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Mountain biking injuries: a review

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Introduction: Mountain biking is a fast, exciting adventure sport with increasing numbers of participants and competitions.

Methods and results: A search of PubMed, Medline, CINAHL, DH data, and Embase databases was performed using the following keywords: mountain, biking and injuries. This revealed 2 review articles, 17 case controlled studies, 4 case series and 5 case reports. This review summarises the published literature on mountain biking injuries, discusses injury frequency and common injury mechanisms.

Conclusions: Riders are quick to adopt safety measures. Helmet usage is now increasingly common and handlebar adaptations have been discontinued. Although the sport has a reputation for speed and risk with research and awareness, injury prevention measures are being adopted making the sport as safe as possible.

Keywords: mountain biking/injury

Introduction

Mountain biking is a fast, exciting adventure sport with increasing numbers of participants and competitions. This article reviews and compares the published literature on mountain-biking injuries, discusses injury frequency, common injury mechanisms and specific injuries related to mountain bike riding.

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Historical background

In the western world, the mountain bike is the most popular type of bicycle to ride and off road cycling as a recreational activity is currently enjoying a period of popularity. Competitive off road cycling or mountain biking is also increasingly popular. There is an annual World Cup Series and a World Championships organised by the governing body the Union Cycliste Internationale (UCI) and after demonstration at the

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Atlanta Olympic Games in 1996; the mountain biking was awarded full Olympic status at the 2000 Games in Sydney.[1]

MTB competitions were previously limited to the disciplines of Cross Country and Downhill, but more recently Dual Slalom or four Cross and Free or Trials 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 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 four cross and Dual Slalom races, riders race head to head over a prepared artificial course. Although physical contact is not allowed, riders jostle with each other for the best line and so falls commonly occur. Free or Trials riding involves performing stunts and jumps over obstacles. Speeds are low, but the height from riders may fall is considerable.

Mountain biking has a reputation as a fast, exciting adventure sport that is rapidly developing. This review demonstrates how research has followed the sport progression and how mountain-biking injuries are more appreciated.

Methods and results

A search of PubMed, Medline, CINAHL, DH data and Embase databases was performed using the following keywords: mountain, biking and injuries.

This revealed 2 review articles,[2,3] 17 case-controlled studies and cross-sectional surveys,[4–20] 6 case series and 5 case reports. There was one prospective study. These studies are presented in Table 1.

Injury rates and demographics

In summary, the risks of injury are 0.49% for cross-country riding and 0.51% for downhill. Injury rates are 0.37 riders per 100 h cross country and 4.34 riders per 100 h downhill racing.

More serious injuries to the head and neck occur whilst 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 male, tend to be more seriously injured than male riders; however, most injuries sustained mountain biking occur to young males aged 20–39 years.

Table 1 Published case controlled studies and cross sectional surveys of mountain biking injuries

Reference	Year of study	Type	Method	Control/injury definition	Outcome	Additional data
Chow *et al.*[4]	1993	Cross-sectional study	Questionnaire survey of bicycling club: injuries divided into mild vs. mod/severe	Mild: no hospitalisation	MTB more frequent, but not more severe injuries	Demographics Injury distribution Ride characteristics
Pfeiffer[5]	1992	Cross-sectional survey of competing riders	Comparison of groups surveyed: 1991, 1992 and 1993	No formal control group. Injury is defined as one which forces the rider to stop and seek attention before returning to participation	Females more likely to get injured. Wounds most common injury. Knee most common area injured	Males more likely to sustain an injury during racing
Krosnich and Rubin[6]	1992	Cross-sectional study	Questionnaire survey of 21 bicycling clubs	Injury: sought medical attention or unable ride for 1 day	Four times risk injury if competing	Most common: fracture, shoulder. Loss control, high-speed descent and competing main risk factors
Rajapaske and Horne[7]	1992–1994	Cohort study of forearm and wrist fractures in MTB riders	Questionnaire and clinical examination	No control. Injury defined as a fracture	MTB accidents can result in significant injury, majority do well, with min. discomfort and no long-term consequences	Commonest injury: undisplaced radial head fracture
Krosnich *et al.*[8]	1995	Case–control series. Controls were the different groups of injured riders with respect to each condition	Riders sustaining injury at three off-road races completed questionnaires and were examined following injury	3 groups of riders	Injury rates 0.49% for CC and 0.51% for DH. 0.37 injuries per 100 h of racing in CC and 4.34 per 100 h in the DH	Risk of being injured in race is similar in both CC and DH. Greater severity of injury when fall forward over the handlebars. Female riders more likely to fall forwards than male riders and more likely injured

Continued

Table 1 *Continued*

Reference	Year of study	Type	Method	Control/injury definition	Outcome	Additional data
Krosnich *et al.*[9]	1994	Cross-sectional study of riders at a single event. Mammoth Mountain	Injured riders completed a questionnaire interview and were examined by a research physician	Injury considered significant if occurred during competition and prevented the rider from completing that event	Overall injury rate 0.40%, 81.2% injuries occurred whilst DH. Abrasions were most common injury. Injuries more severe when riders were thrown from bikes. Head to head riding riskier	The small number of injuries that occur in 1 event may not reflect those that occur during a long sports season
Rivara *et al.*[10]	1992–1994	Cross-sectional study	Questionnaire survey of those injured whilst riding off road	No controls. Injury is defined as any rider who attends Emergency Dept with their injury	3.7% riders injured were sustained cycling off road. 4% cyclists had severe injuries (ISS $>$ 8). Upper extremity and lower extremity were most likely to be injured. Abrasion was the most common injury	Majority of injuries minor. Off road cyclists are less likely to have head injuries than other cyclists? higher rate of helmet usage (4x)
Gassner *et al.*[11]	1991–1996	Cross-sectional survey	Notes review and comparison of riders referred to Max. Fax. Dept	Max fax injury any rider referred to clinic	Severe injury profiles of MTB riders compared to road cyclists. 15.2% Le Fort fractures. Facial rather than Jaw fractures	Recommend face guards for MTB riders
Gassner, Hackl, Tuli, *et al.*[12]	1991–1996	Cohort studies	Comparison between bicyclists and MTB riders. Review patient records	Road bicyclist	More severe injury profile with MTB riders: more facial bone fractures	Increased face guard use together with helmets for MTB and bicycle riders
Grooten *et al.*[13]	1997	Cross-sectional survey	Mailed self administered questionnaire survey to riders of Swedish Cross Country World Cup	Injury definitions: Minor: discomfort whilst riding, Major: prevents from riding	75% riders sustain a major or minor injury. 73% riders sought medical treatment. Minor discomfort whilst riding, Major injury prevents from riding. Those who train more hours per week incurred fewer injuries	Better dosed training and the use of better equipment may prevent minor and major injuries

Jeys *et al.*[14,15]	1999	Cross-sectional study	Notes review from patients seen in Orthopaedic Fracture Clinic		23% riders reqd. ops. most common injury, clavicle fracture	
Frauscher *et al.*[16]		Case–control series	Ultrasound comparison of the scrotal contents of mountain bikers compared with non-bikers	Non-bikers acted as controls	94% bikers had abnormal scrotal contents. 46% had history of intermittent scrotal discomfort. Commonest: 81% scrotal calculi, 46% epididymal cysts. Significant differences were reported	High prevalence of extratesticular and testicular disorders in MTB riders
Quigley and Boyce[17]	2004	Cross-sectional survey	Questionnaire and notes review of riders attending A&E dept	No control. Injury definition is anybody attending A&E	Peak incidence in June. 8% were admitted. Low speed, 65% cases. 18% whilst competing, 69% in CC, 21% in DH	
Gaulrapp *et al.*[18]	2000	Cross-sectional survey of German magazine readership with >1 years experience off-road riding	Subscribers were randomly selected, subscribers who had not sustained an injury asked not to reply	Injury definitions: minor, pause in biking for <1 week; Severe, pause >3 weeks, intensive OP treatment or hospitalisation	Overall risk rate of 0.6% per year and per injury per 1000 h riding. 75% injuries minor 10% injuries severe Commonest site: calf and knee. Commonest fracture: shoulder	Uses the National Athletic Injury Reporting System
Chow and Krosnich[19]	1994–1998	Cross-sectional survey of those injured	Interview and examination of all riders competing at seven off-road cycling events		Most injuries minor and involved the extremities (70.5%). Falling over the handlebars results in injury more frequently than falling to the side and injuries were more severe (ISS 3.4 versus 1.7)	Falling over the handlebars produced more head and neck injuries whereas falling to the side produced more lower limb injuries

Continued

Table 1 *Continued*

Reference	Year of study	Type	Method	Control/injury definition	Outcome	Additional data
Kim *et al.*[20]	1992–2002	Cross-sectional study	Review of Trauma Registries, i.e. Notes Review	Entry requirements: presentation within 7 days of injury, admission for 3 or more days, ISS $>$12 and expiration in hospital	Three times inc. in incidence of mountain biking injuries over 10 year period. Ortho. Injuries most common 46.5%. High operative rate was observed 38% of injuries and 66% of patients required surgery. One patient died from his injuries	Mountain biking is a growing cause of serious injuries

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.

The commonest injuries (60–75%) are soft-tissue abrasions, lacerations and contusions. The commonest fracture is the clavicle and the commonest dislocation is the acromioclavicular joint.

Limitations of research

Although there are many studies reporting mountain-biking injury, it is difficult to compare these directly and extrapolate information. These studies range from the cross-sectional survey of the readership of MTB magazines to the interview of injured riders at national and international competitions.

One of the key difficulties is the determination of when an injury has occurred. This difficulty is not just restricted to mountain biking and occurs in other sports.[21] Self-reported injuries may vary from superficial abrasions and contusions to life-threatening falls. Some studies have tried to define injuries as to whether the rider is unable to complete an event if an injury occurs during competition or if a rider subsequently misses a days riding. The extreme nature of MTB competitors must be considered and certainly in downhill events, riders are very 'pumped up' and may complete events even with significant injuries, e.g. fractures, if they are mechanically able to ride.

Questionnaire surveys may be more accurate than event-side medical care reporting, as riders may note abrasions and contusions on a survey of recreational riders but professional riders may not consider these to be significant enough injuries to trouble event medical support. Surveys may more accurately report a prolonged period of potential exposure compared with the duration of a single or series of events.

Some studies have used standardised assessment tools such as the Abbreviated Injury Scale[22] or the Injury Severity Score.[23] These tend to be studies at relatively large trauma units for monitoring hospital admissions and may not necessarily reflect the true frequency of injury. The use of speciality referral, i.e. fracture clinic, may show a higher proportion of fractures and may suggest a higher frequency of required operative intervention. It is not surprising that a few injured riders presenting to medical services over a short period of time can overwhelm local resources.[24] The American studies tend to involve riders racing on dirt and gravel mountain roads at ski areas. Within Europe the terrain may be more mixed, involving grass, woodland and even small

proportion of tarmac surface. These differing terrain types may produce different injury patterns.

Specific injury patterns

There are several studies and case reports focussing on specific anatomical areas, and these deserve further discussion. These include the head and face, the cervical spine, the upper limbs, the abdominal viscera, the perineum and the lower limbs.

Head and face

Kelly has reported that 13% of sport-related head injuries presenting to an emergency department were sustained whilst cycling.[25] But in McDermott's study of 1710 bicycling injuries, helmet use has reduced the risk of head injuries by 39% and the risk of facial injury by 28%.[26] The importance of head protection has been appreciated with the majority of off-road MTB riders wearing helmets [15].

Head injury has even resulted in a dislocation of the incus into the external auditory meatus,[27] so protection for the whole of the cranial vault must be considered.

Bicyclists and mountain bikers are prone to facial trauma, and Chow[28] has suggested that conventional bicycle helmets may not provide adequate protection for the face whilst mountain biking.[28] MTB riders 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%).[11,12] Of the facial fractures, 15.2% was maxillary fractures.

Dental injuries can also occur. This may range from the chipping of teeth to the degloving of the mandibular mucosa.[29] The high incidence of facial trauma has led to the increased use of helmets with attached face protectors and face guards. The use of dental guards has not been reported; however, this is likely to be negligible.

Cervical spine

With the speeds involved in downhill racing and the frequency, mechanism and forces involved in over the handlebar falls, it is surprising that more cervical spine injuries have not been reported. A fall onto the top of the head could result in a flexion injury, whereas a fall onto the face could results in hyperextension.[30] A series of three patients have been left paraplegic as following falls from mountain bikes.[31] The riders in this series had sustained either over the handle bar 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's series of patients.[20]

Upper limbs

The upper limb extremities have already been identified as an area commonly injured whilst falling from the bike. This may be either in an attempt to stop the fall by outstretching a hand or in an attempt to protect injury to the face or head. In Rajapaske's series of forearm injuries, the distal radius and scaphoid were commonly injured bones (30 and 28%, respectively); however, surprisingly the commonest fracture was the radial head (35%).[7] Prolonged cycle riding of any form, as been shown to be associated with nerve compression at the wrist by Patterson, with 92% riders reporting sensory or motor or both symptoms[32] and hypothenar hammer syndrome, i.e. Ulna artery occlusion, has been reported with the vibrations of off road riding.[33]

Abdominal viscera

Large series of patients with liver haematomata sustained during mountain-biking crashes have been reported.[34] All of these patients had blunt focal blows to the right side of the abdomen due to the handlebars, and all were using 'bar ends' on their handle bars. These forward facing bar extensions allow additional riding positions for comfort and energy efficiency. Following a media information programme of the implication of bar ends for abdominal injury in Austria, bar ends cease to be used in mountain biking. Nehoda's group have noticed an almost complete cessation of liver injury from the sport.

Kim[20] has 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%).[20]

Perineum

Perineal numbess due to nerve compression after long periods of sitting on a hard saddle will be familiar to the majority of riders,[35] and modern saddles are moulded to reduce pressure on the pudendal nerves in the perineum.

The scrotal contents can be subjected to repeated microtraumatisation during mountain biking. A total of 96% of mountain bikers had pathological abnormalities of scrotal contents compared with 16% of a control group on ultra sound examination.[16] The most common abnormal ultrasound findings were scrotal calculi (81%), epididymal cysts (46%), epididymal calcifications (40%), testicular calcifications (32%), hydoceles (28%) and varicoceles (11%).[36] Short padding and alteration of the saddle position could help reduce this incidence.

It is not just the male genitalia which have been shown to suffer from prolonged riding. Female road cyclists have been reported to develop unilateral vulval hypertrophy.[37] A case of external iliac artery occlusion has been reported in a young female cyclist although this is not thought to have a gender predeliction.[38]

Lower limbs

The shins of bikers are vulnerable to scratches and scrapes when riding through undergrowth, but this can be minimised by wearing long trousers, gaiters or shin guards. Riders find it essential to have a firm foothold on the pedal to permit stability and straps, or quick release pedals have been developed for this purpose. Quick release pedals hold the shoe securely onto the pedal improving power transfer,[39] but conversely make it more difficult to put the foot down onto the ground when dismounting or 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 significant pretibial lacerations, an area prone to poor healing and Patel has reported a series which required debridement under anaesthesia and skin grafting.[40] Failure to remove the foot from the pedal can result in the cyclist toppling over onto their side. These falls can result in a direct blow to the hip resulting in a neck of femur fractures[41] or acetabulum fractures.[42]

Although classically described falling off horses with the foot caught in the stirrup, Lisfranc's dislocation of the mid-foot has also been described in a mountain biker. In Callaghan'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 whilst trying to put his foot on the ground.[43]

Future prevention

This review recommends that 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. They should also wear helmets with facial protection, padded gloves and shorts, use cushioned seats and shin protection.

Future research

The gold standard of the randomised, prospective, controlled study is probably impossible to perform in this sport as riders will always take

steps and alter their riding to prevent injury. Comparative cohort studies for injury prevention have been performed retrospectively; therefore, it is possible that the highest standard of research possible is being performed.

Summary

Mountain biking is a fast, exciting adventure sport that may lead to serious injury. However, the majority of injuries are minor and can be minimised with care and precautions.

References

1 International Olympic Committee (2000) *The Games of the XXXVIII Olympiad Mountain Bike Official Results Book*. Lausanne: International Olympic Committee.
2 Pfeiffer RP, Krosnich RL. (1995) Off road cycling injuries: an overview. *SportsMed*, **19**, 311–325.
3 Krosnich RL, Pfeiffer RD (2002) Mountain biking injuries: an update. *SportsMed*, **32**, 523–537.
4 Chow TK, Bracker MD, Patrick K (1993) Acute injuries from mountain biking. *West J Med*, **159**, 145–148.
5 Pfeiffer RP (1994) Off road bicycle racing injuries—The NORBA Pro/Elite Category. *Clin Sports Med*, **13**, 207–218.
6 Kronisch RL, Rubin AL (1994) Traumatic injuries in off road bicycling. *Clin J Sport Med*, **4**, 240–244.
7 Rajapaske BN, Horne G, Devane P (1996) Forearm and wrist fractures in mountain bike riders. *N Z Med J*, **109**, 147–148.
8 Kronisch RL, Pfeiffer RP, Chow TK (1996) Acute injuries in cross country and downhill off road cycle racing. *Med Sci Sports Exerc*, **28**, 1351–1355.
9 Krosnich RL, Chow TK, Simon LM *et al*. (1996) Acute injuries in off-road bicycle racing. *Am J Sports Med*, **24**, 88–94.
10 Rivara FP, Thompson DC, Thompson RS *et al*. (1997) Injuries involving off road cycling. *J Fam Prac*, **44**, 481–485.
11 Gassner R, Tuli T, Emshoff R *et al*. (1999) Mountain biking—a dangerous sport: comparison with bicycling on oral and maxillofacial trauma. *Int J Oral Maxillofac Surg*, **28**, 188–191.
12 Gassner RJ, Hackl W, Tuli T *et al*. (1999) Differential profile of facial injuries among mountain bikers compared with bicyclists. *J Trauma*, **47**, 50–54.
13 Grooten WJA, Genberg S, Jonasson L *et al*. (1999) Injuries among Swedish mountainbike cyclists at an elite level. *J Sports Traumatol Rel Res*, **21**, 196–205.
14 Jeys LM, Cribb G, Toms AD *et al*. (2001) Mountain biking injuries in rural England. *Br J Sports Med*, **35**, 197–199.
15 Jeys L, Cribb G, Toms A, Hay S (2001) Bicycle helmets: mountain biking is particularly dangerous. *BMJ*, **322**, 1065.
16 Frauscher F, Klauser A, Hobisch A *et al*. (2000) Subclinical microtraumatisation of the scrotal contents in extreme mountain biking. *Lancet*, **356**, 1414.
17 Quigley MA, Boyce SH (2005) Mountain biking injuries in south west Scotland: an analysis of injuries attending A&E. Presented at the British Association of Sport and Exercise Medicine meeting 2005 Edinburgh. *Br J Sports Med*, **40**, 90.
18 Gaulrapp H, Weber A, Rosemeyer B (2001) Injuries in mountain biking. *Knee Surg Sports Traumatol Arthrosc*, **9**, 48–53.

19 Chow TK, Kronisch RL (2002) Mechanisms of Injury in competitive off road bicycling. *Wild Environ Med*, **13**, 27–30.
20 Kim PTW, Jangra D, Ritchie AH *et al.* (2006) Mountain biking injuries requiring trauma centre admission. *J Trauma*, **60**, 312–318.
21 Noyes FR, Lindenfeld TN, Marshall MT (1988) What determines an athletic injury (definition)? Who determines an injury (occurrence)? *Am J Sports Med*, **16**, S65–S68.
22 Association for the advancement of automotive medicine, Committee on Injury Scoring. The Abbreviated Injury Scale-1990. Des Plains, IL: Association for the Advancement of Automotive Medicine, 1990.
23 Baker SP, O'Neill B, Haddon N *et al.* (1974) The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*, **14**, 187–196.
24 Carmont MR, Daynes R, Sedgwick DM (2005) The Impact of an Extreme Sports Event on a District General Hospital. *Scot Med J*, **50**, 106–108.
25 Kelly KD, Lissel HL, Rowe BH *et al.* (2001) Sport and recreation-related head injuries treated in the emergency department. *Clin J Sports Med*, **11**, 77–81.
26 McDermott FT (1993) The effectiveness of bicyclist's helmets: a study of 1710 casualties. *J Trauma*, **34**, 834–845.
27 Saito T, Kono Y, Kukuoka Y *et al.* (2001) Dislocation of the incus into the external auditory canal after mountain biking accident. *ORL*, **63**, 102–105.
28 Chow TK, Corbett SW, Farstad DJ (1995) Do conventional bicycle helmets provide adequate protection in mountain biking? *Wild Environ Med*, **6**, 385–390.
29 Revuelta R, Sandor GKB (2005) Degloving injury of the mandibular mucosa following an extreme sport accident: a case report. *J Den Chi*, **72**, 104–106.
30 Allen BL Jr, Ferguson RL, Lehmann TR, O'Brien RP (1982) A mechanistic classification of closed, indirect fractures and dislocations of the lower cervical spine. *Spine*, **7**, 1–27.
31 Aspingi S, Dussa CU, Soni BM (2006) Acute cervical spine injuries in mountain biking. *Am J Sports Med*, **34**, 487–489.
32 Patterson JMM, Jaggars MM, Boyer MI (2003) Ulnar and median nerve palsy in long distance cyclists. *Am J Sports Med*, **31**, 585–589.
33 Applegate KE, Speigel PK (1995) Ulnar artery occlusion in mountain bikers. *J Sports Med Phys Fit*, **35**, 232–234.
34 Nehoda H, Hochleitner BW, Hourmont K *et al.* (2001) Central liver haematomas caused by mountain bike crashes. *Injury*, **32**, 285–287.
35 Ricchuti VS, Haas Ca, Seftel AD *et al.* (1999) Pudendal nerve injury associated with avid cycling. *J Urol*, **162**, 2099–2100.
36 Frauscher F, Klauser A, Stenzl A *et al.* (2001) US findings in the scrotum of extreme mountain bikers. *Radiology*, **219**, 427–431.
37 Humphries D (2002) Unilateral vulval hypertropy in competitive female cyclists. *Br J Sports Med*, **36**, 463–464.
38 Korsten-Reck U, Rocker K, Schmidt-Trucksass A, Schumacher YO, Striegel H, Pimpler H, Dickhuth HH (2007) External Iliac artery occlusion in a young female cyclist. *J Sports Med Phys Fit*, **47**, 91–95.
39 Fregly B, Zajac F (1996) A state space analysis of mechanical energy generation, absorption and transfer during pedalling. *J Biomech*, **29**, 81–90.
40 Patel ND (2004) Mountain bike injuries and clipless pedals: a review of three cases. *Br J Sports Med*, **38**, 340–341.
41 Slootmans FC, Biert J, de Waard JW *et al.* (1995) Femoral neck fractures in bicyclists due to clipless pedals. *Ned Tijdschr Geneeskd*, **139**, 1141–1143.
42 Barnett B (1993) More on mountain biking. *West J Med*, **159**, 708.
43 Callaghan MJ, Jane MJ (2000) Fracture dislocation of the tarsometatarsal (Lisfranc's) joint by a mountain biker. *Phys Ther Sport*, **1**, 15–18.