improve functional movement. Technology-assisted proprioceptive training also requires further investigation through well-designed randomized controlled trials.

Clinically, proprioceptive training may be particularly appropriate for individuals demonstrating impaired joint-position sense, poor single-leg control, reduced dynamic balance or movement-control deficits. It should be progressively integrated with strengthening and functional exercise according to individual impairment and symptom response.

CONCLUSION

Proprioception is an important component of sensorimotor control and represents a relevant rehabilitation target in PFPS. Evidence indicates that individuals with patellofemoral pain may demonstrate altered proprioceptive function and neuromuscular performance, which can contribute to deficits in dynamic stability and functional movement.

Current evidence-based guidelines continue to support hip- and knee-focused strengthening as the foundation of PFPS rehabilitation. Proprioceptive and neuromuscular training should therefore be considered complementary interventions. Recent evidence demonstrates that neuromuscular training can improve pain and physical function, although the specific independent contribution and optimal dosage of proprioceptive training remain uncertain (Maleki et al., 2026).

Future research should use standardized proprioceptive interventions and objective measures of proprioception, dynamic balance, pain and functional status. Overall, proprioception should be regarded as a key component of multimodal PFPS rehabilitation, rather than as an isolated mandatory treatment.

Table 1. Relationship Between Proprioception and PFPS Rehabilitation

Component	Possible impairment	Rehabilitation target
Joint-position sense	Increased repositioning error	Position-reproduction exercises
Neuromuscular control	Altered movement coordination	Neuromuscular training
Dynamic balance	Reduced postural stability	Balance training
Functional control	Poor single-leg movement	Functional/sport-specific training

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