Cycling Injuries of the Lower Extremity

Article *in* The Journal of the American Academy of Orthopaedic Surgeons · January 2008

DOI: 10.5435/00124635-200712000-00008 · Source: PubMed

Cycling Injuries of the Lower Extremity

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Abstract

Cycling is an increasingly popular recreational and competitive activity, and cycling-related injuries are becoming more common. Many common cycling injuries of the lower extremity are preventable. These include knee pain, patellar quadriceps tendinitis, iliotibial band syndrome, hip pain, medial tibial stress syndrome, stress fracture, compartment syndrome, numbness of the foot, and metatarsalgia. Injury is caused by a combination of inadequate preparation, inappropriate equipment, poor technique, and overuse. Nonsurgical management may include rest, nonsteroidal anti-inflammatory drugs, corticosteroid injection, ice, a reduction in training intensity, orthotics, night splints, and physical therapy. Injury prevention should be the focus, with particular attention to bicycle fit and alignment, appropriate equipment, proper rider position and pedaling mechanics, and appropriate training.

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None of the following authors or a member of their immediate families has received anything of value from or owns stock in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Wanich, Dr. Hodgkins, Dr. Columbier, Ms. Muraski, and Dr. Kennedy.

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J Am Acad Orthop Surg 2007;15:748-756

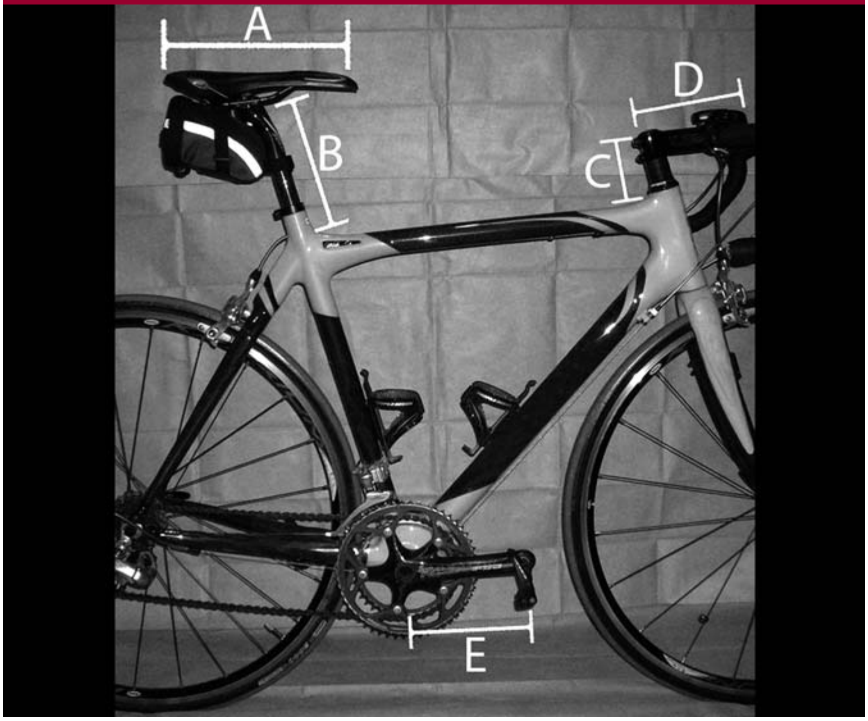
From November 2001 through October 2002, approximately 33 million US residents rode a bicycle an average of 6 days a month, for an average of >1 hour on a typical day.[1] The number of bicycling trips taken between 1990 and 1995 doubled following implementation of the *National Bicycle and Walking Study*;[2] this trend continues. The increased number of bicyclists has led to increased numbers of associated injuries.[2,3] Traumatic injury occurs as a result of overuse injury from repetitive motion and from unexpected motion. Overuse injury is caused by repetitive loading of bone, joint, and soft tissue with inadequate recovery time. Both intrinsic and extrinsic factors contribute to injury potential. Intrinsic causes include anatomic alignment of the lower limb, alterations in the normal kinetic chain, and level of fitness. Extrinsic factors include equipment fit, training, and riding technique. Lower limb injury can be sustained by both the elite cyclist and the casual cyclist.

Equipment

An understanding of bicycle design, fit, and function is important in treating the patient with an overuse injury. There are multiple variations of bicycle design, depending on the purpose of the bike (eg, road bike versus mountain bike). In addition, several manufacturing materials subsequently can affect the rider. The basic components of a bicycle, however, are maintained across all designs. These components include the frame, seat post, saddle, handlebar, crank arm, and pedals (Figure 1).

Proper fit is essential in reducing the incidence of injury. Bicycle dealers use commercial systems, such as the Fit Kit (Fit Kit Systems, Billings, MT), to fit the bicycle to the rider.

Figure 1



Photograph of adjustable racing bicycle parts. A = horizontal saddle position, B = vertical saddle position, C = handlebar height, D = handlebar reach, E = crank length

Figure 2

Seat height measurement (white line) taken from saddle to pedal with the leg at 180°.

Several standardized measurements are taken and devices used to determine the optimum fit. To maximize muscle power and efficiency, the elite cyclist takes advantage of electromyography to optimize the fit of the frame. With a basic understanding of bicycle mechanics, however, one can effectively determine appropriate fit without a commercial fit system. Frame size, seat height and position, handlebar height and position, crank length, and foot position are the primary fit-related adjustments that must be made for each cyclist.

Frame Size and Seat Position

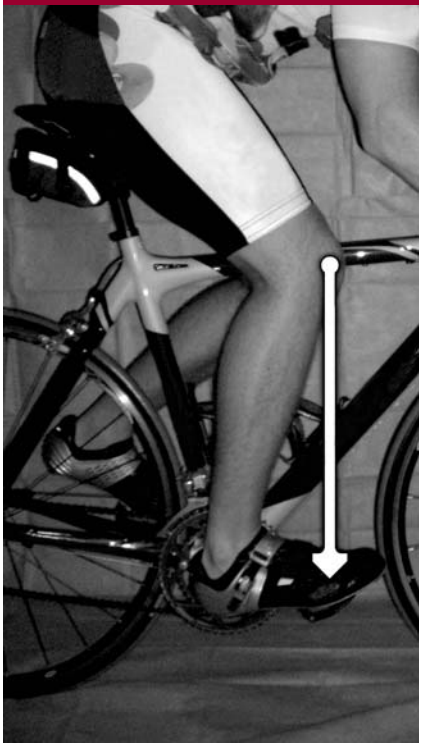
Frame size is determined by evaluating the distance between the crotch of the rider and the top tube of the frame. For on-road use, the distance should be 2.5 to 5 cm; for off-road use, the clearance should be 7.5 to 15 cm.[4] It is essential to select the appropriate frame size because it is the foundation of the bicycle and cannot be adjusted.

Proper seat height and position may be the most important adjustments when fitting a bicycle (Figure 2). Optimal seat height is determined based on inseam, bone length, and leg length. Several studies have indicated that multiplying the inseam measurement by 1.09 provides the optimal seat height for efficient cycling kinematics.[5] Others have found the sum of bone length in the lower extremity to be effective in determining the appropriate seat height.[6] This is determined by measuring the upper leg length from the greater trochanter to the lateral femoral condyle and the lower leg length from the lateral femoral condyle to the tip of the lateral malleolus. The sum of these two values is multiplied by 0.96 to determine the appropriate seat height. The most common method is an estimation based on leg length.[7] With the rider seated on a secured bicycle, the seat is adjusted until the knee is flexed 30° when the pedal is at the lowest position.

Fore and aft saddle position is optimized when a plumb line drawn from the tibial tubercle bisects the axle of the most forward pedal when the rider is seated on the bicycle, with the pedals at the 3 o'clock and 9 o'clock positions[8] (Figure 3). The saddle angle should be level; this can be confirmed with a standard carpenter's level.

Handlebar position determines the reach or distance between the saddle and the center of the handlebar. With the handlebar in the appropriate position, the distance from the forward tip of the saddle to the center of the handlebar should match the distance from the olecranon to the tip of the long finger.[8]

Figure 3



The ideal relative position of the knee to the pedal. With the rider seated on the bicycle and the pedals at the 3 o'clock and 9 o'clock positions, a plumb line is drawn from the tibial tubercle to the point at which it bisects the axle of the most forward pedal (white line).

Figure 4

A

B

A, Lateral photograph of a bicycle cleat. **B,** Bicycle cleat clipped to the pedal.

Normally, the height of the handlebars is lower than the seat height. The difference depends on the use of the bicycle. For road bicycling, the handlebar typically is 3 to 10 cm lower than the seat. Lower handlebar height allows the cyclist to assume a more aerodynamic position. For off-road biking, the handlebar height is typically not more than 5 cm below the seat height.

Crank length is the distance from the center of the chain ring to the center of the pedal (Figure 1). The crank length determines the diameter of the circle made during a revolution, which affects the amount of hip and knee flexion and extension. A longer crank length provides a greater mechanical advantage but forces the hips and knees to undergo a larger range of motion, with increased flexion at both joints, thus increasing the risk of injury. Crank length can be determined by measuring the length from the greater trochanter to the ground and multiplying the distance by 0.185.[9]

Toe clips are plastic or metal devices that attach to the pedals and act as a cage to secure the front part of the foot to the pedal. They increase performance by allowing the quadriceps muscle to contribute to the pedal cycle. Cleats and tight straps also allow recruitment of the hamstrings (Figure 4). Improper positioning of the toe clips can affect the position of the foot on the pedal. It is critical to ensure that the ball of the foot is over the pedal axle. Clip placement too far medially or laterally can result in an adducted or abducted foot position. Toe clips also can cause nerve compression; as a result, most modern bicycles offer clipless pedals.

Cleated cycling shoes may be used to improve the mechanical advantage of the rider. The cleats must be properly positioned so that the foot remains in a neutral position, assuming normal tibial alignment.

Training and Technique

Stretching is an essential part of the cycling regimen. There is a tendency in cyclists for shortening of the gastrocnemius-soleus complex and hamstring groups in particular.[10] Even so, stretching is often neglected. Cyclists generally have very strong leg and low back muscles. Relative muscle imbalance is a larger contributor to injury than absolute weakness. Traditionally, quadriceps strengthening with squats has been encouraged. More recently, however, the focus has been on strengthening the gluteal, hamstring, quadriceps, and calf muscles over a range of motion that matches an individual's pedal cycle.

Cadence refers to the number of times the pedal makes a 360° turn each minute. A cyclist should be able to comfortably maintain a cadence of 70 to 80 rpm. A lower cadence rate indicates that too much strain is being applied to the limb, thereby increasing the potential for injury. The incidence of injury may be reduced by avoiding excessive hill riding and by gear selection that forces a cadence <70 rpm.

Lower Limb Pain

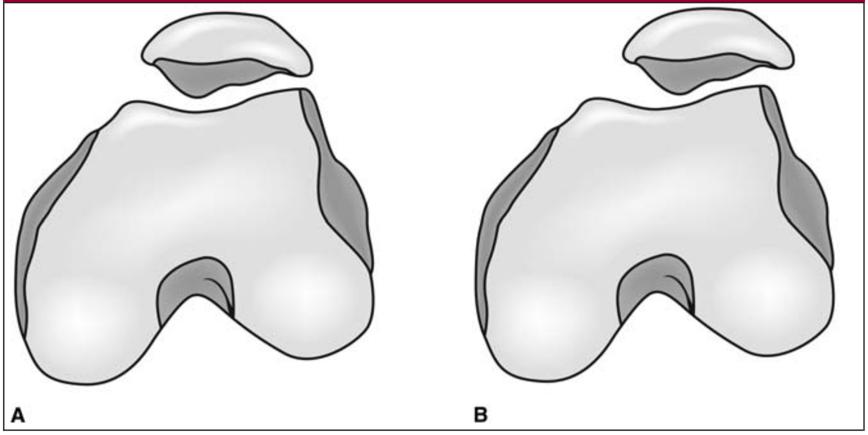
To properly address lower limb pain in the cyclist, the physician must look not only at the patient but also at the entire cycling regimen, from training and preparation to equipment and technique. It is particularly useful to perform the examination while the patient is in a riding position. Ideally, the examination should be performed during or after a cycling session. Specialized computer biomechanical examination of technique is now available and can be helpful.

Injury About the Knee

The knee is the most common site of overuse injury in the cyclist, with an estimated 40% to 60% of riders experiencing knee pain.[11,12] Patellofemoral syndrome ("cyclist's knee"), which typically presents as anterior, retropatellar pain, is the most common cause of knee pain in the cyclist. This pain is caused by increased pressure across the patellofemoral joint, poor patellofemoral tracking, or a combination of both. Excessive pressure across the patellofemoral joint is caused by hill climbing, riding in high gears, and a too-slow cadence.[3] The increased pressure results in excessive shear and compression of articular cartilage, leading to chondromalacia.

Patellofemoral malalignment also may cause patellofemoral syndrome as a result of the uneven distribution of pressures across the joint surface (Figure 5). Risk factors for malalignment include high or lateral position of the patella; dysplasia of the vastus medialis obliquus (VMO) muscle; a large quadriceps angle; inflexibility of the hamstrings and quadriceps muscles; and limb deformities, including femoral anteversion, external tibial torsion, and hyperpronated feet with hindfoot valgus.[13,14]

Figure 5



Normal **(A)** and abnormal **(B)** patellofemoral alignment.

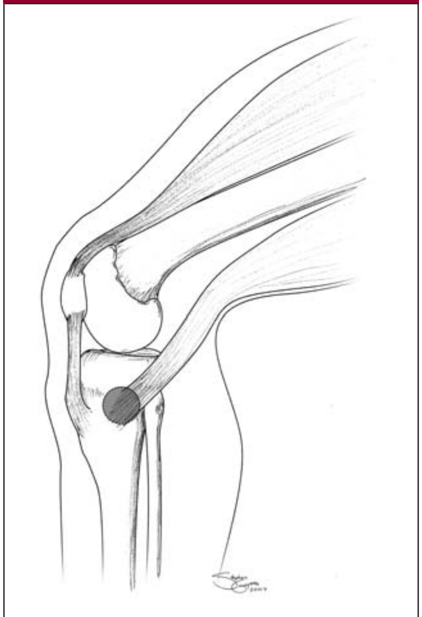
Improper bicycle fit also can lead to patellofemoral syndrome. When the bicycle seat is positioned too low or too far forward, excessive pressure is experienced across the patellofemoral joint. These positions result in excessive flexion of the knee, leading to a more perpendicular vector force across the joint.[10] In addition to proper seat position, adequate training can help minimize the incidence of patellofemoral syndrome. Quadriceps strengthening focused on the VMO, along with stretching of the quadriceps, hamstring, and gastrocnemius-soleus complex, may help improve patellofemoral alignment. Another method of strengthening is electrical muscle stimulation, which helps establish the desired 1:1 ratio between the VMO and the vastus lateralis (VL) muscles during quadriceps contraction.

Other aids, such as an ultra-light patellofemoral brace or McConnell taping, may be helpful in the recreational cyclist; however, these are too cumbersome and uncomfortable for the competitive cyclist.

Foot and cleat position must be evaluated in the patient with anterior knee pain. Foot hyperpronation with hindfoot valgus causes a functional increase in the quadriceps angle (Q angle), which leads to muscle imbalance and patellofemoral malalignment. Orthoses or wedges, the alteration of cleat position and angle, and customized pedals are helpful in managing the hyperpronated foot. Strengthening of the intrinsic foot musculature may promote longitudinal and transverse arch strength. Furthermore, the cyclist should restrict the intensity of rides to flat terrain with low resistance and a cadence of 90 rpm until symptoms resolve. Symptomatic treatment with ice and nonsteroidal anti-inflammatory drugs (NSAIDs) is also beneficial.

Patellar tendinitis in the cyclist is caused by excessive angular traction during the pedal cycle.[15,16] In addition to pain while biking, the cyclist often reports pain during knee extension. On examination, the patient exhibits focal swelling and tenderness over the patellar tendon, often with palpable crepitus. Intrinsic and extrinsic malalignment must be addressed. Internal tibial rotation or valgus alignment may be countered with cleat position. VMO training may help counteract angular traction during the pedal cycle by restoring a 1:1 VMO-to-VL ratio. Foot hyperpronation must be addressed with cleats or wedges.[3] Saddle height and fore-aft position also should be evaluated. Nonsurgical management (eg, rest; ice; quadriceps, vastus lateralis, and iliotibial band [ITB] stretching; NSAIDs) in conjunction with a reduc-

Figure 6



The location of pain (shaded circle) associated with pes anserine bursitis.

Figure 7

The location of the medial plica (shaded area).

tion in training intensity is essential in managing patellar tendinitis.

Although quadriceps tendinitis may present as medial or lateral knee pain, it is commonly lateral in the cyclist. The diagnosis of quadriceps tendinitis may be confused with ITB syndrome or patellofemoral syndrome. Physical examination should readily reveal tenderness over the quadriceps tendon, which aids in diagnosis. Varus or valgus misalignment of the knees can cause excessive stress on the quadriceps tendon; such misalignment is best addressed with orthoses, wedges, and/or cleat position. A seat position too low or too far forward also precipitates this condition. Rest, NSAIDs, and ice, along with a reduction in training intensity, should be implemented until symptoms resolve. In addition, the cyclist should avoid squats, lunges, and resisted knee extension. Once symptoms resolve, pain-free eccentric strengthening is commenced to address possible underlying weakness caused by overuse.

The most common causes of medial knee pain in the cyclist are pes anserine bursitis and mediopatellar plica syndrome. Pes anserine bursitis results from repeated friction of the hamstring insertion over the bursa, leading to inflammation and the insidious onset of pain. The patient typically has significant tenderness to palpation over the pes anserine bursa, located 2 to 3 cm below the medial joint line (Figure 6). Hamstring stretching may help to relieve the pressure across the pes anserine bursa. Physical therapy may help in resolving muscle imbalance, and the patient may benefit from application of low-pulse laser and ultrasound. NSAIDs, along with a local corticosteroid injection, are another beneficial adjunct.

The medial plica, an embryonic remnant of the embryologic synovial septum, is present in approximately 30% of the general population (Figure 7). Anatomically, this structure has been described as a capsular condensation running over the medial femoral condyle that inserts onto the superomedial border of the patella.[17] The presence of a plica does not necessarily indicate pathology, but with repeated trauma or irritation, the plica can become thickened and fibrotic. Once this occurs, the fibrotic and inelastic plica can cause impingement of the medial femoral condyle and the patella during knee flexion, leading to pain and a popping sensation with each stroke. On examination, the patient typically has tenderness over the medial aspect of the knee near the joint line. In some instances, a thickened plica can be palpated. Valgus knee alignment, internal tibia rotation, and foot hyperpronation can increase the pressure of a medial plica across the medial femoral condyle during cycling.

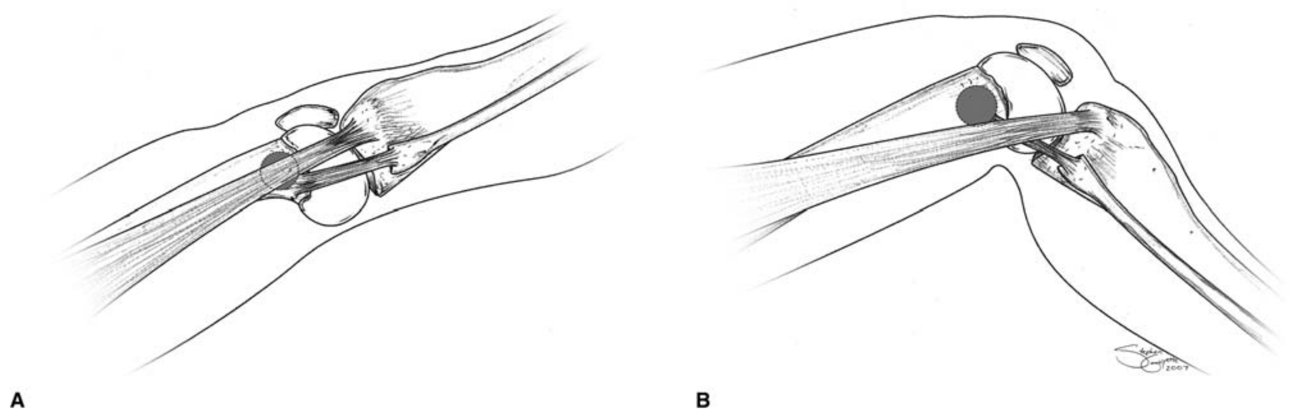
It is important to recognize and compensate for any of these anatomic variants. The cyclist should cut back on any activities that cause pain. Rest and NSAIDs are typically effective in managing this condition, but in refractory cases, arthroscopic resection of the plica and surrounding synovium may be necessary.[18]

Injury About the Iliotibial Tract and the Hip

The ITB is a thick, fibrous band originating from the iliac crest and extending across the hip and knee to insert onto Gerdy's tubercle on the lateral aspect of the tibia (Figure 8). Repetitive hip and knee flexion and extension cause the ITB to rub over the lateral femoral condyle, creating friction and irritation. This typically occurs when the knee is within 30° of full extension.[19] Greater knee extension is necessary with higher seat position. Increased tension on the ITB may be caused by intrinsic tightness in the band, extrinsic tightness from the gluteus maximus and tensor fascia lata (which inserts on the ITB), and/or from adduction of the knee during hip flexion. With repeated ITB irritation, the cyclist typically reports sharp, stabbing pain in the lateral aspect of the knee.

On examination, the patient

Figure 8



The position of the iliotibial band (ITB) relative to the lateral femoral condyle in knee flexion **(A)** and extension **(B)**. As the ITB snaps over the condyle, it creates friction (shaded area), which can lead to inflammation and pain.

demonstrates tenderness over the ITB where it crosses the lateral femoral condyle or as it inserts onto Gerdy's tubercle. With ITB tightness, the patient may demonstrate a positive Ober test.[20] Common anatomic variants found on examination include varus knee alignment, internal tibia rotation, and foot hyperpronation. Cleat position, along with orthoses or wedges, may help address internal tibia rotation and foot hyperpronation. Lowering the seat below the typical height reduces the amount of knee extension and tension across the ITB. Placing the cyclist in a more upright position by raising the handlebars and/or moving the seat forward reduces hip flexion, thus releasing tension on the gluteus maximus and, in turn, the ITB. Stretching of the ITB and the gluteus maximus is essential in addressing ITB syndrome, as are rest, NSAIDs, and local corticosteroid injection. For the patient with refractory ITB syndrome, surgical management may involve excision of the bursa and/or release/resection of the ITB.[21]

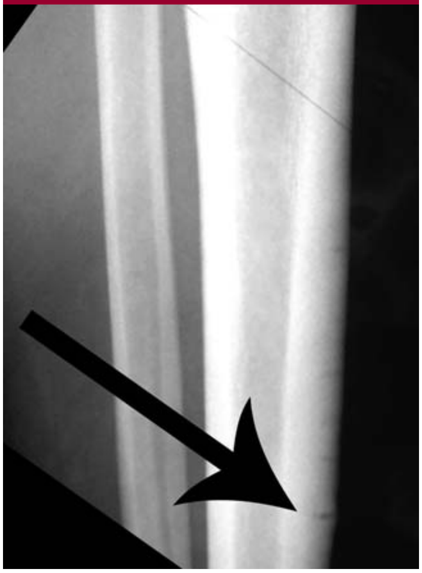
Hip pain in the cyclist is typically caused by trochanteric bursitis and iliopsoas tendinitis. In both cases, the exacerbating factor usually is riding with the bike seat too high. This results in undue tension on both the ITB and the iliopsoas tendon. The bike seat should be lowered to allow 30° to 35° of knee flexion at the bottom of the pedal cycle. Nonsurgical management involves stretching of the respective structure, along with rest, ice, NSAIDs, and local steroid injection, as needed. Iliopsoas tendinitis also may be closely connected to low back pain; a tight psoas muscle can inhibit the transversus abdominis, internal obliquus, and gluteus maximus.[22,23] This, in turn, causes decreased hip mobility. Physical therapy may be indicated to address alignment of the pelvis and sacrum. The tight muscular structures may be released with therapeutic techniques such as trigger point massage or injection. Additionally, pelvic alignment may be corrected with muscle energy techniques.[22,23]

Lower Leg Injury

Although it is more commonly found in runners and athletes participating in high-impact activities, medial tibial stress syndrome (ie, shinsplints) should be considered in the cyclist who reports pain in the medial or posteromedial calf. Medial tibial stress syndrome typically arises as a result of a sudden increase in training intensity or misalignment of the lower extremity, leading to excessive pronation of the foot. It is thought that the pronated position of the foot, in conjunction with sudden increases in activity, leads to traction-induced periostitis of the medial tibia.[24,25] Magnetic resonance imaging and a bone scan may be helpful in confirming the diagnosis. Management usually involves activity modification (specifically, nonimpact activity to maintain cardiovascular fitness until the pain is resolved), along with NSAIDs, stretching, and antipronation taping to correct excessive pronation of the foot.[26] Strengthening exercises may include isometrics and foot intrinsics, with progression to eccentric dorsiflexion for deceleration control of the anterior tibialis. It is important to reestablish distance before speed.

Another uncommon entity in the cyclist, but with clinical features similar to those of medial tibial stress syndrome, is stress fracture. This injury is caused by a sudden increase in activity coupled with the inability of the bone to appropriately respond to the stress. Magnetic resonance imaging or a bone scan is essential in the diagnosis; these tests help to distinguish stress fracture

Figure 9



Plain radiograph demonstrating periosteal stress reaction in the distal medial tibial cortex (arrow).

from medial tibial stress syndrome. Stress fracture is commonly located in the posteromedial cortex of the tibia[27] (Figure 9). Predisposing factors, such as anatomic abnormalities, nutritional deficiencies, metabolic disorders, and hormonal diseases, should be addressed. Stress fracture of the lower leg typically heals without surgical intervention. Fracture involving the posteromedial cortex heals within 1 to 2 months, but fracture of the anterior cortex may take up to 6 months to heal.[28]

Compartment Syndrome

Exertional compartment syndrome is an often overlooked diagnosis as a cause of calf pain in the cyclist. The compartment syndrome arises from increased intracompartmental pressure, leading to muscle ischemia. It remains unclear why some people develop elevated compartment pressures with exertion. The patient reports pain shortly after commencement of exercise; that pain persists for several minutes after exercise has ceased. The patient also may report associated paresthesias, cramps, and weakness. Increased pressure may cause transient neurapraxia of many of the enclosed nerves. The diagnosis is confirmed by measuring compartment pressures before exercise, as well as 1 minute and 5 minutes after exercise.[29] When activity modification is not an option, open or endoscopic fasciotomy of the involved compartments remains the treatment of choice for exertional compartment syndrome.

Injury About the Heel

Achilles tendinitis can be a problem, particularly in the cyclist who rides an improperly fitted bicycle. Repetitive dorsiflexion during the power phase of the pedaling cycle may cause overuse injury of the Achilles tendon. Mechanical factors that may contribute include riding with the seat too low, improper pedaling technique, and poor foot alignment. A low seat increases tension in the Achilles tendon and restricts the ability of the gastrocnemius muscle to assist the soleus muscle in counteracting excessive dorsiflexion.[10] Placement of the foot too far behind the center of the pedal axle creates excessive ankle motion, leading to increased stress on the Achilles tendon. Similarly, a rotated foot position may create abnormal stresses across the tendon. In addition to correcting alignment, stretching, nonsurgical management, and a reduction in training are advisable until symptoms resolve. Although rare, surgery may be required in the patient with recalcitrant Achilles tendinitis. A gastrocnemius slide procedure may improve dorsiflexion at the ankle joint and reduce tension in the Achilles tendon, while maintaining muscle power.

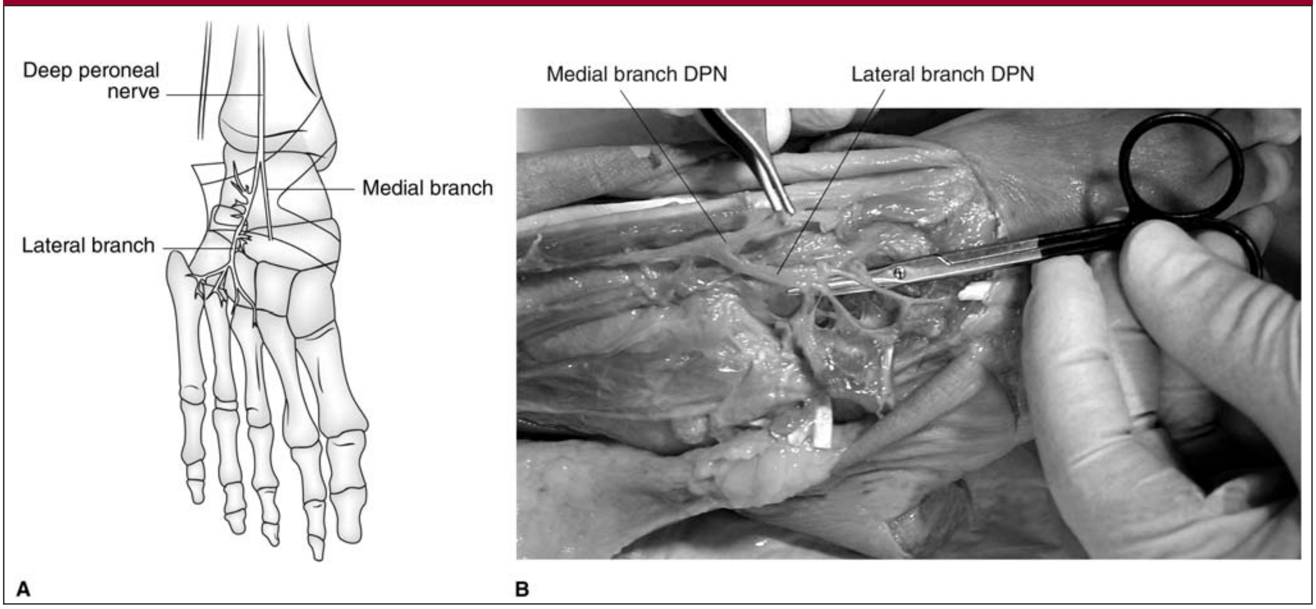
Pain over the calcaneus at the insertion of the plantar fascia may be the result of plantar fasciitis. The pain may be either acute or chronic and is typically worst first thing in the morning or after prolonged rest. The rider with pes planus, pes cavus, or equinus deformity of the feet is at increased risk for developing plantar fasciitis. One study indicates that limited ankle dorsiflexion is the single most important risk factor for developing plantar fasciitis.[30] Raising seat height reduces the amount of ankle dorsiflexion during the pedaling cycle, thus reducing stress on the plantar fascia. A higher cadence with reduced resistance also minimizes tension on the plantar fascia. Several nonsurgical options may be beneficial, including NSAIDs, orthoses, and night splints, as well as physical therapy (with the aid of ultrasound, massage, low-pulse laser, and biomechanical alterations) to address persistent edema and pain. Corticosteroid injection may be considered in the patient who does not respond to other treatment. However, repeated injections can be associated with plantar fascia rupture and atrophy of the fat pad. Fewer than 5% of patients require surgical release of the plantar fascia.[31] Symptoms typically resolve within 6 to 18 months.

Numbness and paresthesias of the foot are common complaints among cyclists. The incidence has been reduced with the advent of clipless pedals. Riders who use toe clips with straps are susceptible to nerve compression at points where straps are overtightened, leading to paresthesias. The most common area of numbness tends to be over the dorsum of the foot or great toe, as a result of compression of the superficial dorsal cutaneous nerves and the lateral branch of the deep peroneal nerve (Figure 10). Shoes that are too tight or too narrow are another common etiology of foot paresthesias. Management consists of addressing the underlying equipment problem, namely, loosening the straps or converting to clipless pedals, and using properly fitted shoes.

Injury About the Forefoot

Metatarsalgia is caused by repeated load across the metatarsal heads during the pedal cycle. Potential causes

Figure 10



A, Lateral and medial branches of the deep peroneal nerve (DPN). **B,** Intraoperative photograph demonstrating the relative position and size of the lateral and medial branches of the DPN.

of the excessive pressure include pedaling at a low cadence with excessive pedal resistance, poor foot position, poor cleat position, and rigid cycling shoes. Because of their lighter weight, carbon fiber shoes have become popular. However, compared with plastic shoes, carbon fiber shoes are 42% stiffer in longitudinal bending and 550% stiffer in three-point bending.[32] The increased stiffness may provide more efficient energy transfer, but that comes at the expense of increased forefoot pressure. Treatment involves verifying proper foot and cleat position. Soft-soled shoes, a metatarsal pad, or a soft insert may help decrease pressure and reduce symptoms. Furthermore, the cyclist should increase the cadence and reduce the resistance of each ride.

Summary

Cycling injuries may be secondary either to unexpected accidents, resulting in a multitude of trauma scenarios, or to repetitive motion and overuse. The latter injuries are more consistent and predictable. Fitness, cycling technique, and lower limb anatomy often contribute to injury that results from repetitive motion and overuse. Injury is especially common in the cyclist with poor technique. Prevention of these injuries is centered around several basic principles, such as proper bicycle fit and alignment, appropriate equipment, correct rider position and pedaling mechanics, and appropriate training regimens. Nonsurgical management, in the form of rest and physical therapy, often is sufficient.

Acknowledgment

The authors would like to acknowledge Stephen Guyette for his artwork and Jeff Ackerman for his bicycle photography. Both are affiliated with the University of Miami Miller School of Medicine.

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Citation numbers printed in **bold type** indicate references published within the past 5 years.

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