Knee Pain and Bicycling

Fitting Concepts for Clinicians

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In Brief: Anterior knee pain and patellofemoral pain syndrome are among the most common leg overuse injuries in cyclists. Bicycle fit, recent change in equipment, training distance and intensity, and individual anatomic factors are important evaluation considerations. Clinicians need a basic understanding of bicycle fitting and how anatomic factors and training errors contribute to repetitive stress injuries. After problems are addressed, a gradual return to activity is recommended to avoid further injury and improve performance.

With Lance Armstrong's successes in the Tour de France and the increasing popularity of mountain biking, participation in bicycling has steadily increased over the past 10 years. Cycling is an excellent alternative for runners and other athletes seeking low-impact exercise. The Bureau of Transportation Statistics at the US Department of Transportation estimates that more than 49 million Americans ride bicycles at least monthly, with over 5 million people riding at least 20 days per month.[1]

The number of cycling-related injuries has also risen, with the majority caused by overuse. Injuries may also be related to improper bicycle fit or equipment, poor technique, or inappropriate training patterns. Cycling is very repetitive; during 1 hour of cycling, a rider may average up to 5,000 pedal revolutions. The smallest amount of malalignment, whether anatomic or equipment related, can lead to dysfunction, impaired performance, and pain.

Several studies in athletes[2-5] have demonstrated that knee injuries, including anterior knee pain and patellofemoral pain syndrome, are the most common overuse injuries evaluated in sports medicine centers. Overuse injuries occur when a tissue accumulates damage caused by repetitive submaximal loading. Repetitive activity fatigues a specific structure, such as tendon or bone. Without adequate recovery, microtrauma stimulates an inflammatory response, causing the release of vasoactive substances, inflammatory cells, and enzymes that damage local tissue. Cumulative microtrauma from further repetitive activity eventually leads to clinical injury.

In chronic cases, continued activity produces degenerative changes that lead to weakness, loss of flexibility, and chronic pain. Thus, in overuse injuries, the problem is often not acute tissue inflammation, but chronic degeneration or tendinosis instead of tendinitis.[6] Pain in overuse injuries typically has insidious onset, but it may have an acute-on-chronic presentation. Overuse injuries most likely occur when an athlete changes the mode, intensity, or duration of training. Biomechanic (intrinsic) factors and equipment or training (extrinsic) issues are the main contributors to overuse injuries.

Training errors are leading causes of overuse knee injuries. Holmes et al[7] showed that heavy training loads and high mileage contribute substantially to knee injuries. Likewise, a rapid increase in training distance or intensity, seen in the early cycling season, also leads to overuse injuries.

Knee pain is the most common lower-extremity overuse problem in cyclists.[7,8] In one recreational long-distance bicycling tour, 65% of all riders reported knee pain.[9] Another study[10] of more than 500 recreational cyclists indicated that almost 42% of all riders experienced overuse knee pain. While major problems such as fractures, dislocations, and ligament ruptures usually occur only after major trauma, overuse injuries are much more common.

When evaluating knee pain and cycling-related overuse injuries, important considerations include bicycle fit, training distance and intensity, and anatomic factors such as leg-length discrepancy, muscle imbalance, and inflexibility (table 1).[7,8,11]

TABLE 1. Causes of Knee Pain in Bicycling

Factor	Possible Result
Anatomy	
Leg-length discrepancy	ITB stretch on shorter leg, posterior knee stress
Wide pelvis	Lateral knee stress (increased Q angle)
Pes planus and/or pronation	Medial knee pain
Internal tibial rotation	Patellar malalignment
Muscle weakness of quadriceps, hamstrings, hip flexors, gluteus	Fatigue-induced alterations in pedaling technique that transfer stress to other parts of the kinetic chain
Leg inflexibility	ITB syndrome
Bike Fit	
Saddle too high	Knee extension that irritates the ITB, stress on biceps tendon, patellofemoral loading, hips stressed by rocking while pedaling, posterior knee pain
Saddle too low	Stress on patellar and quadriceps tendons
Saddle too far forward	Stress on anterior knee from pedaling in hyperflexed position
Saddle too far back	ITB stretch from excessive forward reach for pedal, stress on biceps tendon
Crank arms too long	Increased forces on the entire knee; patellar tendon and quadriceps tendon are most affected
Internally rotated cleats	Patellar tendinosis, tibial rotation stress on anterior knee
Externally rotated cleats	Medial knee stress
Training	
Rapid increase in distance or intensity	Muscle tightness, microtrauma
Excessive hill work (on bike)	Cartilaginous breakdown, chondromalacia
Pushing high gear ratio	Medial knee stress
Hill running (on foot)	Medial knee stress (uphill), tight quadriceps (downhill)
Deep leg squats	Increased stress on entire knee

ITB = iliotibial band

Bicycle Anatomy

Bicycles consist of a frame, handlebars, brakes, wheels, pedals, gears, and other components (figure 1). The key part is the frame, made of metal or metal alloys such as titanium, aluminum, steel, or carbon. Frames can be thought of as two triangles. The front triangle consists of the top tube, the seat tube, and the down tube. The chainstay, seatstay, and seat tube compose the rear triangle. Handling and maneuverability can be affected by the angles within each of these triangles. Racing bicycles have a more upright geometry, with steeper angles for increased maneuverability. Touring bicycles are more stable, with a flatter geometry for comfort.

Frame size is determined by the seat tube dimension in centimeters, measured from the center of the bottom bracket to the center of the top tube or from the top of the bottom bracket to the top of the top tube. The top tube length affects the reach of the rider and is also an important measurement for proper frame fit.

The crank arm, chain ring, chain, gears, and derailleurs make up the drive train and transfer human energy to mechanical energy. The pedal stroke can be thought of as a continuous circular movement, with the ultimate goal of spinning the pedals in a smooth, circular motion. Gearing is a method of overcoming resistance that allows the cyclist to pedal comfortably at a uniform cadence to improve pedaling efficiency. Higher gears result in higher resistance, and lower gearing provides less resistance. The shoe-pedal interface is vital to energy transfer. Stiff-soled cycling shoes clip directly into the pedals, linking the rider directly to the bicycle.

Bicycling Biomechanics

One complete circular movement of the pedals around the bottom bracket is one two-phase pedal cycle. In the power phase, the cyclist pushes down on the pedal and transfers the greatest amount of energy to move the bicycle forward. The power phase begins with the pedal in the 12-o'clock position and ends with the pedal at the 6-o'clock position. The power phase is followed by the recovery phase, which progresses from 6-o'clock back to the 12-o'clock position.

During the pedal cycle, the knee goes through approximately 75° of motion. The knee begins the power phase flexed about 110° and extends to about 35° of flexion. The quadriceps muscle provides most of the force, with input from the hamstring and gluteal muscles. While the knee extends, it also adducts because of the normal valgus angulation of the distal femoral condyles relative to the femoral shaft and foot motion during the power phase. This motion leads to medial translation of the knee during the pedal stroke while the knee extends.

Additionally, the foot pronates during the power phase, causing an internal rotation of the tibia that increases stress on the medial knee. Also, an increased Q angle, seen in females, may further stress the medial joint. During the recovery phase of the pedal stroke, the knee flexes and moves laterally while the tibia externally rotates to ready the leg for the power phase of the next pedal cycle.

Biomechanic abnormalities may arise from anatomic as well as functional factors. Muscular inflexibility is a leading contributor to injury. Most cyclists' quadriceps and hamstrings will tighten with prolonged riding. Inflexibility of the quadriceps, hamstrings, or iliotibial band (ITB) may restrict range of motion around the knee and are likely to increase the forces on the knee.[6] Weakness in the leg muscles may lead to fatigue-induced alterations in pedaling technique, which will also alter the forces on the knee. Inappropriate saddle height or improperly aligned shoe cleats transmit increased repetitive forces through the knee, with a greater likelihood of injury.[12]

Anterior Knee Pain

Patients frequently report anterior knee pain that may be related to repetitive stress or to inflammation. In fact, anterior knee pain is the most common reason bicyclists seek physician care.[13] Causes of anterior knee pain include patellofemoral pain syndrome, chondromalacia, quadriceps tendinosis, patellar tendinosis, and, occasionally, prepatellar bursitis.

Patellofemoral pain syndrome, also called retropatellar pain syndrome, refers to anterior knee pain emanating from the patellofemoral joint and supporting soft tissues. Patellofemoral pain syndrome is an early indication of cartilage softening that can progress to frank cartilaginous damage (chondromalacia). Patellofemoral pain syndrome is typically an office diagnosis, while chondromalacia is a surgical or radiologic diagnosis. Because both usually arise from collagen breakdown rather than frank inflammation, they are currently seen as tendinosis rather than tendinitis.[6]

Patellofemoral pain syndrome is related to a combination of factors involving malalignment of the knee extensor mechanism.[14,15] Patients generally report that anterior knee pain is worse when the knee is loaded (eg, when climbing or descending stairs, during prolonged sitting or squatting). Patellofemoral joint problems frequently differ between cyclists and runners--many cyclists will point to the center of their patella and describe the pain as being directly under the patella, rather than on the medial or lateral side.[12] The pain, sometimes severe, often occurs after cycling, rather than during the ride.

Chondromalacia, characterized by pain or crepitation in the retropatellar area, is described as a grating sensation with anterior patellofemoral discomfort that worsens with climbing, squatting, or prolonged sitting. The condition may be caused by articular cartilage breakdown or chronic synovial inflammation. Excessive patellar shear forces over the femoral condyles and patellar groove with malalignment of the patella contribute to cartilaginous breakdown. Cyclists who have pes planus, overpronation of the foot, or hindfoot valgum may also have a greater degree of patellar malalignment. During cycling, the pain is precipitated by riding up hills or when the rider pushes higher gears with a slow pedal cadence.

Quadriceps tendinosis is characterized by pain at the quadriceps tendon's insertion into the patella. The pain may be located medially or laterally to the suprapatellar area but is more commonly seen on the lateral side in cyclists. Tendinosis may follow an acute traumatic event but is usually caused by repetitive stress, with poor bike fit as a common contributing factor.

Patellar tendinosis can result from irritation of the patellar tendon and is most likely caused by excess angular traction on the tendon when the rider pedals with improperly positioned cleats.[7] Cyclists usually report significant patellar tendon pain related to pedaling and other knee-extension activities. Focal swelling around the patellar tendon with palpable crepitus may be seen.

Prepatellar bursitis, less common in cycling, should be suspected when swelling and tenderness anterior to the patella exist and can arise from acute trauma. Chronic prepatellar bursitis is more common than the acute form and usually results from repeated microtrauma, such as bicycle pedaling.

Careful Inspection

When evaluating a cyclist who has anterior knee pain, inspect the bicycle fit. The saddle may be too low, too far forward, or both, causing excessive patellofemoral loading throughout the pedal cycle. When the saddle is low, the knee functions in hyperflexion, increasing compression of the patella on the femur.

Improper shoe cleat position or float may force the rider to pedal with poor biomechanics, increasing patellar forces. Float is the motion of the cleat on the body of the pedal and is usually measured in degrees of internal or external angulation (ie, 9° of float means that the foot may rotate 9° inward or outward relative to the pedal body). Cleats with excessive internal or external rotation may cause exaggerated tibial rotation, placing more stress on the anterior knee.

Medial Knee Pain

The normal pedaling motion causes the tibia to internally rotate when the knee is extended. Medial knee pain results when increased stress from improper saddle height, saddle fore-and-aft position, or cleat position (toes pointed too far outward) increases internal tibial rotation. Poor leg flexibility and training errors, such as riding in gears that are too high or excessive hill climbing, increase stress and exacerbate medial knee conditions. Anatomic abnormalities, such as genu varus, overpronation, inherent tibial rotation, and hamstring tightness, may also exacerbate medial knee pain. Medial knee pain often is caused by pes anserine bursitis or mediopatellar plica syndrome.

Pes anserine bursitis is identified by insidious-onset pain over the medial proximal tibial metaphysis approximately 2 to 4 cm below the joint line.[16] Direct trauma or repeated friction over the bursa can lead to inflammation. When the bursa is inflamed, contraction of the hamstring muscles, tibial rotation, and direct pressure over the pes anserine bursa usually produce pain. The popliteal angle should be measured and tightness treated with hamstring-stretching exercises.

Mediopatellar plica syndrome causes pain over the medial retinaculum. A plica is a synovial septum remnant from the embryologic knee. Medial plica occurs in up to 30% of the population.[17] Medial plica may impinge on the femoral condyle during knee flexion, leading to inflammation and swelling. If a normal medial plica is chronically inflamed and turns fibrotic, it may bow-string over the medial femoral condyle during knee flexion and cause irritation and a snapping sensation. The cyclist who has plica symptoms may describe a disabling medial knee pain accompanied by a sensation of medial popping that occurs with each pedaling stroke. Treatment for a symptomatic plica involves adjusting the saddle fit and cleat position to reduce forces on the anterior knee. A local anesthetic may be injected directly into the plica to give temporary relief. Orthopedic referral should be made if symptoms persist longer than 6 months.

Lateral Knee Pain

Anatomic factors and improper bike fit are important considerations when evaluating cyclists who report lateral knee pain.

Iliotibial band syndrome. The ITB is a thick, fibrous band that runs on the outside of the leg from the hip to the knee. ITB syndrome is caused by inflammation of the intra-articular synovium or ITB fascia when the tight ITB repeatedly rubs over the lateral condyle as it moves posteriorly with flexion and anteriorly with extension. Tight, inflexible leg muscles may worsen the condition. Cyclists who have ITB syndrome experience sharp or stabbing lateral knee pain and may report decreased pedaling power because of pain.

The most obvious sources of ITB irritation are anatomic abnormalities and improper bicycle fit. Excess internal tibial rotation, either anatomic or caused by improper cleat position, places significant stress on the distal ITB as it crosses the lateral femoral epicondyle. Varus knee alignment or excess pronation will increase the stretch on the ITB.

Similarly, leg-length discrepancies cause difficulty, because only one leg is correctly fitted to the pedal, producing excessive ITB stretch on the shorter leg. Saddle position can also be a contributing factor. A saddle that is too high results in knee extension greater than 150° that can irritate the distal ITB. Saddles that are too far back cause excessive forward reach for the pedal, also stretching the ITB.

Posterior Knee Pain

Posterior knee complaints in cycling are rare. Most often they are attributed to biceps tendinosis or, less frequently, medial hamstring tendinosis. Cyclists who have biceps tendinosis report insidious onset of point tenderness at the tendinous attachment of the biceps femoris where it inserts on the fibular head.[7]

Saddles that are too high or too far back can stress the biceps tendon. Excessive internal rotation of the cleats will also increase stress. Varus alignment of the knees or leg-length discrepancies may also contribute to posterior knee pain. If the saddle height is set for the longer leg, the shorter leg will be forced to stretch farther with each pedal stroke, increasing posterior knee stress.

Addressing Pain

Initial management following an overuse injury should follow the PRICEMM acronym (protection, rest, ice, compression, elevation, modalities, and medications)[5] to help control inflammation and allow the tissue to heal. Decreasing inflammation and pain helps increase range of motion, allows early rehabilitation, and speeds return to competition. Once healing and rehabilitative exercise have restored damaged tissues to normal strength, patients will need further training to achieve the supernormal endurance and power required for the demands of sports.

With tendinosis, relative tendon unloading is critical for treatment success.[6] Unloading may be accomplished by correcting anatomic, functional, or equipment related errors.

Bicycle adjustment. Most bicycle shops will evaluate and adjust bike fit for the primary rider at a reasonable cost. The quality of bike fits can be quite variable, and local bike clubs should be able to provide references.

A simple saddle height adjustment may ease the forces placed on the knee. If the saddle is too low, too much stress is placed on the knee from the patellar and quadriceps tendons. If the saddle is too high, pain may develop behind the knee. Proper saddle height can be determined in several different ways. The easiest way is to allow one pedal to drop to the 6-o'clock position and observe the angle of flexion in the knee joint. There should be a 25° to 30° flexion in the knee when the pedal is at the bottom-most point.[7] Another method is to measure the inseam (in cm) and multiply by 0.883 to get the correct distance from the top of the saddle to the center of the bottom bracket.[18] If the hips rock back and forth when pedaling, the saddle is too high; lower the saddle until a smooth pedal stroke is achieved.

Saddle fore-and-aft positions and shoe cleat position may also contribute to knee pain. Saddles that are too far back cause the cyclist to reach for the pedal and stretch the ITB, resulting in knee pain. Saddles that are too far forward will force pedaling in a hyperflexed position, increasing the force on the anterior knee. Saddle position can be evaluated with the plumb bob technique. Seated with the pedal in the 3-o'clock position, a plumb hung from the most anterior portion of the knee should intersect the ball of the foot and the axle of the pedal.

Cleats that are internally rotated too far may increase stress on the ITB as it crosses the outside of the knee. Excessive external rotation will cause medial knee stress. Cleats should be positioned fore or aft so that the ball of the foot is directly over the axle of the pedal. Rotational cleat position can be evaluated with a bike shop "fit kit" or rotational adjustment device--this is more important for cleats with less than 5° of float. Most new road cleats allow greater degrees of float to protect the knees.

Correcting anatomic problems. Individual cyclist anatomy may contribute to knee and hip pain. Cyclists with leg-length discrepancies may develop knee pain, because only one side is correctly fitted to the bicycle.

Cyclists with flat feet may be more prone to excessive pronation (internal rotation) of the leg, causing greater stress on the ITB at the knee, as well as on the medial knee. Customized orthoses may correct the alignment of the knee and decrease or prevent medial or lateral rotational stress on the connective tissue in the ankle, knee, or hip, thus reducing pain. Orthoses may influence the pattern of leg movement through a combination of mechanical control and biofeedback[19] or the clinical functions of motion control, pressure relief, and redistribution of forces.[20] Cyclists require a different type of orthoses than runners; cycling orthoses are longer and provide additional metatarsal support. Pedal shims or shoe lifts may help correct malalignment or leg-length discrepancies.

Return After Injury

The first guideline during a rebuilding period is to start slowly. In the early stages of a comeback, cyclists should do a condensed version of their normal training schedule, progressing only when easy rides are pain-free (table 2). During this transition, the athlete should use lower resistance and higher cadence to allow a gradual return to activity. A good rule is that for every week of cycling-specific training missed, allow 1 to 2 weeks of training to return to previous form.[21,22]

TABLE 2. Recommended Program for Return to Cycling After Injury

Length of Rehabilitation Multiply the duration of the layoff (in weeks) by 1 (for less severe injuries) or 2 (for more severe injuries) to estimate how many weeks it will take to return to preinjury training level. Example: Layoff for a more severe injury (2 wk missed) X 2 = 4 wk of reduced training
Stages for a 4- to 6-Wk Rehabilitation Stage 1 (1-2 wk): Easy rides without fatigue or pain Stage 2 (1-2 wk): Endurance pace work at 50% to 75% of effort and distance of preinjury workouts Stage 3 (1 wk): Moderate-intensity work until the cyclist can complete full preinjury distance

Stage 4 (1 wk): High-intensity work at full preinjury distance
Stage 5: Return to full competition

Note: Cyclists may advance to the next stage when they can perform the current stage on 2 consecutive days without pain.

Preventing Overuse Injuries

The preparticipation physical exam is an excellent opportunity to ask about and address previous overuse injuries. The cyclist should be counseled about increasing activity using the "10% rule"--increasing distance and intensity by 10% each week during early- season and build-up periods.[23] Athletes who have a history of overuse injuries should be examined for weakness and flexibility deficits and may benefit from early-season stretching and strengthening programs.[5] A pre- and postworkout stretching routine is important for continuous pain-free riding.

Weakness of the quadriceps, hamstrings, or hip flexors may be assessed by manually testing resisted extension of the knee, flexion of the knee, and flexion of the hip, respectively. More accurate, quantifiable results can be obtained by performing mechanical isokinetic testing with a commercial machine such as the Biodex System 3 (Biodex Medical Systems, Inc, Shirley, New York). Flexibility of the quadriceps may be assessed by performing Ely's test and comparing the amount of passive knee flexion in each leg. Hamstring flexibility can be evaluated using the popliteal angle or the sit-and-reach test. Hip flexors can be evaluated with the Thomas test, and flexibility of the ITB may be tested with the Ober test.[24]

Progressive strengthening exercises are warranted for patients who have muscle weakness.[6] Initial activities include isometric quadriceps and hamstring exercises, such as quad sets and hamstring sets. Isotonic exercises such as straight-leg extension and flexion are the next phase in strengthening. Finally, patients perform eccentrically resisted knee flexion and extension with weights.[25] Flexibility focusing on the quadriceps, hamstrings, hip flexors, and ITB is important and should be a regular part of a cyclist's training regimen.

As more people seek low-impact ways to improve and maintain their cardiovascular fitness, physicians will no doubt see more patients who have knee pain related to bicycling. By learning a few simple bike fitting techniques, physicians can treat and prevent many common problems of this popular activity.

The opinions or assertions presented here are the private views of the author and are not to be construed as official or as reflecting the views of the US Department of the Army or Department of Defense.

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