

# Clinical Rehabilitation of Anterior Knee Pain: Current Concepts

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## Abstract

Rehabilitation is the hallmark of the nonoperative treatment of anterior knee pain (AKP). Whether a patient has had appropriate rehabilitation can be assessed in the office with a selection of basic and advanced screening tests. Most important, providing specific instructions in your referral to a therapist skilled in treating patients with AKP can ensure that any identified deficits are appropriately addressed. The etiology of AKP is multifactorial. Whatever its “cause,” AKP alters neuromuscular function, and correcting these altered body movement patterns will benefit the patient. Understanding how to assess and guide treatment of neuromuscular deficits in this population is essential for managing care and optimizing outcomes. In this article, factors associated with the diminished neuromuscular control seen in AKP are reviewed, appropriate rehabilitation concepts are discussed, and practical strategies are provided that can aid in identifying neuromuscular deficits and the need for further rehabilitation.

**A**nterior knee pain (AKP) is a common presentation. Although the exact etiology and nature of AKP continue to be poorly understood, overuse principles can be useful in directing treatment. In overuse injury, repetitive submaximal or subclinical trauma results in macroscopic trauma, microscopic trauma, or both. The structural tissue unit is damaged or its clinical responsiveness is exceeded, which can lead to pain or movement dysfunction. Overuse injuries commonly have an endogenous source, mechanical circumstances in which the musculoskeletal tissue is subjected to more tensile force or stress than the tissue can tolerate. The approach to treatment and rehabilitation of AKP is best facilitated with a thorough understanding of the concept of tissue homeostasis and the “envelope of function.”

Although the cause of AKP is multifactorial, the contributions of muscle strength deficits, diminished neuromuscular control, and altered muscle firing patterns to the development and severity of AKP are well established.<sup>1-5</sup> The hallmark of nonoperative management of AKP is physiotherapy that re-establishes strength, neuromuscular control, muscle activation, and optimal biomechanics during daily activities, advancing to graded levels of sporting activities.

The purpose of this paper is to discuss the factors associated with the diminished neuromuscular control observed in AKP and to review appropriate rehabilitation concepts for patients with AKP. Practical tools are provided to aid the surgeon to identify neuromuscular deficits in the clinic setting, along with assessing the adequacy of prior therapy and the need for further rehabilitation.

## Common Neuromuscular Deficits in AKP

Weakness of the knee extensor muscles has long been implicated as the main issue in AKP, and therefore the focus of rehabilitation has been on muscle strengthening, especially of the vastus medialis obliquus. Research has found that knee extensor weakness is not only a characteristic of patients with AKP but a risk factor for developing AKP.<sup>4</sup> Restoration of knee extensor strength and function is essential for recovery.<sup>6</sup> Another issue in AKP may be incorrect firing of the knee extensor muscles. Altered vastus medialis obliquus response time and a motor control deficit of the quadriceps musculature have been demonstrated.<sup>7,8</sup> Restoration of knee extensor strength, though important, is too often the sole focus of some rehabilitation programs.

Hip muscle weakness has also been implicated as an important component of AKP.<sup>9-12</sup> Impaired gluteal muscle function can lead to increased hip joint adduction and internal rotation during

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activities such as stair climbing, squatting, and sports.<sup>9,10,13</sup> In a systematic review, Meira and Brumitt<sup>12</sup> concluded that hip strength and position are linked to AKP and that patients with AKP present with a common deficit once symptomatic. The dysfunction in neuromuscular control in AKP may also stem from disordered firing sequences in the muscles. A systematic review of hip electromyographic studies found moderate to strong evidence that gluteus medius muscle activity is delayed and of shorter duration during stair ascent and descent in patients with AKP.<sup>11</sup> The study also found some evidence that this activity is delayed and of shorter duration during running and that gluteus maximus muscle activity is increased during stair descent. The authors recommended that interventions focused on correcting these deficits—such as hip strengthening, biofeedback, and gait retraining—should be included in AKP treatment and research.

In recent AKP research, the core, including hip and abdominal muscles, demonstrated decreased strength and altered recruitment patterns during functional movement.<sup>14,15</sup> The authors recommended including core strengthening and core stability exercises in AKP management. In combination, these knee extensor, hip, and core strength deficits in patients with AKP lead to altered movement patterns during functional activities and may in turn exacerbate symptoms. Addressing both the strength deficits and the recruitment patterns of these core and lower extremity muscles is essential for optimizing rehabilitation and limiting recurrence of AKP symptoms.

Stretching to improve muscle tendon length is another component of AKP treatment. Reduced quadriceps muscle length has been implicated as a cause of AKP and is a common finding in symptomatic patients.<sup>16</sup> In addition, a recent randomized controlled trial found decreased hip flexibility in patients with AKP.<sup>17</sup> It is important to assess the flexibility of the gastrocnemius, soleus, quadriceps, and hamstrings muscles and the iliotibial band, as well as the hip flexors, extensors, and rotators, so that rehabilitation can be designed to address any specific deficits in range of motion (ROM).<sup>16,23</sup> In patients with AKP, it is also important to address muscle tendon length deficits and strengthening simultaneously to avoid exceeding the available envelope of function. Gaining full ROM at joints can facilitate increasing strength gains<sup>24</sup> and potentially improve the synergy of muscle contractions during functional activities.

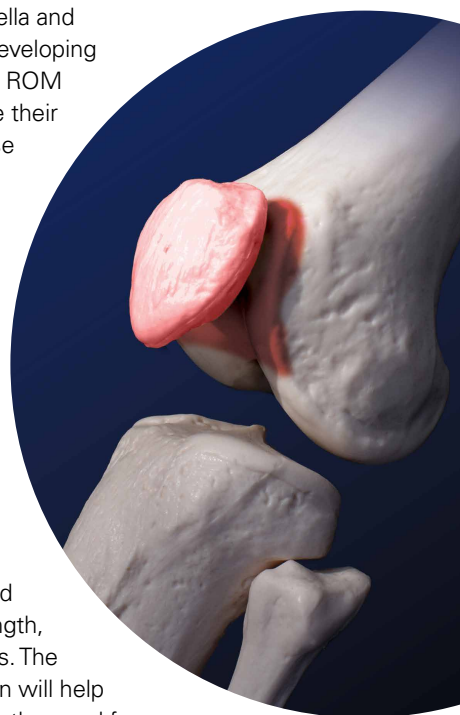
### Take-Home Points

- Ensure that relative rest and activity modification allow the knee to stay within the available “envelope of function” of the joint.
- Careful physical examination is imperative to assess strength, flexibility, and altered movement patterns, which in many cases are all part of the etiology of AKP.
- Patience and perseverance are paramount. Patients need to clearly understand the goals of rehabilitation as well as the concepts related to “envelope of function” so they can continue to keep themselves within this envelope. This education is crucial to their success.
- Only once a patient has been brought into the pain-free functional envelope can rehabilitation be redirected to expanding the envelope toward the patient’s particular goals.
- Quantity does not equal quality. To create an appropriate care plan, the physician must assess the adequacy of the patient’s rehabilitation thus far—ask specific questions about the types of exercises the patient is doing in physical therapy and quickly assess strength with a few simple in-office tests.

### Appropriate Rehabilitation in AKP

Appropriate rehabilitation addresses all identified strength and flexibility deficits in order to improve functional biomechanics and normalize altered body movement patterns during daily activities (eg, walking, squatting, stair climbing). Often, if part of the kinetic chain is weak or injured, the body engages in an activity by “working around” the injured body part. This change often results in faulty body mechanics or altered movement patterns. In AKP, these modified biomechanics can result in pain centered on the patella and associated soft-tissue structures. In developing ways to compensate for strength and ROM deficits, patients with AKP exacerbate their symptoms. In long-standing AKP, these compensatory strategies are most often unintentional and ingrained.

The main role of physical therapists is to identify any faulty movement patterns, dissect the underlying neuromuscular causes of these deficits, and build an individualized rehabilitation program. Physical therapy should be customized to the patient’s level of strength and fitness and whenever possible should be made challenging (and fun!) for the patient. The exercises should be increased in intensity and duration as the patient improves strength, endurance, and control in the activities. The patient’s response to each intervention will help guide exercise progression and define the need for further treatments.



Basic Strength and Muscle Length	Assessment	Example	Observations
Knee extensor strength	Assess in sitting with resistance at ankle and palpation of muscle tone. Can also be assessed as resisted straight leg-raise in supine.		Monitor for lateral deviation of thigh, hip flexion and/or trunk rotation due to muscle weakness or altered activation patterns.
Hip abductor strength	Assess in side-lying with pelvis stabilized in mid-line and resistance above knee.		Monitor for hip and/or trunk flexion due to weakness or altered muscle activation patterns.
Hip external rotation strength	Assess in supine with both the hip and knee flexed to 90°. Resist rotation at knee and ankle.		Monitor for hip flexion and/or poor through-range strength.
Quadriceps muscle flexibility	Assess in prone with pelvis stabilized while examiner flexes knee.		Compare heel to buttock distance. Monitor for hip flexion, hip or thigh rotation to attain length.

**Figure 1.** Example of clinical neuromuscular tests used to assess control and strength deficits in patients presenting with anterior knee pain. Physician assesses bilaterally to compare limbs and monitor for any aggravation of symptoms.

Modified with permission from *Clin Sports Med*.<sup>26</sup>

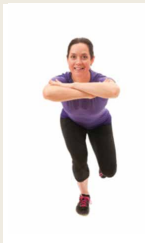



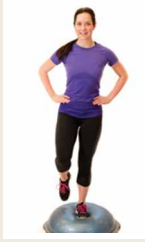



Patients should be assessed for overuse patterns. Overuse can occur with repetitive exercise activity, such as running, or with repetitive work activity that involves lifting, squatting, or stair climbing. It is important to modify or reduce such activity to ensure that a patient with AKP remains within an envelope of pain-free function. Once the patient is functioning in this envelope, rehabil-

itation can be redirected to expand it, while improving strength, coordination, balance, and overall dynamic control of the core and lower limbs.

The purpose of any rehabilitation program is to build strength through the entire kinetic chain, focusing on hip and core strength initially, and then adding concentric and eccentric lower limb strength. Having a strong base from which to initiate lower limb movements makes correct lower limb form more likely to follow. Corrected muscle firing patterns allow for appropriate sequencing of the muscle activation needed for proper movements. Corrected muscle tendon lengths allow for optimal firing of the muscles controlling the lower limb, and for the flexibility needed for everyday ROM and biomechanics. Patients with AKP require re-education of movements that occur during daily functional activities, including gait. Once correct movement patterns are established in daily activities, it is important to address sporting or work-related activities. This is one important reason to ensure that physiotherapy visits are distributed over time and that patient-centered goals are addressed during each visit. In addition, during therapy, it is essential to reexamine body movement patterns to identify any relapse to prior dysfunction as the intensity or frequency of activity increases.

In AKP management, the dosage and duration of exercise prescriptions are challenging, and patience and perseverance are paramount. The initial goal of therapy is to increase strength and ROM to enable practice of correct motion in daily activities (eg, stair climbing, sitting, and walking). The physical therapist's challenge is to teach correct motion within the envelope of function, as described by Dye.<sup>25</sup> Pain is not gain,

and all exercises must be performed without pain to avoid flaring symptoms. The patient and the therapist must collaborate to complete a pain free rehabilitation program, and must operate within that zone. Providing prescriptions with specific goals may be helpful. Example goals are, "Increase core and lower extremity strength to achieve squatting without medial collapse of knee," "Hip

Neuromuscular Strength and Control Tests	Assessment	Correct Neuromuscular Control	Poor Neuromuscular Control	Observations
Single-leg squat	Instruct patient to stand on one leg and lower to squat. Tests for core, gluteal, and quadriceps strength and control.			Compare depth and control of squat, quadriceps inhibition, dynamic valgus, and/or side flexion of trunk.
Hop down	Instruct patient to stand on one leg and then hop off step to land 4-6 inches in front of step. Tests dynamic core, gluteal, and quadriceps strength and balance.			Monitor for evidence of dynamic valgus, hip drop or rotation, or lateral flexion of trunk due to poor gluteal and/or core strength.
Balance	On a BOSU ball or foam block, instruct the patient to balance on one leg for 30 seconds. Compare balance duration and quality.			Monitor for dynamic valgus, hip drop or rotation, and/or lateral trunk flexion secondary to decreased strength and control.
Hip extension	With the patient lying prone instruct them to lift leg 2-4 inches off bed. Examiner palpates gluteal and hamstring muscle activation. Ideally, the gluteals should fire first to stabilize the pelvis.			Monitor for excessive motion, altered timing of hamstring and gluteal muscle firing, and/or lumbar lordosis, hip or trunk rotation.

**Figure 2.** Example of neuromuscular tests used to assess functional deficits in patients presenting with anterior knee pain. Physician assesses bilaterally to compare limbs and monitor for any aggravation of symptoms. Physician examines in both frontal and sagittal planes. Additional tests may include single-leg hop for distance and vertical jump.

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and core strengthening and endurance,” “Equal quadriceps strength and girth,” and “Functional movement retraining.”

### Assessing Adequacy of Rehabilitation in AKP

When a patient presents with a diagnosis of AKP, it can be difficult to establish whether a prior rehabilitation program was appropriate. The fact that a patient attended physiotherapy says nothing about the quality of the therapy provided. Neither does the number of sessions attended. To assess the quality of the rehabilitation and determine if there are any major deficits in neuromuscular function, the physician can perform a simple battery of screening tests (**Figure 1**).<sup>26</sup> These tests may reveal

gross strength deficits that equate to significant functional deficits. Alternatively, core and gluteal strength can be assessed by having the patient perform a pelvic bridge, as another test that is appropriate and easy in the physician clinical setting.

More advanced tests can be used to better understand the neuromuscular function of the patient with AKP and tease out specific deficits. **Figure 2**<sup>26</sup> describes some of these tests and the typical compensatory motions seen in patients with altered movement patterns. For example, observing a single- or double-leg squat in the frontal and sagittal planes can be useful in assessing the quality of prior rehabilitation and determining the need for further physical therapy. Observing for dy-



dynamic alignment provides a snapshot of the forces that the knee may be subjected to, with increased force and repetition, while participating in daily activities and sport. In the frontal plane, functional valgus with dynamic activities (eg, single- and double-leg squats) may result from weakness in the core and hip musculature. In the sagittal plane, increased anterior translation of the knee over the foot can indicate poor squat mechanics, lack of gluteal activation, or poor eccentric quadriceps control. Gripping with the toes and increased ankle dorsiflexion are often a sign of anterior muscle recruitment and therefore increased load through the anterior compartment of the knee. Lack of appropriate body movement patterns is often evident to both the physician and patient, and this feedback can provide the patient with incentive for further (more directed) rehabilitation.

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### References

1. Bolgla LA, Malone TR, Umberger BR, Uhl TL. Comparison of hip and knee strength and neuromuscular activity in subjects with and without patellofemoral pain syndrome. *Int J Sports Phys Ther.* 2011;6(4):285-296.
2. Fredericson M, Yoon K. Physical examination and patellofemoral pain syndrome. *Am J Phys Med Rehabil.* 2006;85(3):234-243.
3. Halabchi F, Mazaheri R, Seif-Barghi T. Patellofemoral pain syndrome and modifiable intrinsic risk factors; how to assess and address? *Asian J Sports Med.* 2013;4(2):85-100.
4. Lankhorst NE, Bierma-Zeinstra SM, van Middelkoop M. Factors associated with patellofemoral pain syndrome: a systematic review. *Br J Sports Med.* 2013;47(4):193-206.
5. Smith TO, McNamara I, Donnell ST. The contemporary management of anterior knee pain and patellofemoral instability. *Knee.* 2013;20(suppl 1):S3-S15.
6. Natri A, Kannus P, Järvinen M. Which factors predict the long-term outcome in chronic patellofemoral pain syndrome? A 7-yr prospective follow-up study. *Med Sci Sports Exerc.* 1998;30(11):1572-1577.

7. Witvrouw E, Bellemans J, Verdonk R, Cambier D, Coorevits P, Almqvist F. Patellar tendon vs. doubled semitendinosus and gracilis tendon for anterior cruciate ligament reconstruction. *Int Orthop.* 2001;25(5):308-311.
8. Voight ML, Wieder DL. Comparative reflex response times of vastus medialis obliquus and vastus lateralis in normal subjects and subjects with extensor mechanism dysfunction. An electromyographic study. *Am J Sports Med.* 1991;19(2):131-137.
9. Prins MR, van der Wurff P. Females with patellofemoral pain syndrome have weak hip muscles: a systematic review. *Aust J Physiother.* 2009;55(1):9-15.
10. Fukuda TY, Rossetto FM, Magalhães E, Bryk FF, Lucareli PR, de Almeida Aparecida Carvalho N. Short-term effects of hip abductors and lateral rotators strengthening in females with patellofemoral pain syndrome: a randomized controlled clinical trial. *J Orthop Sports Phys Ther.* 2010;40(11):736-742.
11. Barton CJ, Lack S, Malliaras P, Morrissey D. Gluteal muscle activity and patellofemoral pain syndrome: a systematic review. *Br J Sports Med.* 2013;47(4):207-214.
12. Meira EP, Brumitt J. Influence of the hip on patients with patellofemoral pain syndrome: a systematic review. *Sports Health.* 2011;3(5):455-465.
13. Powers CM. The influence of abnormal hip mechanics on knee injury: a biomechanical perspective. *J Orthop Sports Phys Ther.* 2010;40(2):42-51.
14. Biabanimoghadam M, Motealleh A, Cowan SM. Core muscle recruitment pattern during voluntary heel raises is different between patients with patellofemoral pain and healthy individuals. *Knee.* 2016;23(3):382-386.
15. Cowan SM, Crossley KM, Bennell KL. Altered hip and trunk muscle function in individuals with patellofemoral pain. *Br J Sports Med.* 2009;43(8):584-588.
16. Witvrouw E, Lysens R, Bellemans J, Cambier D, Vanderstraeten G. Intrinsic risk factors for the development of anterior knee pain in an athletic population. A two-year prospective study. *Am J Sports Med.* 2000;28(4):480-489.
17. Hamstra-Wright KL, Earl-Boehm J, Bolgla L, Emery C, Ferber R. Individuals with patellofemoral pain have less hip flexibility than controls regardless of treatment outcome [published online June 22, 2016]. *Clin J Sport Med.* doi:10.1097/JSM.0000000000000307.
18. Piva SR, Goodnite EA, Childs JD. Strength around the hip and flexibility of soft tissues in individuals with and without patellofemoral pain syndrome. *J Orthop Sports Phys Ther.* 2005;35(12):793-801.
19. White LC, Dolphin P, Dixon J. Hamstring length in patellofemoral pain syndrome. *Physiotherapy.* 2009;95(1):24-28.
20. Waryasz GR, McDermott AY. Patellofemoral pain syndrome (PFPS): a systematic review of anatomy and potential risk factors. *Dyn Med.* 2008;7:9.
21. Hudson Z, Darthuy E. Iliotibial band tightness and patellofemoral pain syndrome: a case-control study. *Man Ther.* 2009;14(2):147-151.
22. Winslow J, Yoder E. Patellofemoral pain in female ballet dancers: correlation with iliotibial band tightness and tibial external rotation. *J Orthop Sports Phys Ther.* 1995;22(1):18-21.
23. Tyler TF, Nicholas SJ, Mullaney MJ, McHugh MP. The role of hip muscle function in the treatment of patellofemoral pain syndrome. *Am J Sports Med.* 2006;34(4):630-636.
24. McMahan GE, Morse CI, Burden A, Winwood K, Onambélé GL. Impact of range of motion during ecologically valid resistance training protocols on muscle size, subcutaneous fat, and strength. *J Strength Cond Res.* 2014;28(1):245-255.
25. Dye SF. The knee as a biologic transmission with an envelope of function: a theory. *Clin Orthop Relat Res.* 1996;(325):10-18.
26. Hiemstra LA, Kerslake S, Irving C. Anterior knee pain in the athlete. *Clin Sports Med.* 2014;33(3):437-459.