Mountain Bike Injuries: An Overview 231

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Abstract

Mountain biking is a popular outdoor recreational activity, an exciting adventure sport, and now an Olympic cycling discipline. The overall injury rate is 16.8 injuries per 1,000 h exposure; 0.4 riders are injured per 100 h cross-country and 4.3 riders per 100 h downhill racing. The rate is higher for experts (17.9/1,000 h) compared to professional riders (13.4/1,000 h). More serious injuries to the head and neck occur while falling over the handlebars rather than falling off the bike to the side, which tends to result in lower limb injuries. Most injuries sustained mountain biking occur in young males aged 20–39 years. This chapter reviews the current literature on mountain biking injuries and developments in injury prevention.

Background

Off-road biking began as a means of transport during the nineteenth century, when "Buffalo" soldiers are reported to have cycled home, cross-country from Missoula, to Montana, to Yellowstone. The first recorded modification of a bicycle for off-road riding was made by John Finlay Scott in 1953 with his "woodsie" bike. Joe Breeze, Otis Guy, and Gary Fisher are attributed to have started mountain bike racing in Marin County, California, in the 1970s. After inaugural "World Championships" were held simultaneously in the United

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States and Europe in the 1990s and subsequently, the sport was recognized by the Union Cycliste Internationale (UCI). There are an annual World Cup Series and a World Championship, and after demonstration at the Atlanta Olympic Games in 1996, the mountain biking was awarded full Olympic status at the Olympic Games in Sydney in 2000 (IOC 2000).

MTB competitions were previously limited to the disciplines of cross-country and downhill, but more recently dual slalom or 4 cross and free or trial riding have developed. Cross-country races require considerable stamina and may last over several hours, whereas downhill events may be over within a couple of intense minutes. During downhill racing speeds approaching 70 mph may be obtained over treacherous rocky terrain. At such speeds the slightest loss of attention can lead to a high-speed crash with obvious consequences of injury. During 4 cross and dual slalom races, riders race head to head over a prepared artificial course similar to ski cross and boardercross disciplines. Although physical contact is not allowed, riders jostle with each other for the best line and consequently falls commonly occur. Free or trial riding involves performing stunts and jumps over obstacles. Speeds are relatively low, but the height from riders may fall is considerable (Carmont 2008).

Mountain bike riding is also a popular recreational activity, occurring in both urban and rural surroundings by young and old alike. The literature of mountain biking injuries has been comprehensively covered in other book chapters (Carmont 2013). This chapter reviews mountain biking injuries and developments reported in the literature.

Injury Rates and Demographics

The reporting of mountain biking injuries commenced in parallel with the sport development. Initial questionnaire surveys of off-road bicycling organizations by Chow et al. had high response rates of 82.8 %. Eighty-four percent of respondents had been injured previously, and 51 % had sustained injuries in the past year. Most injuries were minor; however, 26 % required professional medical care and 4.4 % required hospital admission. Ninety percent of injuries were abrasions, lacerations, and contusions, whereas 12 % sustained a fracture or dislocation, e.g., clavicle and shoulder. Frequent riding was associated with increased severity of injury, but most (87.6 %) injuries occurred off paved roads. This survey suggested that compared with road cyclists, off-road cyclists had more frequent, however, not necessarily more severe, injuries (Chow et al. 1993).

Pfeiffer surveyed the National Off-Road Bicycling Association (NORBA), a bicycle race series, by questionnaire (Pfeiffer 1994). Wounds and bruises were the commonest types of injury reported, occurring in 58.1 % and 68.2 % of male and female riders, respectively. Sprains, fractures, and dislocations occurred much less commonly. In males the commonest injured regions were the knee (22.6 %) and the lower leg (12.3 %); however, in females it was the lower back (16.5 %). Typically leg injuries are due to the rider falling to the side or putting out the leg in an attempt to slow down. The majority of injuries (56 %) occurred during racing compared with training.

A questionnaire survey of the 1992 cycling season revealed that 85.7 % of respondents were reporting injuries. Significant injuries were defined to have occurred if the cyclist sought medical attention or was unable to ride on the following day. Ninety percent of these injuries were traumatic with fractures being the most common significant injury reported. Contrary to other series the shoulder complex was the most commonly involved anatomical region. Loss of control, high-speed descent, and competitive activity were shown to be variables associated with traumatic injury. Competitive activity level was the only independent risk factor positively associated with traumatic injury, with an adjusted odds ratio of 4.24 (Kronisch and Rubin 1994).

Reports from large mountain bike areas, e.g., Mammoth Mountain Ski Area in the United States, again by Krosnich et al., have revealed injury rates of 60 % for recreational riders; however, the majority of these were superficial injuries (65 %) not requiring medical treatment (Krosnich et al. 1996a, b). Riders that were involved in

formal racing had injury rates of 0.4 %, and no differences in the severity of injuries were found between downhill and cross-country riders (Krosnich et al. 1996a). Significant injuries are considered to be those in which riders miss a day, or more, of cycling, and 26 % of injuries met these criteria. The commonest of these injuries were fractures of which 57 % involved the upper extremity compared to 21 % the lower extremity. The acromioclavicular joint was the most commonly injured joint and fracture of the clavicle the most common fracture (40 %).

Further studies on the US NORBA series identified injury rates of 0.37 cyclists per 100 h cross-country racing and 4.34 per 100 h of downhill racing (Krosnich et al. 1996b). Turning was the commonest reported mechanism of injury, others being loss of control or traction and mechanical problems. Riders who fell forward over the handlebars sustained more severe injuries (Injury Severity Score (ISS) 3 vs. 1.3) and required more emergency department visits than those who fell to the side. Also females were more likely to fall over the handlebars than male riders (Krosnich et al. 1996b). This is probably due to the weight difference between males and females. Falling over the handlebars produced more head and neck injuries than falling to the side (56 % vs. 8 %), and greater injury severity score (ISS 3.4 vs. 1.7) conversely falling to the side generally led to more lower extremity injuries (88 % vs. 57 %) (Chow and Kronisch 2002). Thus, female riders could be considered to be more prone to severe injuries.

When injuries sustained during bicycling resulting in attendance at an emergency department were analyzed by Rivara et al., almost 4 % of riders were injured off road. Of these 73 % were aged 20–39 years and 88 % were male. Injuries were less severe, and riders required less hospitalization than road cyclists (Rivara et al. 1997). In this questionnaire study at the time of the crash, more off-road riders (80.3 %) wore helmets than other cyclists (49.5 %).

When Swedish racers were surveyed by Grooten et al., 75 % reported having had an injury and once again the knees and lower back were most commonly affected, and 71 % reported minor injuries. Although not statistically significant, riders that trained more and had partaken in preseason training sustained fewer injuries (Grooten et al. 1999).

Some studies have reported on the seasonal variation of injuries. Within the United Kingdom more off-road riders presented to an emergency department during the summer months, most commonly in August. In Jey et al.'s study, the commonest injury was a clavicle fracture, and alarmingly 23 % of injuries required surgical intervention (Jeys et al. 2001). Given that minor injuries may not present to the emergency department, this is not necessarily an indication of the overall pattern of injury. German questionnaire surveys have revealed an injury rate of one injury per 1,000 h of biking; 75 % of injuries were minor, while 10 % required hospitalization (Gaulrapp et al. 2001).

Recent work from Canada has also shown high rates of injury (38 %) requiring surgery and an increasing injury rate with a threefold increase in injuries reported over the last decade (Kim et al. 2006). As a result of this increased injury rate, injury prevention has been targeted. It is worthwhile to note that for inclusion into the Canadian trauma registry, the study relied upon a presentation within 7 days of injury, a hospital stay of longer than 3 days, and an injury severity score of >12 or expiration in the hospital.

A recent review by Nelson and McKenzie of mountain bike-related injuries treated in emergency departments from 1994 to 2007 has conversely suggested decreasing injury rates falling from 23,177 in 1995 to 10,267 in 2007 (56 %) (Nelson and McKenzie 2011). The reasons for this were considered to be an increase in the use of disk brakes together with suspension. They also affirmed that females (6.1 %) were more likely than males (4.5 %) to require hospitalization and that there was an increased risk of traumatic brain injury for those aged 14–19 years (8.4 %) (Nelson and McKenzie 2011).

Quigley and Boyce's review on mountain bike-related emergency department presentation to a district general hospital within the United Kingdom has revealed that 74 % (64) of riders were cycling recreationally, 16 % (14) were racing, and 9 % (8) were free riding over man-made/natural

Fig. 1 Cross-country endurance riding

obstacles. Seventeen percent of riders were wearing body armor with the majority of these being downhill racers (Quigley and Boyce 2005).

Another recent study reports on recreational mountain biking from the southeast of Scotland. The number of injuries sustained by bikers was compared to the number of riders visiting a popular mountain biking area. Mechanism and injury data was obtained from questioning riders at the center first aid posts and surrounding hospitals and by follow-up telephone interview (90 %). The overall injury rate was determined to be 1.5 injuries per 1,000 biker exposures. Males were more commonly injured than females with those aged 30–39 being the highest at risk. The commonest types of injury were wounding, skeletal fracture, and musculoskeletal soft tissue injury. Joint dislocations occurred more commonly in older mountain bikers. The limbs were more commonly injured than the axial skeleton. The highest hospital admission rates were observed with head, neck, and torso injuries. Protective body armor, clip in pedals, and use of full suspension bikes were thought to confer a protective effect (Aitken et al. 2011).

Becker et al. have recently presented results of an online injury survey of 249 bikers using a prospective data collection to reduce recollection bias. This revealed an overall injury rate of 16.8 injuries per 1,000 h exposure. The rate was higher for experts (17.9/1,000 h) compared to professional riders (13.4/1,000 h). The majority of these injuries were contusions or abrasions that did not require medical attention and most were attributed to rider errors (72 %) particularly on the hard rocky downhill tracks. Seventy-four percent of riders were described as being expert or professional (Becker et al. 2013).

Lareau and McGinnis have recently suggested there was no increase in risk of injury in cross-country races, of less than 6 h duration, compared to endurance races of more than 6 h duration (odds ratio 1.6, 95 % CI [0.50, 2.92]) (Lareau and McGinnis 2011; Fig. 1). Data was acquired by surveying the participants in six races: two cross-country (<6 h), two 6–12 h, and two 24 h races. Endurance races typically involve riding multiple laps of a looped course for a predetermined time period. This means that riders are unlikely to encounter new terrain as they become more tired and as a consequence are more likely to be injured. Riding at night has added risks, and riders typically use helmet or handlebar-mounted lights.

At the 2008 Beijing Olympic Games, cycling is one of the events in which athletes sustained

injury least commonly. Mountain biking injuries were included in the same category as cycling injuries, and only 30 out of 518 cycling competitors (5.8 %) reported injuries. Two-thirds (20) of these were sustained during competition rather than training (10) (Junge et al. 2009). Specifically only nine mountain bike riders sustained injuries roughly equally in training (5) and competition (4) [personal communication Astrid Junge]. In the London 2012 Olympic Games however, 21 % of competitors in the mountain biking events reported having sustained injury making it the fifth most injurious sports behind Tae Kwon Do (39 %), football (35.3 %), BMX (31.3 %), and handball (21.8 %) (Engebretsen et al. 2013).

Specific Injury Patterns

There are several studies and case reports on specific anatomical areas injured while mountain biking. These include the head and face, the cervical spine, the upper limbs, the abdominal viscera, the perineum, and the lower limbs.

Head and Face

Bicyclists and mountain bikers are prone to facial trauma, and Chow has suggested that conventional bicycle helmets may not provide adequate protection for the face while mountain biking (Chow et al. 1995). Gassner et al. have revealed that mountain bikers have more severe injury profiles than bicyclists for maxillofacial trauma with 55 % having facial bone fractures, 22 % having dentoalveolar injuries, and 23 % having soft tissue injuries. Dentoalveolar injuries were the commonest site of facial injury in road bicyclists (50.8 %) (Gassner et al. 1999a, b). Of the facial fractures, 15.2 % were maxillary fractures.

Kelly et al. reported that 13 % of sports-related head injuries presented to an emergency department were sustained while cycling (Kelly et al. 2001). In McDermott's study of 1,710 bicycling injuries, helmet use has reduced the risk of head injuries by 39 % and the risk of facial injury by 28 % (McDermott 1993). This data on the reduction of the rate of head injury may be extendable to mountain bike riding, but it may be difficult to distinguish head injuries sustained by those riding a mountain bike from those partaking in pure off-road MTB riding in the literature.

Revuelta and Sandor have reported on dental injuries including degloving of the mandibular mucosa in children (Revuelta and Sandor 2005). The high incidence of facial trauma has led to the increased use of helmets with attached face protectors and face guards. In Becker et al.'s prospective survey, 96 % of downhill riders wore full-face helmets (Becker et al. 2013).

Spinal Injuries

With the speeds involved in downhill racing and the nature of over-the-handlebar injuries, it is surprising that cervical spine injuries do not occur more commonly. A series of paraplegic patients injured while mountain biking have been reported by Aspingi et al. (2006). The three riders in this series had sustained either over-the-handlebar falls or falls directly onto the helmet. The cervical spine is the commonest site of spinal injury, and cord injury was present in 24 % of Kim et al.'s series (Kim et al. 2006).

Dodwell et al. presented a 13-year review of spinal column and spinal cord injuries in mountain bikers. One hundred and seven patients were included. The mean age at injury was 32.7 years with the majority sustaining cervical injuries and 73.8 % and 40.2 % sustaining spinal cord injuries. Just over 40 % were American Spinal Injury Association grade A and a third improved one ASIA category. This series reports a bleak outcome for those sustaining cervical cord injuries while mountain biking, typically young male recreational riders. It is recommended that injury prevention should be the primary goal with educational programs, helmets, and other protective equipment awareness (Dodwell et al. 2010). Thirty-four percent and 29 % of downhill mountain bikers wore neck braces and back protectors, respectively, in Becker et al.'s survey (Becker et al. 2013).

Upper Limbs

The upper limbs have been identified as an area being commonly injured. In Rajapaske et al.'s series of forearm injuries, the distal radius and scaphoid were commonly injured bones (30 % & 28 %); however, surprisingly the commonest fracture was the radial head (35 %) (Rajapaske et al. 1996).

Given the numbers of children riding mountain bikes and the increased popularity of competitions in this age group it is not surprising that mountain bike use features prominently in childhood and adolescent injuries given that an upper limb fracture is a very common injury in this age group (Aleman and Meyers 2010).

Prolonged cycle riding of any form has been shown to be associated with nerve compression at the wrist by Patterson et al., with 23/25 riders reporting sensory or motor or both symptoms (Patterson et al. 2003). When the rough nature of off-road riding is considered, hypothenar hammer syndrome, i.e., ulna artery occlusion and pisotriquetral arthritis, has been associated (Applegate and Speigel 1995) (Singer et al. 2011).

Abdominal Viscera

Nehoda et al. have reported a large series of patients with liver hematomata sustained during mountain biking crashes (Nehoda et al. 2001). All of these patients had blunt focal blows to the right abdomen due to the handlebars, and all were using "bar ends" on their handle bars. These bar ends were used to provide additional riding positions and so optimize rider comfort. After a media information program of the implication of bar ends for abdominal injury, bar ends were no longer used in mountain biking. Nehoda et al. have noticed an almost complete cessation of liver injury in mountain biking.

Kim et al. have shown that the spleen was the organ most frequently injured (49 %); the liver (15 %) was injured less commonly. The small bowel was the most frequently injured hollow organ (13 %) (Kim et al. 2006).

Perineum

Richiuti et al. have shown that perineal numbness due to nerve compression after long periods of sitting on a hard saddle commonly occurs (Ricchuti et al. 1999). Modern saddles are molded to reduce pressure on the pudendal nerves in the perineum and aim to alleviate this problem.

The scrotal contents can be subjected to repeated micro-traumatization during mountain biking. Studies by Frauscher et al. have revealed that 96 % of mountain bikers had pathological abnormalities compared to 16 % of a control group on ultrasound examination (Frauscher et al. 2000, 2001). Short padding and alteration of the saddle position could help reduce the incidence of these problems.

Lower Limbs

The shins of bikers are vulnerable to scratches and scrapes when riding through undergrowth, but this can be minimized by wearing protective leg cover, gaiters, or shin guards. Riders find it essential to have a firm foothold on the pedal to permit stability and pedaling efficiency, and straps or quick-release pedals have been developed for this purpose. These pedals hold the shoe onto the pedal securely allowing improved power transfer but conversely making it more difficult to put the foot down onto the ground when falling off. This delay in foot release means that there is less time to put the foot down for support so it is placed closer to the bike and the sharp teeth of the chain ring. The sharp teeth can result in pretibial lacerations, an area prone to poor healing and may require debridement under anesthesia and sometimes skin grafting (Patel 2004). Failure to remove the foot from the pedal can result in the cyclist toppling over onto their side. Although these falls may be perceived as being comical they can result in significant trauma with the potential for complications. A direct blow to the hip can result in a neck of femur fractures (Slootmans et al. 1995) or acetabular fractures (Barnett 1993). Padded shorts are designed to provide protection against this

injury. This mechanism also results in more upper limb fracture when the athlete attempts to reduce the impact with his wrist/elbow or shoulder.

In stunt, trial, and downhill events, riders may prefer flat pedals to those with pedal devices or clips for ease of removal and rapid dismount. These pedals, known as "flatties," have a layer of small proud screws on their surface, which give the rider's rubber sole shoe more friction to avoid skidding. These screws are also responsible for major shin laceration when the foot skids backward and the shin meets the rough pedal surface. Putting the foot out in an attempt to slow down may lead to spiral fractures of the tibia or external rotation injuries of the ankle. However, studies are lacking in this specific area.

Although classically described as falling off horses with the foot caught in the stirrup, Lisfranc's dislocation of the midfoot has also been described in a mountain biker. In Callaghan and Jane's case rather than having the foot caught in the toe clip, pain occurred as the rider suffered a forced plantar flexion injury of the midfoot while trying to put the foot on the ground (Callaghan and Jane 2000).

Injury Prevention

A number of methods can be adopted to minimize injury while mountain biking. Riders should be well trained, ride within the level of their capability, learn to dismount safely and use a well-maintained bike without handlebar ends. Excessive speed, adverse environmental conditions, inadequate conditioning, and rider behavior are factors which contribute to injuries.

The use of body armor and leg guards is contentious. The use of body armor may also lead to a false sense of security for some riders although its use has been shown to lead to reduced risk of crash-related injury and hospitalization (De Rome et al. 2011). This may encourage riders to ride at a level beyond their skill and experience leading to injury. This effect has been shown in the use of helmets in team sports, e.g., schoolboy rugby, encouraging increasingly aggressive play and increased head injury rates as a result (Finch et al. 2001).

In Becker et al.'s downhill mountain biking study, the most commonly injured areas were the lower leg (27 %) and forearm (25 %). The majority of injuries were abrasions and contusions and although over half of riders (56 %) wore shin guards, very few wore arm guards (Becker et al. 2013).

Summary

Mountain biking is a fast and exciting outdoor sport placing riders at risk of injury. A summary of injuries is listed below:

1. Injury rates are 0.37 riders per 100 h cross-country and 4.34 riders per 100 h downhill racing. An overall injury rate of 16.8 injuries per 1,000 h of exposure. The rate is higher for experts (17.9/1,000 h) compared to professional riders (13.4/1,000 h).
2. More serious injuries to the head and neck occur while falling over the handlebars rather than falling off the bike to the side, which tends to result in lower limb injuries. As a consequence of this, female riders who are lighter and as a result fall over the handlebars easier than males who tend to be more seriously injured; however, most injuries sustained from mountain biking occur to young males aged 20–39 years.
3. Etiological factors for injury are loss of control, high-speed descent, and competitive activity, i.e., riders are most likely to be injured racing downhill rather than training. Turning, loss of traction, and mechanical problems can also lead to injury.
4. The commonest injuries (60–75 %) are soft tissue abrasions, lacerations, and contusions.
5. The commonest fracture is the clavicle, and the commonest dislocation is the acromioclavicular joint.

Mountain biking is a fast adventure sport, which may lead to serious injury; however, the majority of injuries are minor and can be minimized with care and precautions. Prevention is of great importance, and further studies in this area are important.

Cross-References

▶ Head Injuries in Sports

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