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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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.

Tony Wanich, MD,

Figure 1

Figure 2

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

Seat height measurement (white line taken from saddle to pedal with the l 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 app priate seat height. The most cc mon method is an estimation ba on leg length.[7] With the rider sea on a secured bicycle, the seat is justed until the knee is flexed when the pedal is at the lowest pc tion.

Fore and aft saddle position is timized when a plumb line dra from the tibial tubercle bisects axle of the most forward pedal wl the rider is seated on the bicy with the pedals at the 3 o'clock a 9 o'clock positions[8] (Figure 3). T saddle angle should be level; this be confirmed with a standard c penter's level.

Handlebar position determi the reach or distance between saddle and the center of the hanc bar. With the handlebar in the app priate position, the distance fr the forward tip of the saddle to center of the handlebar sho match the distance from the ol ranon to the tip of the long fing

Figure 3

The ideal relative position of the knee to the pedal. With the rider seated on the bicycle and the pedals at the

Figure 4

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

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 mea-

foot remains in a neutral position, assuming normal tibial alignment.

Training and Technique

Stretching is an essential part of 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).

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 suring 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 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

Figure 5

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

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

ation of cleat position and angle, a customized pedals are helpful managing the hyperpronated fo Strengthening of the intrinsic f musculature may promote longitu nal and transverse arch strength. F thermore, the cyclist should restr the intensity of rides to flat terr with low resistance and a cadence 90 rpm until symptoms resol Symptomatic treatment with ice a nonsteroidal anti-inflammatory dr (NSAIDs) is also beneficial.

Patellar tendinitis in the cyclis caused by excessive angular tract during the pedal cycle.[15,16] In addit to pain while biking, the cyclist of 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]

Improper bicycle fit also can lead

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 alter-

reports pain during knee extensi
On examination, the patient exh
its focal swelling and tenderness o
the patellar tendon, often with pal
ble crepitus. Intrinsic and extrin
malalignment must be addressed.
ternal tibial rotation or valgus ali
ment may be countered with cleat
sition. VMO training may h
counteract angular traction during
pedal cycle by restoring a 1:1 VM
to-VL ratio. Foot hyperpronat
must be addressed with cleats
wedges.[3] Saddle height and fore
position also should be evaluat
Nonsurgical management (eg, re
ice; quadriceps, vastus lateralis, a
iliotibial band [ITB] stretchi
NSAIDs) in conjunction with a red

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

dial 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

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. Greater knee extension is necessary with higher 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 me-

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

seat position.[19] 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

... Outside this plane, the results are very sensitive to possible errors due to marker placement or alterations in the trajectory of the markers due to a soft tissue artefact (STA) [18]. However, movements outside the sagittal plane are important from a clinical point of view, as they are the main cause of possible joint overload, pain or injury [13,[19][20][21] [22]. ...

... Patellofemoral syndrome ("cyclist's knee") is the most common cause of knee pain in the cyclist [21] . This pain is caused by increased pressure in the patellofemoral joint. ...

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... Long-distance cycling leads to overuse of leg muscles, particularly among novice cyclists. This can result in anterior knee pain, patellofemoral pain syndrome, and iliotibial band syndrome [4], [5], [6] . Novices, particularly those cycling for tourism, face difficulties identifying and correcting irregular cycling forms because of their lack of experience. ...

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... Cycling is a form of exercise that improves fitness and cardiovascular health. 1 However, the repetitive nature of recreational and competitive cycling lends itself to overuse injuries. 2, 3 Studies have found that a majority of recreational cyclists have experienced a self-reported overuse injury, with prevalences as high as 85-88%, 4,5 though a much lower 2.8% lifetime prevalence was found by du Toit et al. 6 when an injury was restricted to incidents that required the cyclist to stop cycling and seek medical treatment. Regardless of population sampling method, the lower extremity is the most cited area of overuse injury, with the knee the most International Journal of Exercise Science http://www.intjexersci.com ...

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... Many aspects of bicycle fit have been examined with respect to lower-limb joint biomechanics when cycling, including vertical/horizontal saddle position, handlebar height/reach, and crank length (Wanich et al., 2007) . A low saddle height has been shown to increase internal knee adduction moment (Wang et al., 2020), while no changes in knee joint contact forces were observed due to anterior/posterior shifts in saddle position (Bini et al., 2013). ...

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... Previous studies have reported that cycling exercises may lead to injuries, such as anterior knee pain, patella tendonitis, iliotibial band stress fracture, and compartment syndrome. 17, 18 Researchers use biomechanical evaluation methods to detect the causes of sports injuries. The applied forces need to be measured accurately to analyze the biomechanics of the lower limb during exercise 19,20 and calculate the lower limb moments. ...

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... Regarding the trunk flexion angle, since no references are presented in scientific literature, we relied on cyclists' perceived comfort feedback. Moreover, for the saddle retraction, the Knee over Pedal Spindle (K.o.P.S.) method was used [30, 31] . ...

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