ORIGINAL RESEARCH

The Epidemiology of Mountain Bike Park Injuries at the Whistler Bike Park, British Columbia (BC), Canada

Zachary Ashwell, MSME; Mary Pat McKay, MD, MPH; Jeffery R. Brubacher, MD, MSc; Annie Gareau, MD

From the School of Medicine (Mr Ashwell), and the Department of Emergency Medicine (Dr McKay), The George Washington University, Washington, DC; the Department of Emergency Medicine (Dr. Brubacher), The University of British Columbia, Vancouver, BC, Canada; and Whistler Health Care Centre (Dr Gareau), Whistler, BC, Canada.

Objective.—To describe the epidemiology of injuries sustained during the 2009 season at Whistler Mountain Bike Park.

Methods.—A retrospective chart review was performed of injured bike park cyclists presenting to the Whistler Health Clinic between May 16 and October 12, 2009.

Results.—Of 898 cases, 86% were male (median age, 26 years), 68.7% were Canadian, 19.4% required transport by the Whistler Bike Patrol, and 8.4% arrived by emergency medical services. Identification of 1759 specific injury diagnoses was made, including 420 fractures in 382 patients (42.5%). Upper extremity fractures predominated (75.4%), 11.2% had a traumatic brain injury, and 8.5% were transferred to a higher level of care: 7 by helicopter, 62 by ground, and 5 by personal vehicle. Two patients refused transfer.

Conclusions.—Mountain bikers incurred many injuries with significant morbidity while riding in the Whistler Mountain Bike Park in 2009. Although exposure information is unavailable, these findings demonstrate serious risks associated with this sport and highlight the need for continued research into appropriate safety equipment and risk avoidance measures.

Key words: mountain biking, epidemiology, injury

Introduction

The sport of mountain biking has grown significantly from its inception more than 30 years ago and is now a mainstream activity with worldwide participation on both recreational and professional levels. In 2009, nearly 28% of more than 38 million Americans who regularly bicycled were riding mountain bikes.¹ Mountain biking in which the rider navigates down steep slopes and technical terrain with manmade jumps, gaps, and obstacles, also referred to as “free-riding,” has become very popular, accounting for almost 50% of the total participation in some off-road cycling events.² The popularity of this style of riding has been spurred by the development of lift-accessed mountain biking in which participants make summertime use of chairlifts at ski resorts to gain access to longer and more technical terrain. Lift-accessed mountain biking enables riders to increase the

amount of downhill riding they can do in a given day while minimizing laborious uphill climbs.

As of the 2011 season, at least 42 ski resorts across the United States and Canada have opened their mountains to summer riding.³ Operating seasons for such locations are nearly 5 months long, and resorts are expanding access and building more technical terrain, including larger jumps and drops as well as steeper and rougher descents.^{4,5} Advances in equipment, rider skill sets, and increased participation in the sport have increased the number of people exposed to the risk of injury.^{6–11} In addition, the ease of access to difficult terrain provided by the lifts likely increases each rider’s exposure to high-speed complex terrain and may therefore increase the injury risk per descent as well as the number of descents per day.

Because lift-accessed downhill mountain biking is a relatively new sport, research on its associated risks has been quite limited; we could find no reports of injuries occurring during lift-accessed downhill biking in a recent PubMed search. Understanding the epidemiology of in-

Corresponding author: Mary Pat McKay, MD, MPH, Professor, Emergency Medicine and Public Health, 2150 Pennsylvania Ave, Suite 2B, Washington, DC 20037 (e-mail: mpmckay@gmail.com).

juries associated with the sport could lead to improvements in sport-specific protective gear as well as more appropriate staffing, training, and resources for mountain-based bike patrols and nearby medical care providers. The objective of this study was to evaluate the types and extents of injuries occurring during one season at a downhill bike park that is serviced by a single emergency care clinic in Whistler, British Columbia (BC).

Methods

SETTING

The Whistler Blackcomb Mountain Bike Park in Whistler, BC, has 3 lifts offering riders access to 45 trails totaling more than 250 km in length and more than 1175 m of vertical height. Trails range in difficulty from beginner (17%) to intermediate (23%) to expert (60%). There are wide green trails without manmade structures that flow smoothly downhill around broad, banked turns and are just steep enough to eliminate the need to pedal for the entire length of the trail. Black trails (usually ridden at much higher speeds) contain multiple manmade jumps, some of which allow a rider to easily gain 8 feet of vertical air and 10 to 15 feet of horizontal distance. Other trails are more technical but slower speed; steeper with large sections of rocks and roots with off-camber sections. Most of the trails fall somewhere in between, with a mix of jumps, rock rolls, drops, and rocky or root-filled sections. Access to the mountain generally runs from mid-May through mid-October, with hours ranging from 10 AM to 5 PM in the early and late season and until 8 PM during the peak summer season. Park riders are required to wear helmets and use bikes with a minimum wheel diameter of 24 inches, and must be at least 6 years of age. Although not required, full face shield helmets as well as additional body armor are strongly encouraged.

Much like their winter ski operations, the park hires a trail crew to maintain the trails in safe condition and a bike patrol of emergency medical technicians (EMTs) to stabilize and transport injured riders off the mountain. Unless emergent helicopter rescue is required directly from the mountain, all individuals who are injured while riding in the park and require physician evaluation are transported to the single, centrally located urgent care center in Whistler village (the Whistler Health Clinic), located 1 km from the base of the mountain. Injured riders may refuse transport from the bike patrol and may self-refer without the bike patrol's involvement. There may also be agreement between the two that physician level care is unnecessary. The Whistler clinic is staffed by physicians who are mostly family physicians with 1

year of extra training in emergency medicine (FP/EM). One is Royal College trained and certified FRCP (C) in Emergency Medicine. One or two are general practitioners who have been working in the urgent care clinic for more than 20 years. The clinic has x-ray capability and can provide wound care, splinting, and other patient-stabilizing forms of care, but did not have a computed tomography scanner during the period of this study in 2009. Patients requiring a higher level of care for their injuries are transported by private vehicle, ground ambulance, or air to one of the major metropolitan hospitals in Vancouver, BC, more than 120 km away. No data are available about patients transported by helicopter directly from the mountain, those who were treated and released by the bike patrol team, or those who may have gone home to seek medical attention.

DESIGN

A retrospective chart review was performed for all patients admitted to the Whistler Health Clinic for injuries incurred while riding in the bike park during the full 2009 Whistler Bike Park operating season, between May 16 and October 12, 2009. Patients injured while riding in the bike park are categorized as "bike park" injuries in their electronic records; only visits with that designation were included. For each case, the patient's medical record was reviewed, and data were hand extracted by a single researcher. Data collected included month, day, day of week, time of triage, age, gender, home country, zip or postal code, mode of arrival (ambulance, park first aid vehicle, walk in, other), triage category using the Canadian Triage and Acuity Scale (CTAS),¹² the first 5 diagnostic codes, radiographic findings, disposition (discharge, ground/air transfer, death), and charges. The note narrative was also reviewed. No data were available about park usage during this period.

Frequency analysis and the relationship of visits and visit-severity to demographics and day of week were analyzed using SPSS (version 17.0; SPSS Inc, Chicago, IL).¹³ This study was approved by the institutional review boards of The George Washington University and the University of British Columbia and by the Information Privacy Office of the Vancouver Coastal Health Authority.

Results

A total of 910 patient files were reviewed for this study, with 12 patients excluded, leaving 898 (98.7%) with acute injuries for analysis. The excluded patients included 1 case of an allergic reaction attributable to an insect sting, 1 revisit for wound dehiscence, 1 patient

Figure. Mountain bike visits by month.

with dehydration, 2 for late wound infections, a single visit for an overuse injury (shoulder bursitis), and 6 patients who left without being seen. Of the 898 subject visits, 86% (772) of the patients were male. The median age was 26 years (quartiles 19, 26, 34), ranging from 7 to 66 years. Canadian residents made up 68.7% (617) of the total, with 42% (259) residing in British Columbia and 13.8% (85) of the total specifically from the Resort Municipality of Whistler. Of the 281 non-Canadian residents, 48.8% (137) were US residents, 16.0% (45) were from Great Britain, 8.2% (23) were from Australia, 4.3% (12) were from Germany, and 3.9% (11) were from New Zealand. The rest of the injured resided across the globe from Japan to Liechtenstein.

Seasonally, clinic visits peaked in August when 35% of all injury cases visits presented (see the Figure). Visits on Saturday and Sunday (28.6% of the week) accounted for 39.5% of all injuries. Independent of the specific day, clinic arrival times peaked in early afternoon, with 52.3% of cases (470) registering between the hours of 1:00 PM and 4:00 PM.

The majority of patients arrived at the clinic ambulatory (79.8%, 717). Less than 1% (0.6%, 5) were carried, 8.0% (72) arrived on a stretcher, and 11.6% (104) entered in a wheelchair. Most patients, 52.2% (469), arrived alone, 20.0% (180) were accompanied by friends or family members, 19.4% (174) were escorted by the Whistler Bike Patrol, and 8.4% (75) arrived by emergency medical services. Only 4 visits were recorded to have resulted from bike-to-bike or person-to-bike collisions; the remaining visits were the result of the rider falling while riding.

The CTAS is mandatory for Canadian emergency departments and is used at Whistler to triage clinic patients during the initial nursing evaluation.¹² Table 1 presents these results.

A total of 1759 specific injury diagnoses were identified for the 898 cases. At discharge, 43.3% (389) had

only 1 injury diagnosed, whereas 4% (40) received the maximum of 5 separate diagnoses. A total of 445 fractures were identified in 382 patients (Table 2). Upper extremity fractures predominated with a total of 330 (74.2% of all fractures). In addition to fractures, injuries included abrasions in 518 individuals, sprains or strains in 255 individuals, 101 (11.2%) individuals with a traumatic brain injury (including 8 who had decreased level of consciousness on arrival), 32 patients with at least 1 rib fracture, and 12 pneumothoraces, but only 1 documented hemopneumothorax. In addition, 27 patients were transferred to another facility because of suspected internal abdominal trauma.

Regarding protective gear, 95.1% (854) of patient charts had no documentation on the use of additional pads or armor beyond the mandatory helmet. Of the 24 remaining cases, 1 was documented as not wearing armor; the rest (23) were documented as wearing a variety of protective devices beyond a helmet, including knee and elbow pads as well as full body protective suits and neck guards.

Table 1. Patients' triage severity

<i>Subjects N (%)</i>	<i>Triage Category</i>	<i>Description of Severity</i>
2 (0.2%)	1	Need to see a physician is immediate
109 (12.1%)	2	Need to see a physician is emergent or less than 15 minutes
299 (33.3%)	3	Need to see a physician is urgent or within 30 minutes
483 (53.8%)	4	Need to see a physician within an hour
5 (0.6%)	5	Need to see physician within 2 hours

Table 2. Fractures by body region and location

<i>Body Region (N, %)</i>	<i>Location</i>	<i>Number</i>
Face (8, 1.8%)	Face	8
Vertebrae (21, 4.7%)	Neck	2
	Spine	21
Torso (38, 8.5%)	Ribs	32
	Pelvis	6
Upper extremity (330, 74.2%)	Shoulder (includes clavicle)	122
	Humerus	12
	Elbow	37
	Forearm	8
	Wrist	109
	Hand/fingers	42
	Hip	4
Lower extremity (48, 10.8%)	Femur	1
	Knee	4
	Lower leg	1
	Ankle	25
	Foot	13
Sum		445

The disposition was missing for 7 cases. Of the total 898 patients, 90.5% (813) were discharged from the clinic, and 8.5% (76) were transferred to a higher level of care. Two of these were transferred by helicopter to a children's trauma center (a 12-year-old with suspected intraabdominal bleeding and a 10-year-old with a thoracic spine injury who was neurologically intact). Seven more were taken to a level 1 trauma center by helicopter (Table 3). Five traveled by personal vehicle. An additional 6.9% (62) were transferred to a higher level of care by ambulance, whereas the remaining 2 refused transfer (1 with no cervical fractures but abnormal cervical spine alignment without cord injury and 1 with a concern for intraabdominal bleeding).

The fees incurred as a result of treatment for the above injuries varied widely. BC residents are not charged directly for medical care at the Whistler Clinic ($n=259$). Canadians residing outside of the province are charged a flat fee of C\$238 ($n=358$). Among non-Canadians (3 missing), the median charge was C\$969.68 with a minimum of C\$301.05 and a maximum of C\$2669.60.

Discussion

The Whistler Medical Clinic sees approximately 19,000 patients per year. With 898 visits in this case series, nearly 5% of all clinic visits are a result of an injury sustained while riding in the bike park, which is open for about 5 months of the year. The fact that 86% of the cases were male may follow the usual ridership patterns

of a traditionally male-predominated sport or may result from male downhill mountain bikers engaging in riskier behavior than women. Similarly, those who were injured were generally in their mid to late 20s, which may simply mirror general ridership in the sport or indicate that young men are more likely to engage in risky behaviors on the mountain and are therefore more likely to become injured.

The peak in clinic admissions during August was not surprising. Not only does it correspond with common vacation times but fair weather and easy trail access are most frequent during late summer. Additionally, there are several extreme sporting events held on the mountain during the month of August that may contribute to the increase in clinic visits. There is no information regarding injuries related to specific events.

Collisions between riders were rarely a cause for a clinic visit. Trail design in addition to the finite lift carrying capacity likely limit the possibility for collisions. Instead, most injuries appeared to involve riders losing control of or falling off their bikes. We lack the detailed data to comment on the type of terrain or specific trail or trail section most associated with injury in this retrospective study. Regardless of the mode of injury, our findings suggest a need for greater clinic and bike patrol staffing on afternoons, during weekends, and especially during the month of August.

Although the majority of patient injuries were triaged by the CTAS scoring system as mild to moderate in severity, 12.3% of riders experienced injuries that were considered potentially threatening to life, limb, or function (CTAS level 1 or 2), and 9.5% required transfer to a higher level of care. These injuries ranged from intraabdominal bleeding or internal organ injury to spinal cord injury or traumatic brain injury. Although most spinal injuries were compression fractures of the thoracic and lumbar spine without cord involvement, 1 patient did have a C7 spine injury resulting in quadriplegia. Previously, data have suggested a predominance of cervical

Table 3. Adults transferred by helicopter

<i>Age</i>	<i>Injury Description</i>
25	Cervical spine cord injury; quadriplegia
18	Multiple rib fractures/intraabdominal injury (pancreatic injury)
23	Intraabdominal bleeding/hypotension
29	Multiple rib fractures and pneumothorax
38	Abdominal pain/concern for organ injury, shoulder fracture
41	Hemopneumothorax
25	Abdominal pain/hypotension

injuries, but this report came from spine referral centers; compression fractures of the thoracic and lumbar regions may not be referred the same way.⁸ In addition, there may have been spinal cord injuries that were evacuated by helicopter from the mountain, bypassing the Whistler Clinic.

Among patients with a fracture, more than 75% were located in the upper extremity. The downhill nature of this type of riding appears to lend itself to falling forward over the handlebars, with the rider landing on outstretched hand and arm. Alternatively, riders may fall to the side and use an arm to protect themselves. A recent review of data from the National Electronic Injury Surveillance System found that 18.9% of injuries to those riding a mountain bike (regardless of the terrain) were fractures of the shoulder and upper extremity; this is quite similar to our total of 18.8% of all recorded injuries.¹⁴ Although innovative neck and spine protection has been developed in recent years, protective gear for wrists and shoulders remains almost nonexistent. Effective protection has to support a full range of arm and hand motion to adequately control the bike while at the same time preventing injury. Our results support the need for successful development and use of such protective gear for the upper extremity.

There were far fewer lower extremity injuries, which were mostly ankle fractures. These injuries may have been caused by riders' feet slipping off the pedals on a jump or drop and impacting the ground with their foot directly on landing. Falling to the side against rough terrain may also be an injury mechanism for the lower extremity. Although not as frequent, such injuries pose a significant challenge to emergency personnel as the remote nature of certain trails as well as the technical nature of the terrain create significant challenges when transporting injured riders who are unable to walk. In such cases litter or backboard transport may be the only option, and rescue personnel should be well trained in the use of such devices.

An unexpected finding was the number of closed head injuries despite the mandatory helmet requirement. Of riders seen at the clinic, 11.2% ($n=101$) had suffered a closed head injury as diagnosed by the clinic physician without the use of computed tomography. Although most of these were minor, there were 8 cases in which patients had marked decline in neurologic function as indicated by the narrative. This finding suggests an area for further research: is the issue that the user failed to tighten the straps and the helmet fell off, or does the protective effect of the helmet need to be improved? Is this an acceptable level of risk in a high-velocity sport?

Slightly more than half of the patients treated at the clinic were diagnosed with some form of abrasion or

laceration, an injury that is predictably common given the inherent nature of the sport. Clinic physicians are not required to code more than one diagnosis, so it is possible that patients with more serious injuries (head injury, pneumothorax, fracture) also had abrasions that were underreported. Use of protective equipment by the injured cyclist was seldom documented in the medical record, but such equipment may protect against some soft tissue injuries. In addition, focusing safety improvements on sections of trail with a greater incidence of injury may be one method of decreasing injury risks.

Although BC residents were not charged for their medical care and out-of-province patients incurred a nominal fee, international visitors were charged at the time of service. It is impossible to calculate a cost to charge ratio for these cases, and the charges include only clinic care and not any surgery, future hospital, physician or rehabilitation visits, or lost wages caused by these injuries. The median charge of nearly C\$1000 highlights the expensive nature of many of these injuries.

There were several limitations to this study. We were unable to obtain the annual number of lift tickets sold by Whistler Blackcomb during the 2009 biking season. Without this or any other exposure information, we cannot comment on injury risks or rates, but the quantity of visits for bike park injuries supports the notion that downhill free-riding mountain biking is a sport with potentially high morbidity. Our methods may have underestimated the number of bicycle park injuries. Many of the most critically injured patients are transferred directly from the park to outlying trauma centers by helicopter and were therefore not included in this study. In addition, there may have been cases that were not flagged by the clinic as occurring at the bike park, and some injured riders may have waited until arriving home to seek medical attention. There may have been more injury diagnoses per patient than were recorded in the records. Because there was no computed tomographic scanner in the clinic during the time of this study, intra-abdominal injuries had to be transferred for diagnosis, preventing evaluation of internal injuries or serious head injuries in any depth.

These results are the first attempt at describing the epidemiology of injury associated with lift-accessed free-ride mountain biking. They demonstrate the spectrum of morbidity of such injuries. At least at Whistler, our findings suggest planning for increased staffing for injuries on weekends and during the month of August, and highlight the need for improved upper extremity protection and more effective head injury protection for this sport. Given the relative rarity of injury from bike-to-bike crashes, injury prevention strategies will need to focus on methods for maintaining control of the bike.

Further research should include exposure information as a whole as well as specific information about which trail features are associated with injury, evaluate the long-term outcomes after bike park injuries, longitudinally assess the costs of care after injury, and attempt to identify acceptable injury rates in this increasingly popular sport.

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