Bicycle-Related Injuries

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Bicycle riding is a popular form of recreation among persons of all ages, and related injuries cause significant morbidity and mortality. Most injuries occur in males and are associated with riding at high speed; most serious injuries and fatalities result from collisions with motor vehicles. Although superficial soft tissue injuries and musculoskeletal trauma are the most common injuries, head injuries are responsible for most fatalities and long-term disabilities. Overuse injuries may contribute to a variety of musculoskeletal complaints, compression neuropathies, perineal and genital complaints. Physicians treating such patients should consider medical factors, as well as suggest adjusting various components of the bicycle, such as the seat height and handlebars. Encouraging bicycle riders to wear helmets is key to preventing injuries; protective clothing and equipment, and general safety advice also may offer some protection. (Am Fam Physician 2001;63:2007-14,2017-8.)

A patient information handout on bike safety, written by the authors of this article, is provided on page 2017.

In 1994, the Centers for Disease Control and Prevention estimated that 72.7 percent of children aged five to 14 years rode bicycles, amounting to 27.7 million child bicyclists.[1] Off-road bicycles (mountain bicycles) now account for 62 percent of new bicycle sales in the United States and are popular on both city streets and rough trails.[2] Other types of bicycles include sport/touring, racing, bicycle motor-cross (BMX) stunt bicycles as well as increasingly popular stationary bicycles. Bicycling is a wonderful form of exercise and sport but, as with any activity, carries a risk of injury. In this article, the cause and epidemiology of bicycle-related injuries are reviewed, and strategies for treatment and prevention of common injuries are discussed.

Incidence and Risk Factors for Injuries

INCIDENCE

Bicycle-related injuries account for approximately 900 deaths, 23,000 hospital admissions, 580,000 emergency department visits and more than 1.2 million physician visits per year in the United States, resulting in an estimated cost of more than $8 billion annually.[3-5] The Child Health Supplement to the 1988 National Health Interview Survey estimated that approximately 4.4 million children aged five to 17 years were injured annually because of participation in sports and recreation; bicycle-related injuries were responsible for 10 to 40 percent of these.[6]

Important risk factors for bicycle-related injuries include not wearing a helmet, involvement with motor vehicles, unsafe riding environment and male sex.

Bicycle crashes rank second only to riding animals as a sports- or recreation-associated cause of serious injury; one study[7] estimated the rate of severe injuries to be 37.4 per 100,000 population in urban areas. Although injuries to mountain bikers of all ages account for only 3.7 percent of bicycle injuries overall, up to 51 percent of recreational and 85 percent of competitive mountain bikers sustain injuries each year.[8-10] Riders of BMX bicycles often tend to be injured while performing stunts, and in competition, 6.3 percent of BMX riders sustain injuries.[11-13]

RISK FACTORS

The peak incidence of bicycle-related injuries and fatalities is in the nine- to 15-year age group with a male-to-female ratio of 2 to 3:1.[7,14-16] Important risk factors for bicycle-related injuries include not wearing a helmet, crashes involving motor vehicles, an unsafe riding environment and male sex *(Table 1)*.[7,14-18] The influence of socioeco-

TABLE 1
Risk Factors for Bicycle-Related Injuries

Cyclist is male.
Cyclist is nine to 14 years of age.
Cycling in the summer.
Cycling in late afternoon or early evening.
Cyclist does not wear helmet.
Motor vehicle involved.
Unsafe riding environment.
Cyclist is from an unstable family environment.
Cyclist has preexisting psychiatric condition.
Cyclist is intoxicated.
Cyclist is involved in competitive mountain-bike racing.

Information from references 7, 14-18.

nomic status itself on the incidence of bicycle-related injuries is unclear—in some cases, an increased incidence of such injuries occurs in children from more highly educated households.[17] However, most studies have not adjusted for the amount of time spent riding. In adolescents and young adults, alcohol and substance abuse can be associated with bicycle injury.[18]

Causes of Injuries

The precise contribution of rider errors (losing control, speed, performing stunts, inexperience), motorist errors, environmental hazards (objects in the road, loose gravel) or bicycle mechanical failure in causing bicycle crashes is unclear, although they are probably all significant.[16,19,20] Faster riding speed does appear to be associated with serious injury, fatality and mountain-biking crashes.[10] The role of other factors such as distance of trip, duration of ride and sidewalk riding is also not clear. Although collisions with motor vehicles are relatively uncommon, they are responsible for most serious injuries and fatalities.[16]

Mountain-biking injuries peak in 20- to 39-year-old riders and are usually caused by hitting an obstacle in the trail and losing control of the bicycle, often while riding downhill at excessive speeds over unfamiliar terrain. Various components of the bicycle itself can cause injuries; spokes can cause lower extremity injuries when a child riding in a seat behind the cyclist gets a foot caught in the moving wheels,[20] the saddle and seat-post may cause genital and rectal injuries if the rider crashes,[21] and landing on the handlebars in a crash can cause visceral and vascular penetration.[18,19]

Common Injuries

ACUTE TRAUMA

Most bicycle-related injuries occur to the upper or lower extremities, followed by the head, face, abdomen or thorax, and neck *(Table 2*[2,6,8-9,14,18,19,21-31]*)*. Most involve superficial trauma such as abrasions ("road rash"), contusions and lacerations.[14] Indeed, road rash can range from superficial abrasions to those involving partial or full skin thickness requiring removal of embedded debris to prevent "traumatic tattooing." Strains, fractures and dislocations are also common and are usually readily identified by deformity, swelling, pain, bruising or lack of function, and may require imaging studies and further management.

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Head injuries occur in 22 to 47 percent of injured bicyclists, often as a result of collision with a motor vehicle, and are responsible for over 60 percent of all bicycle-related deaths and the majority of long-term disabilities.[14,32,33] Injuries to the facial region include eye trauma from airborne objects such as dust, insects or debris, as well as facial soft tissue injuries and fractures.[34] Only rarely do injuries involve neck trauma, which usually occurs in riders who collide with a motor vehicle. Trauma to the thorax, abdominal organs and viscera, pelvis and great vessels is relatively rare, but may result from blunt injury or penetration from landing on the upturned handlebars, resulting in significant abdominal organ damage.[19,22,23]

Overall, off-road cyclists have a 40 percent lower incidence of head, facial and dental injuries than on-road bicyclists, primarily the result of being separated from vehicular traffic and more frequent helmet use.[8,9,24]

Most serious bicycle injuries are the result of collisions with motor vehicles.

OVERUSE INJURIES

Overuse injuries may occur in bicycle riders who regularly ride their bicycle, especially those involved in competitive racing. Ensuring that the bicycle seat (saddle), handlebars and pedals are correctly adjusted and that the bicycle is the appropriate size can be key in preventing overuse syndromes *(Table 3[2,35])*.[35]

Neck aches and back aches are common complaints resulting from the cyclist's upper body position with hyperextension of the neck and flexion of the lower back.[25,26] In addition to advice on rest, stretching exercise and anti-inflammatory medications, the physician may suggest shortening the handlebar reach *(Table 3[2,35])*, creating a slight upward

TABLE 2
Injuries Sustained by Bicyclists

Type	*Etiology*	*Injuries*
Overuse	Neck and back	Cervical strains, lower back pain
	Handlebar neuropathies	Ulnar nerve (deep palmar branch), median nerve
	Saddle	Skin chafing, ulceration, irritation (saddle sores), ischial tuberosity pain, fibromas, pudendal neuropathies, impotence, urethral trauma (urethritis, hematuria), vulval trauma
	Hip	Trochanteric bursitis, iliopsoas tendonitis
	Knee	Patellofemoral syndrome
	Foot/ankle	Metatarsalgia, plantar fasciitis, Achilles tendonitis, paresthesias
Traumatic	Head	Skull fracture, concussion, brain contusion, intracranial hemorrhage
	Face/eye	Contusions, facial fractures, dental fractures, corneal foreign bodies
	Musculoskeletal	Fractures, dislocation, strains
	Chest	Rib fractures, parenchymal lung injury
	Abdomen	Splenic rupture, hepatic laceration, renal contusion, pancreatic trauma, vascular perforation, small or large bowel contusion, rupture, traumatic hernia
	Genitourinary	Urethral and vulval trauma, rectal trauma, pelvic fractures
	Skin and soft tissue	Abrasions ("road rash"), lacerations, contusions

Information from references 2, 6, 8-9, 14, 18,19, 21-31.

TABLE 3
Correct Fit of Bicycle

Bicycle component	*Key measurements*	*Adjustments*
Frame size	Clearance between frame and crotch	While standing astride the frame of the bicycle: 1 to 2 inches for sports/touring bicycles, 3 to 6 inches for mountain bicycles
Saddle	Height	25 to 30 degrees of knee flexion of the extended leg when the pedal is at 6 o'clock position *or* Measure the inseam (wearing cycling shoes) from floor to crotch, and multiply by 1.09. *or* Maximum height whereby the rider is not rocking back and forth across the seat when riding. Generally lower in mountain bikes to maintain stability and maneuverability
	Fore/aft position	With pedals at 3 and 9 o'clock position, the front of the patella should be directly in line with the front of the crank arm.
	Tilt angle	Set level (use carpenter's level), or with slightly elevated front end.
Upper body	Handlebar height	At least 1 to 2 inches below top of the saddle (up to 4 inches for tall cyclists)
	Reach/extension	When elbow is placed on the tip of saddle, the extended fingers should reach the transverse part of handlebars.
	Width of bars	At shoulder distance, wider in mountain bicycles
Foot	Position on pedal	Foot should be in neutral position, toes not pointing up or down. Ball of foot should sit over pedal axis.

Information from references 2 and 35.

tip of the saddle angle of 10 to 15 degrees, or regularly changing hand and arm position on the handlebars and keeping the elbows slightly flexed while riding.[25-27] Prolonged pressure on the handlebars and the position of the wrists may cause compression neuropathies in the hands.[25,28] The deep palmar branch of the ulnar nerve is most frequently involved, because it is particularly vulnerable as it passes proximal to the ulnar tunnel (tunnel of Guyon) anterior to the palmar fascia.[25,28,29]

Ulnar neuropathy presents as numbness and tingling in the ring and little fingers or weakness on abduction or adduction of the fingers or adduction of the thumb. Compression of the median nerve in the carpal tunnel from prolonged wrist hyperextension is much less common, but may cause paraesthesia in the thumb, index, middle and ring fingers and the radial side of the hand, as well as weakness on abduction and opposition of the thumb. Symptoms usually resolve rapidly with stopping cycling, although in severe cases of ulnar palsy, this can take several months. Electrodiagnostic studies may be useful for patients with persistent injuries to localize the site of nerve compression and determine the extent of defect. Advising frequent changes of hand position on the handlebars, increasing handlebar padding and wearing padded gloves can prevent recurrences.

Sustained pressure over the ischial tuberosities is a frequent cause of buttock tenderness,

especially in new riders.[25] Although this is usually self-limited, attention to the position and type of saddle may be beneficial. With sustained cycling, calluses can form in the skin over the ischial tuberosities, and occasionally prolonged irritation can lead to the development of painful deep fibrous masses.[30] Skin chafing from the saddle can cause "saddle sores," ranging from minor chafing to severe ulceration.[25] Mild skin chafing will respond to drying talcum powders or lubricating ointments such as petroleum jelly, whereas more severe or ulcerating sores may require rest, sitz baths and appropriate ulcer management.

Other preventive measures include ensuring correct seat height and angle, wearing padded shorts and using a more cushioned saddle. The combination of chafing, sweating and tight clothing can cause groin irritation with perineal folliculitis or maceration of the perineal skin. In male cyclists, compression of the dorsal branch of the pudendal nerve between the pubic symphysis and the bicycle seat, as well as the cavernous nerve can cause numbness and tingling of the penis and scrotum, and occasionally impotence.[25,28] Symptoms usually resolve within one week, although they may occasionally last for several months.[28] Affected riders should stop cycling until symptoms resolve. Recurrences can be prevented by correcting saddle position or using a saddle with a "cut-away" midline section.

Traumatic urethritis with hematuria and mild dysuria has also been reported in male cyclists.[31] Female cyclists can develop vulval abrasions, lacerations and contusions, which usually respond to symptomatic measures such as sitz baths and correction of saddle fit.

Hip pain in cyclists is usually caused by trochanteric bursitis from repetitive sliding of the fascia lata over the greater trochanter, or iliopsoas tendonitis, and usually responds to ice, anti-inflammatory medications, iliotibial band stretching and lowering the saddle slightly. Knee pain is usually due to patellofemoral pain syndrome or incorrect foot position, which may result from having the saddle too far forward or too low.[25,35] Correction of the bicycle set-up, advice on strengthening the vastus medialis and stretching of the hamstrings, combined with appropriate use of ice and anti-inflammatories is usually sufficient. Foot pain is commonly a result of metatarsalgia, which should respond to correction of poor shoe position and cushioning insoles or pads. Other causes of foot pain include plantar fasciitis and Achilles tendonitis resulting from a saddle that is too low or self-limiting foot paresthesias caused by tight shoes or toe clips.

Although not unique to cycling, sun and heat can prove hazardous, and cyclists should be aware of sun protection and appropriate fluid and electrolyte replacement.

Prevention of Injuries

PROTECTIVE EQUIPMENT

A number of factors can decrease the risk of injury *(Table 4)*. Bicycle helmets offer a

TABLE 4
Prevention of Bicycle Injuries

Protective equipment	**Mechanical**
Helmets*	Correct fit of bicycle
Gloves	Regular safety checks
Eye protection†	Effective brakes
Padded shorts	Fenders
Shoes	Spoke guards
Reflective and bright clothing	Child carrier seats
Lights, strobes	Suspension
Education	Handlebar padding
Helmet use campaigns	Reflectors—front, rear, pedal, wheels
Rodeos teaching skills	**Environmental**
Media campaigns about safe cycling	Proper road design and maintenance
	Separate bicycle lands/cycle paths

**— As of March 1999, all new helmets must meet a new U.S. Consumer Product Safety Commission (CPSC) federal safety standard. Older helmets may have passed one of the following standards: American National Standards Institute (ANSI Z90.1, ANSI Z90.4), the Snell Memorial Foundation (SNELL B-90, B-90S, B-95, N-94), American Society for Testing and Materials (ASTM F-1447-93, ASTM F-1447-4) or Canadian Bicycle Helmet Standard (CAN/CSA-D113.2-M89).*

†—Protective eyewear should meet minimum safety standards of the ANSI, the ASTM or the Canadian Standards Association (CSA).

Wearing bicycle helmets reduces the risk of head injuries by 74 to 85 percent.

substantial protective effect by reducing the risk for bicycle-related injuries to the head by 74 to 85 percent and to the nose and upper face by approximately 65 percent.[34,37] They should therefore be worn by riders of all ages.[38] Of equal importance is ensuring that the helmet is worn correctly. It should sit snugly in a horizontal position on the head, with the straps forming a 'V' around the ears and held in place with the buckle fastened. Although nearly 50 percent of children have safety helmets, only 15 to 25 percent nationwide wear them consistently and correctly, with the lowest use among older children and teenagers.[1,39]

Barriers to more widespread use of helmets include discomfort, poor fit, cost, misconceptions regarding the personal risks of cycling, lack of knowledge regarding effectiveness and negative pressure from peers, particularly among teenagers and older children.[1] Successful campaigns promoting helmet use in several communities have led to 40 to 50 percent increases in the numbers of children wearing helmets, and are often initiated by a variety of individuals and groups, such as schools, health care professionals, youth clubs, retailers, parent-teacher-student organizations and local health departments *(Table 5)*.[40] Health care professionals can individually influence helmet use by targeting children during routine health examinations or when treating injured children

TABLE 5
Useful Resources

National SAFE KIDS Campaign
1301 Pennsylvania Ave. NW, Ste. 1000
Washington, DC 20004-1707
202-662-0600; 800-289-0117
http://www.safekids.org
(Guides and videos for physicians, parents and children. Lists existing and pending bicycle-related legislation. Provides guide for community bicycle safety programs and media campaigns.)

Strap and Snap Program
Family Medicine Center
1025 Pennock Place
Fort Collins, CO 80524
970-495-8826
http://coloradoafp.org/strap_snap/

American Trauma Society
8903 Presidential Pkwy., Ste. 512
Upper Marlboro, MD 20772-2656
800-556-7890
http://www.amtrauma.org
(Safety campaign kit and resource catalog. Animated childhood safety videos and 'traumaroo' education program)

Harborview Injury Prevention and Research Center
325 Ninth Ave.
Box 359960
Seattle, WA 98104
206-521-1520
http://depts.washington.edu/hiprc
(Guide for communities developing children's bicycle helmet safety program. Campaign guides and safety advice)

National Center for Injury Prevention and Control
4770 Buford Hwy. NW
Atlanta, GA 30341-3724
770-488-1506
http://www.cdc.gov/ncipc
(Information for campaigns, children, parents. Information on the National Bicycle Safety Network)

United States Consumer Product Safety Commission
4330 East-West Hwy.
Bethesda, MD 20814-4408
301-504-0990; 800-638-2772
http://www.cpsc.gov
(Current safety standards for bicycle helmets. Information about safety, products and recalls)

in emergency departments.[41] In the younger age group, targeting educational efforts to parents may be effective, whereas in older children nontraditional approaches are often more effective. Most bicycling organizations now mandate bicycle helmet use, and many states and jurisdictions have added mandatory use legislation—but only for children.[42] Indeed, helmet use among school children appears to be greatest in regions of the county that have implemented helmet use laws.

Cycling gloves can reduce superficial hand injuries, especially in off-road bicycling, provide insulation in cold weather and provide padding to help prevent nerve compression. Riding shorts reduce saddle irritation and often integrate padding to provide some protection from vibration and chafing, while other clothing should emphasize visibility using bright colors, reflective materials or even "strobe" lights. Specialized cycling shoes use toe clips or sole cleats to attach the stiff shoes to the pedals; a correct fit can prevent foot and ankle problems. Eye protection made from polycarbonate material is highly recommended to provide protection against the weather, foreign bodies and ultraviolet light. Finally, all bicycle riders should periodically check their bicycle's mechanical safety features.

In general, children younger than 10 years of age should avoid riding in the vicinity of vehicular traffic. Older riders should be trained to anticipate the errors of motorists and take into consideration road surfaces, weather conditions and other factors. Other environmental solutions include separating bicyclists from road traffic by the use of designated cycle lanes on streets, assuring bicycle pathways are made of smooth surfaces and lacking in obstacles and discouraging "wrong-way" riding on sidewalks and roads. The protective effect of bicycle paths is unclear. A recent study[36] suggested that riding on sidewalks and paths may actually be more dangerous than riding in the road, perhaps because rules of the road are followed less often. Riding on sidewalks and bike paths may also pose greater hazards to walkers and joggers. While there is good evidence that promotion of bicycle helmet use will decrease rates of head injury, there is also increasing evidence that educational programs aimed at teaching children to be safer riders are effective in decreasing the risks of injury.[41]

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