16 Cycling (BMX, Mountain, Road, Track)

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16.1 Sport Characteristics

Cycling is one of the most popular physical activities worldwide and can be either used for transport or performed as a leisure activity or sport. Cycling involves several different types. The most popular types include road cycling, track cycling, mountain biking (MTB), and BMX racing. All these four types are part of the Olympic Program. Road cycling (Fig. 16.1) is usually done in pavement roads, while track cycling in outdoor or indoor velodromes, MTB in off-road terrains and BMX in off-road tracks. Competitions include road races and time trials in road cycling, sprint, endurance, or combination in track cycling, cross-country, or downhill in MTB and sprint races on specially built off-road racetracks in BMX. With the continuous increase in cycling's popularity, cycling-related injuries are becoming more and more common.

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16.2 Epidemiology

Participation in sports activities offers many health benefits, but also involves the risk of injury. Epidemiology of bicycle-related injuries is not well documented yet. The main reason is the lack of registries to record these injuries. Most available data are from hospitals and emergency departments.

Between 2011 and 2014, 5.6 million sports injuries affected children and young adults annually [1]. In the USA, during 2010–2016, the estimated annual average of visits to the emergency department (ED) for sports injuries by patients aged 5–24 years was 2.7 million [2]. Among them, pedal cycling (9.9%) was ranked as the third cause for admission in ED, after football and basketball. Furthermore, cycling has been revealed to be the most common sport-related activity associated with injuries in children aged 5–14 years in the USA at the end of the last century [3]. Mountain biking is among the sports leading to high overall injury rates in Olympic sports [4].

Sports-related concussion accounts for 1.3–9.1% of all injuries reported during cycling events [5, 6]. Rivara et al. [7] evaluated the prevalence of head injury among 3854 injured cyclists in Seattle in 2015. They found that 35% were diagnosed with facial injuries, 22.3% with scalp, skull, forehead, or mild brain injuries, and 6% with more severe brain injuries. Moreover,

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Fig. 16.1 Cyclists during a road cycling competition

according to the National Electronic Injury Surveillance System All Injury Program database from 2001 to 2012, a sport-related traumatic brain injury from cycling was the most common cause in females and the second most common cause in males presenting to an emergency department [8].

Injuries can be classified as traumatic or overuse according to their mechanism. Overuse injuries affect mainly professional or high-level athletes because of high-intense practice. Injury rates vary by sex and age. In the first well-documented study about the incidence of injuries among professional cyclists, Barrios et al. [9] found that the commonest lesions were due to overuse mechanisms (62%) instead of trauma. Patellar and Achilles tendinopathies, and anterior knee pain were the predominant causes of pain according to their study. In another study, Clarsen et al. [10] evaluated overuse lesions in 109 professional cyclists and reported lower back pain (58%) and anterior knee pain (36%) as the most prevalent problems. De Bernardo et al. [11] revealed the iliotibial band friction syndrome as the commonest overuse injury, with the majority of overuse injuries to affect the lower limb and especially the knee. Moreover, most overuse injuries were contractures and chronic muscle shortening. Regarding traumatic injury, De Bernardo et al. [11] reported that 56% of the cases corresponded to fractures, with most of them located at the clavicle (22%), and the rest mainly at the upper limb and ribs.

In an epidemiologic study about injuries during one of the biggest and most famous cycling race, the Tour de France, showed that 49% of the withdrawals were due to fractures, with almost half of them (43%) eventually requiring a surgical treatment for the sustained fracture [12]. Clavicle was also in this study the most frequently fractured bone.

One recent study in Norway with 300 patients treated after cycling injuries [13], reported that most of the injuries were light or moderate. Nevertheless, fractures and minor head injuries dominated, and 45% of patients needed surgery.

In terms of mortality-related cycling, bicycle accidents requiring hospitalization have a high mortality rate, up to 5.7% according to Dutch epidemiological data [14]. 83.3% of the accidents occurred in regular cyclists, 9.8% in race riders, 3.9% in off-road bikers and 2.9% in e-bikes, with the majority of injured patients (92.5%) reported not to wear a helmet. Older patients, multi-trauma and cerebral hemorrhages were identified as risk factors for mortality.

16.3 Causes of Injuries

The main causes of injury during cycling can be summarized under these:

1. Speed: During the races, the athletes develop usually high speed, which can lead to severe injuries if an accident, occurs.
2. Road conditions: Sharp twists or poor road surfaces can lead to accidents.
3. Exhaustion: After intense and/or long races the athletes develop fatigue that can result in exhaustion and reduction of reflexes.

16.4 Types of Injuries

Cycling injuries can practically include all known orthopedic lesions, and a wide variety of injuries, from insignificant ones, till fatal. Some common types of injuries include skin lacerations, injury to bony prominences, friction burns, saddle sores, knee pain, bone and even skull fractures. Additionally, other conditions that can occur are sprains and foreign bodies in the eyes and sometimes exhaustion and collapse of the athletes.

As aforementioned, injuries can be divided into two categories: Traumatic injuries and overuse injuries. The first ones occur most times as a result of a fall, crash, or unexpected motion. On the other hand, overuse injury is mainly caused by repetitive micro-trauma or loading of bone, joint, and soft tissue with inadequate recovery time.

Musculoskeletal injuries include strains, fractures, and dislocations and occur at the upper and lower extremities. Clavicle, wrist, and elbow are mainly affected in upper extremity, pelvis, hip, and femur in lower extremities and ribs in the trunk [15, 16]. Head, neck, and pelvis trauma are less common but can be fatal. It has been reported that 50–73% of traumatic cycling injuries ultimately result in at least one fracture [11, 14]. Superficial soft tissue injuries, such as skin abrasion/laceration are also very frequent, even though they are usually underestimated because they don't always require medical evaluation or care. Skin lesions can be characterized as contusions, lacerations, or abrasions ("road rash") (Fig. 16.2). Even when it seems that the injury involves only the superficial soft tissue, the wound can be deep. One serious, and very difficult to manage lesion, is the Morel-Lavallée lesion, which develops in the thigh, due to shearing of superficial subcutaneous tissues away from underlying fascial layers.

Several traumatic conditions can arise in the lower limb in particular. Knee joint is the most common site of overuse injury in the cyclist. It is reported that 40–60% of riders experience knee pain [17, 18]. The patellofemoral compartment is mainly affected, with persistent anterior knee pain (cyclist's knee). The most important causes are excessive pressure to the patellofemoral joint due to hill climbing or slow pace resulting in cartilage compression and damage, and poor tracking of the patella with malalignment [19, 20]. Other not rare conditions that can appear with pain around the knee are quadriceps tendinitis, and pes anserine bursitis. Quadriceps tendinitis is

Fig. 16.2 Cyclist with skin lacerations all over his trunk and limbs after a race

diagnosed as lateral or medial knee pain, and tenderness over the quadriceps tendon. Pes anserine bursitis results from repeated friction and inflammation of the hamstring insertion in the tibia, with tenderness to palpation over the pes anserine bursa, 2–3 cm below the joint line. Iliotibial band (ITB) syndrome can also cause pain at the lateral side of the knee, usually over the femoral condyle. Hip pain in the cyclist is not as common as knee pain but can exist. Typically, this is due to trochanteric bursitis or iliopsoas tendinitis. Less common injuries of the lower leg include exertional compartment syndrome, medial tibial stress syndrome, and acute bone fractures (Fig. 16.3) or stress fractures [17]. Furthermore, Achilles tendinitis can appear, especially when an improperly fitted bicycle is used.

Regarding upper extremity, the most common injury is clavicle fracture. In general, clavicle fractures are caused mostly by sports activities (45.3%) and most commonly result from bicycling (16%) [21, 22]. These fractures are managed operatively in most cases in athletes, in an attempt for a quicker recovery and earlier return to sports [23, 24] (Fig. 16.4).

Spinal injuries are most common in mountain biking. Dodwell et al. reported that mountain biking-related spine injuries consisted of almost

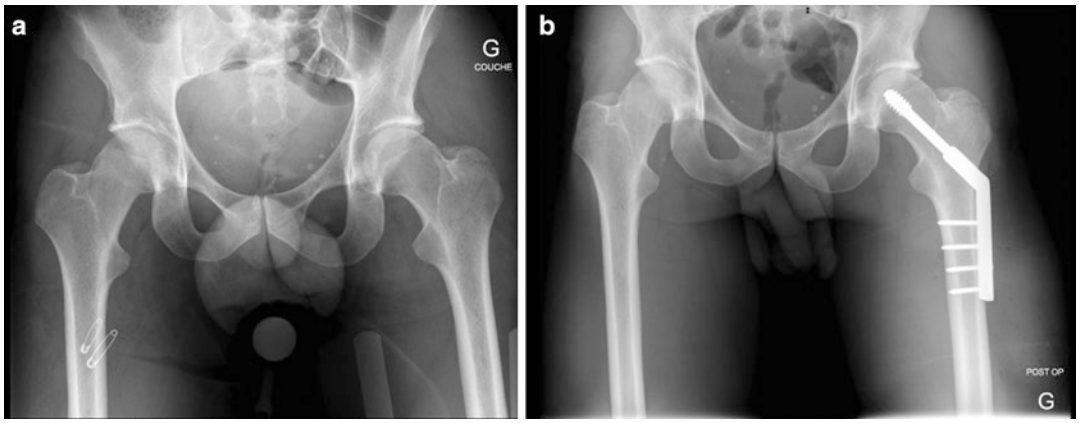

Fig. 16.3 Hip intertrochanteric fracture sustained by a cyclist during the race (**a**). Treated with DHS fixation (**b**) and returned to high-level cycling 3 months later

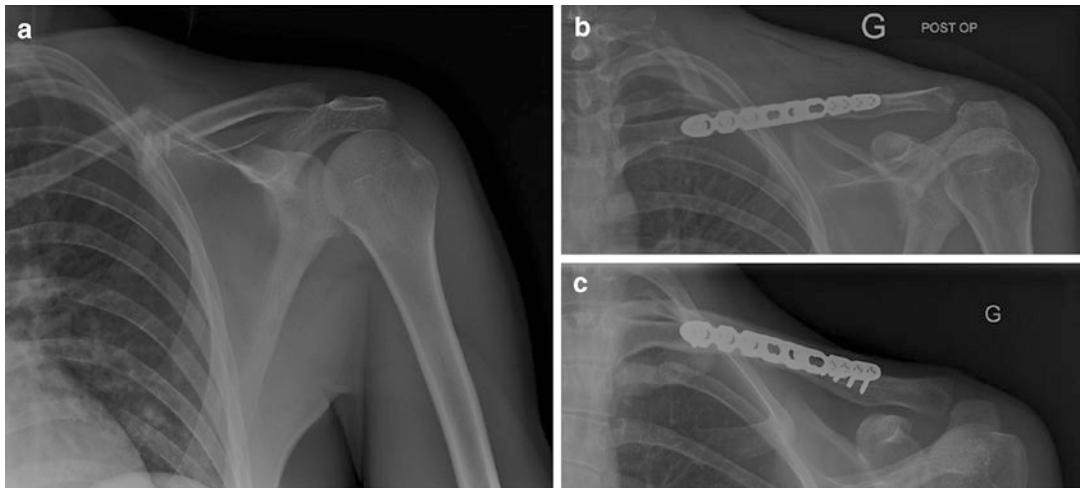

Fig. 16.4 Clavicle fracture sustained during a cycle race (**a**), treated with a plate fixation (**b**, **c**)

4% of all spinal injuries [25], with cervical spine injuries accounting for 74% of them.

Concussions are of huge importance during cycling races. However, not scarce, concussions are underestimated. Cyclists disregard head injuries and prefer to return on their bike feeling willing and able to ride. Nevertheless, they can suffer from impaired performance and reaction time, placing them at risk for further, severe injuries [26]. In professional cycling, helmets are mandatory since 2003, following the death by brain injury of a professional road cyclist in the Paris-Nice race. Their main characteristic is to prevent skull fractures and intracranial hemorrhage (Fig. 16.5).

Heat-related injuries, such as cramping, dehydration, and heat exhaustion can occur during races in extremely hot environmental conditions. According to a survey among elite cyclists who competed in the heat at the 2016 UCI Road World Cycling Championships in Qatar, 22% of respondents reported illness symptoms in the 10 days preceding the Championships, 57% of respondents had previously experienced heat-related symptoms while 17% had previously been diagnosed with exertional heat illness [27].

In terms of mountain biking, the patterns of injuries are similar. However, mountain biking appears to be a high-risk sport for severe spine injuries [16]. The most common mechanism of acute severe injury is by falling forward, mainly during downhill riding [28]. Besides spinal injuries, blunt abdominal and chest trauma are also more common among bikers of this style, caused mostly by bicycle handlebars and bar ends [29, 30].

Same injuries pattern applies to BMX riders, with abrasions and contusions to be the most predominant causes of injury [31]. However, as BMX bicycles are quite popular among young athletes and children, spinal injuries can be devastating and even life threatening in this population, especially after being involved in road traffic accidents [32].

Fig. 16.5 Helmets are the most important equipment for prevention of head injuries

16.5 Rehabilitation and Return to Sport

The protocol of rehabilitation and return to sport for traumatic or overuse injuries depends upon the nature of the lesion (Table 16.1). Time to return to competition varied widely, 7–316 days, among cyclists who suffered an injury during

Table 16.1 Return to sport correlated to the sustained injury

Lesion	Return to sport
Clavicle fractures	Stationary cycles within 1 week, outdoor cycles after 2–3 weeks, and race from 4 to 6 weeks after the trauma. In case of operative treatment, return to training and competition may be sooner
Acromioclavicular dislocations	Stationary workout after 1–2 weeks
Radial head fractures	Return to riding after 1–2 weeks (if non-displaced)
Pneumothorax and ribs fractures	Return to racing may take 4–6 weeks
Patellar tendinopathy	Home exercises for at least 12 weeks before starting to ride, or sooner if other medical therapies are also applied
Overuse injuries	Return to racing depends on the symptoms after and the specific treatments according to the symptoms
Concussion	Physical and cognitive rest until acute symptoms resolve and frequent assessments with a stepwise return to play, initially with stationary bike. Clinical evaluation is essential for a safe return to cycling

Tour de France [12]. Athletes who withdrew from the race because of an injury returned to competition significantly later (52 days on average) in comparison to those who withdrew for non-traumatic reasons. Overall, athletes who had to undergo operative treatment of their injury experienced a longer time to return to competition (77 days) compared to those treated non-operatively (44 days).

As aforementioned, clavicle fractures are of the most frequent and significant injuries that can occur in cyclists. Among cyclists from Tour de France who sustained such a fracture, the time to return to competition managed operatively, was significantly shorter than those whose the same injury was treated non-operatively [12]. Moreover, in another study it is demonstrated that plate fixation accompanied by an early post-operative rehabilitation protocol gives professional cyclists the chance to resume athletic activity 2 weeks postoperatively and return to competition 3 weeks later [21].

Concussion can be a life-threatening trauma. Subsequently, the proper evaluation and decision to return to sport after sustaining a concussion are of huge importance. Evaluation of neurological status must always be performed. Cyclists who have a history of prior concussion are at an increased risk and should undergo cognitive and motor control assessment prior to any race.

One of the most challenging situations is the assessment of the cyclist after an injury during the race. It is not a rare phenomenon that the athlete wants to resume his activity and therefore has a tendency to underestimate any early symptoms. In these cases, on-field SCAT-5 assessment and Maddock's questions can be used. However, Maddock's questions have been validated in a team sport setting, such as football, ice-hockey, and rugby and therefore cannot thoroughly apply to cycling. A recent systematic review [33] suggested the following questions as road cycling specific Maddock's questions:

1. What is the name of this race?
2. How many kilometers are there still to go in today's stage?
3. Who is the road captain today for the race?
4. What was your last race?
5. What is your coach's name?

Table 16.2 RIDE Protocol for head injury (concussion) in cyclists [6]

RIDE 1	Road-side assessment	Symptoms checklist Medical evaluation Cognitive tests
RIDE 2	Immediately after race	SCAT 5 tool Digit Symbol Substitution Testing Full neurological examination
RIDE 3	After one night rest	SCAT 5 tool Digit Symbol Substitution Testing Full neurological examination

In a very recent study, a cycling-specific RoadsIde heaD injury assEssment (RIDE) protocol has been proposed [6]. According to that, there is a three-stage diagnostic process, which consists of three phases (Table 16.2):

1. Initial road-side assessment immediately after the head impact event (RIDE 1).
2. Reassessment immediately following completion of the stage on the same day of the injury (RIDE 2).
3. Reassessment the day following the initial injury (RIDE 3).

However, in the setting of more severe situations, evaluation can be made more than three times as described above.

16.6 Prevention Strategies

In general, self-taken measures include the use of protective gear, especially helmet, the placement of correct position on the bike and adjustment of it to individual morphology. Mountain riders should not overestimate their ability, use well-fitted bikes, avoiding handlebars ends and wear the appropriate equipment, including helmets with facial protection, padded gloves and shorts, and shin pads [34]. Another essential issue is that athletes should also try to maintain a high level of

fitness, which makes them less vulnerable to the aforementioned injuries.

Extremely important are the educational programs that teach youth population to be safe drivers and cyclers, especially encouraging them to wear helmets. Refusal to wear a bicycle helmet has been proven to be the biggest predisposing factor for bicycle head injury (Fig. 16.5) [33, 34]. Specifically built bicycle roads and bicycle-friendly riding environments could lower the risk of traumatic injuries by separating bicycles from motor vehicles.

In professional racing, basic rules of prevention consist of a precise preparation of the race route and a highly experienced security team. Regarding compression and overuse injuries, bike adjustments are the most essential measure. Adjustment of the saddle (posture height) can address problems related to the lower extremity, adjustment of the handlebars (posture length) can address those related to the upper part of the trunk (extremities, neck and spine) [35].

To prevent adverse events resulting from weather conditions, the Union Cycliste Internationale (UCI), cycling's governing body, has established an *Extreme Weather Protocol* that incorporates a discussion among all members involved in a cycling race to discuss and propose modifications to the race route, depending on extreme weather conditions, such as extremely hot conditions [27]. In races that take place under high temperatures, cyclists should use a precooling strategy before competing in the heat. In addition, team doctors should be aware of the four "golden rules" of heat stroke management, which consist of early recognition, early diagnosis, rapid cooling, and on-site cooling [36].

16.7 Equipment and Protection Considerations

In terms of protective equipment, the most efficient one for cyclists is the helmet. Among others, protective equipment can include:

- Eye protection against weather, foreign bodies, and ultraviolet lights.
- Gloves.
- Bicycle shorts with padding integrated.
- Cycling shoes with toe clips or sole cleats that attach the foot to the pedals.
- Bright color clothes and reflective vests to improve cyclists' visibility on the road, in particular when poor weather or in the evenings.

Regarding pedals, the ideal position of the foot on the pedal is the anterior foot position. It decreases the stress across the knee ligaments and gives a mechanical advantage to gastrocnemius and soleus muscles to turn the crank.

Besides the personal prevention equipment, medical cover during races is of high importance. Well-trained and equipped medical personnel should be present during cycling events, with the accompaniment of at least one ambulance.

References

1. Sheu Y, Chen LH, Hedegaard H. Sports- and recreation-related injury episodes in the United States, 2011–2014. Natl Health Stat Report. 2016;(99):1–12.
2. Rui P, Ashman JJ, Akinseye A. Emergency department visits for injuries sustained during sports and recreational activities by patients aged 5–24 years, 2010–2016. Natl Health Stat Report. 2019;(133):1–15.
3. Conn JM, Annest JL, Gilchrist J. Sports and recreation related injury episodes in the US population, 1997–99. Inj Prev. 2003;9:117.
4. Engebretsen L, Soligard T, Steffen K, Alonso JM, Aubry M, Budgett R, et al. Sports injuries and illnesses during the London Summer Olympic Games 2012. Br J Sports Med. 2013;47:407.
5. Roi GS, Tinti R. Requests for medical assistance during an amateur road cycling race. Accid Anal Prev. 2014;73:170.
6. Heron N, Elliott J, Jones N, Loosemore M, Kemp S. Sports-related concussion (SRC) in road cycling: the RoadsIde heaD Injury assEssment (RIDE) for elite road cycling. Br J Sports Med. 2020;54:127.
7. Rivara FP, Thompson DC, Thompson RS. Epidemiology of bicycle injuries and risk factors for serious injury. Inj Prev. 2015;21:47.
8. Coronado VG, Haileyesus T, Cheng TA, Bell JM, Haarbauer-Krupa J, Lionbarger MR, et al. Trends in sports- and recreation-related traumatic brain injuries treated in US emergency departments: the National Electronic Injury Surveillance System-All Injury Program (NEISS-AIP) 2001–2012. J Head Trauma Rehabil. 2015;30:185.

9. Barrios C, Sala D, Terrados N, Valenti JR. Traumatic and overuse injuries in elite professional cyclists. Sport Exerc Inj. 1997;3(4):176–9.
10. Clarsen B, Krosshaug T, Bahr R. Overuse injuries in professional road cyclists. Am J Sports Med. 2010;38:2494.
11. de Bernardo N, Barrios C, Vera P, Laíz C, Hadala M. Incidence and risk for traumatic and overuse injuries in top-level road cyclists. J Sports Sci. 2012;30(10):1047–53.
12. Haeberle HS, Navarro SM, Power EJ, Schickendantz MS, Farrow LD, Ramkumar PN. Prevalence and epidemiology of injuries among elite cyclists in the Tour de France. Orthop J Sport Med. 2018;6(9):2325967118793392.
13. Mjåland O, Nygaard A, Storm-Larsen C, Brommeland T. Sykkelrelaterte skader på Sørlandet sykehus Kristiansand. Tidsskr den Nor Laegeforening. 2019.
14. de Guerre LEVM, Sadiqi S, Leenen LPH, Oner CF, van Gaalen SM. Injuries related to bicycle accidents: an epidemiological study in The Netherlands. Eur J Trauma Emerg Surg. 2020;46(2):413–8.
15. Sillén K, Wallenius V. Rates and types of injuries during the three consecutive years 2016 to 2018 of the Vätternrundan—one of the world's largest and longest bicycle races. Traffic Inj Prev. 2019;20:749.
16. Ansari M, Nourian R, Khodaee M. Mountain biking injuries. Curr Sports Med Rep. 2017;16:404.
17. Wanich T, Hodgkins C, Columbier JA, Muraski E, Kennedy JG. Cycling injuries of the lower extremity. J Am Acad Orthop Surg. 2007;15:748.
18. Wilber CA, Holland GJ, Madison RE, Loy SF. An epidemiological analysis of overuse injuries among recreational cyclists. Int J Sports Med. 1995;16(3):201–6.
19. Dettori NJ, Norvell DC. Non-traumatic bicycle injuries: a review of the literature. Sports Med. 2006;36:7.
20. Ruby P, Hull ML, Kirby KA, Jenkins DW. The effect of lower-limb anatomy on knee loads during seated cycling. J Biomech. 1992;25(10):1195–207.
21. van der Ven DJC, Timmers TK, Broeders IAMJ, van Olden GDJ. Displaced clavicle fractures in cyclists. Clin J Sport Med. 2017;29(6):465–9.
22. Postacchini F, Gumina S, De Santis P, Albo F. Epidemiology of clavicle fractures. J Shoulder Elb Surg. 2002;11:452.
23. Ranalletta M, Rossi LA, Piuzzi NS, Bertona A, Bongiovanni SL, Maignon G. Return to sports after plate fixation of displaced midshaft clavicular fractures in athletes. Am J Sports Med. 2015;43:565.
24. Meisterling SW, Cain EL, Fleisig GS, Hartzell JL, Dugas JR. Return to athletic activity after plate fixation of displaced midshaft clavicle fractures. Am J Sports Med. 2013;41:2632.
25. Dodwell ER, Kwon BK, Hughes B, Koo D, Townson A, Aludino A, et al. Spinal column and spinal cord injuries in mountain bikers: a 13-year review. Am J Sports Med. 2010;38:1647.
26. Silberman MR. Bicycling injuries. Curr Sports Med Rep. 2013;12:337.
27. Racinais S, Nichols D, Travers G, Moussay S, Belfekih T, Farooq A, et al. Health status, heat preparation strategies and medical events among elite cyclists who competed in the heat at the 2016 UCI Road World Cycling Championships in Qatar. Br J Sports Med. 2020;54:1003.
28. Chow TK, Kronisch RL. Mechanisms of injury in competitive off-road bicycling. Wilderness Environ Med. 2002;13:27.
29. Kim PTW, Jangra D, Ritchie AH, Lower ME, Kasic S, Brown DR, et al. Mountain billing injuries requiring trauma center admission: a 10-year regional trauma system experience. J Trauma. 2006;60(2):312–8.
30. Kotlyar S. Cycling injuries in Southwest Colorado: a comparison of road vs trail riding injury patterns. Wilderness Environ Med. 2016;27:316.
31. Brøgger-Jensen T, Hvass I, Bugge S. Injuries at the BMX cycling European Championship, 1989. Br J Sports Med. 1990;24:269.
32. Piggot J, Graham HK, Henderson SA. Death and serious injury in child motorcyclists. Br Med J. 1987;294(6582):1259.
33. Elliott J, Anderson R, Collins S, Heron N. Sports-related concussion (SRC) assessment in road cycling: a systematic review and call to action. BMJ Open Sport Exerc Med. 2019;5:e000525.
34. Carmont MR. Mountain biking injuries: a review. Br Med Bull. 2008;85:101.
35. Nehoda H, Hochleitner BW, Hourmont K, Weiß H, Lanthaler M, Tschmelitsch J. Central liver hematomas caused by mountain-bike crashes. Injury. 2001;32(4):285–7.
36. Racinais S, Casa D, Brocherie F, Ihsan M. Translating science into practice: the perspective of the Doha 2019 IAAF world championships in the heat. Front Sport Act Living. 2019; https://doi.org/10.3389/fspor.2019.00039.