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Mechanisms of Injuries in World Cup Snowboard Cross

A Systematic Video Analysis of 19 cases

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Department of Sports Medicine
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Arnhild Bakken Ål, October 2011

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List of paper

This thesis is based on the following original article:

I. Arnhild Bakken, PT, Tone Bere, PT, MSc, Roald Bahr, MD, PhD, Eirik Kristianslund, Lars Nordsletten, MD, PhD. Mechanisms of Injuries in World Cup Snowboard Cross: A Systematic Video Analysis of 19 Cases. Br J Sports Med, Accepted

Abstract

Background: Snowboard Cross became an official Olympic sport in 2006. This discipline includes manoeuvring several obstacles while competing in heats. It is common for the riders to collide, making this sport both exciting and at risk for injuries. Although a recent study from the 2010 Olympic Games showed that the injury risk was high, little is known about the injury mechanisms.

Objective: To qualitatively describe the injury situation and mechanism of injuries in World Cup snowboard cross.

Study design: Descriptive video analysis.

Methods: Nineteen video recordings of snowboard cross injuries reported through the International Ski Federation Injury Surveillance System for 4 World Cup seasons (2006-2010) were obtained. Five experts in the field of sports medicine, snowboard and biomechanics performed analyses of each case to describe the injury mechanism in detail (riding situation and rider behaviour).

Results: Injuries occurred at jumping (n=13), bank turning (n=5) or rollers (n=1). The primary cause of the injuries was a technical error at take-off resulting in a too high jump and subsequent flat landing. The rider was then unable to recover leading to fall at the time of injury. Injuries at bank turn was characterised by a pattern where the rider in a balanced position lost control due to unintentional contact with another rider.

Conclusion: Jumping appeared to be the most challenging obstacle in snowboard cross, where a technical error at take-off was the primary cause of the injuries. The second most common inciting event was unintentional board contact between riders at bank turning.

Keywords: Snowboard Cross, Snowboarding injuries, injury mechanism, jumping, video analysis

Abbreviations

The following abbreviations, in alphabetic order is used in this thesis

ACL	Anterior Cruciate Ligament
FIS	International Ski Federation
FIS ISS	International Ski Federation Injury Surveillance System
HP	Half pipe
IOC	International Olympic Committee
OSTRC	Oslo Sports Trauma Research Centre
OWG	Olympic Winter Games
SBX	Snowboard Cross
SX	Ski Cross
WC	World Cup
WSC	World Snowboard Championships

1.0 Introduction

"There really is no feeling in the world like soaring through the air with the other guys right next to you. It's really loud, before the lip, with all the boards on the snow. And then it's just silent in the air. Then you hear pop-pop-pop-pop – all the landings. All your senses are perked, for sure"

Nate Holland, American Snowboard Cross athlete, describing the enjoyment of the sport (1)

Snowboard Cross (SBX) is a relatively recent discipline on the international competitive snowboard scene. This motocross inspired mixture of freestyle and alpine disciplines made its debut in the International Ski Federation (FIS) World Cup (WC) in the 1996/97 season and was a new event for the 2006 Olympic Winter Games (OWG) (2). SBX differ from other snowboard events in that after 2 individual qualification runs, 4 or 6 riders at a time barrel down the mountain, navigating banked turns, long-jumps, washboard bumps and – if they can help it – one another (1). It is not uncommon for the rider to collide making this sport both exciting and popular for the riders as well as for the spectators (3).

Unfortunately the enjoyment of SBX is combined with a risk of injury. A study from the 2010 Vancouver Olympic Games found that the injury risk in SBX was the highest of all the Olympic events (4). Recent data from the FIS Injury Surveillance System (ISS) show that during the 5-month FIS snowboard WC season, on average 1 in every 3 riders sustained a time-loss injury (5). In WC competition, the incidence was reported as 2.1 time-loss injuries per 1000 runs from 1 WC season (6), whereas data from the FIS ISS from 4 WC season suggest a rate as high as 8.5 injuries per 1000 runs (Steenstrup et al., accepted October 25, BJSM 2011). The injury pattern in WC snowboarding is found to differ from the injury pattern at recreational level, with less wrist and upper body injuries and more knee, shoulder and back injuries (5, 6).

Before preventive measures can be suggested, injury risk factors and mechanisms need to be characterised (7-9). Little is known about the injury mechanisms in SBX. Torjussen & Bahr (6) reported falling at an obstacle and collisions as the main injury mechanisms based on retrospective interviews of WC SBX riders. Jumping, which is an important feature of the SBX discipline, is thought to be another common cause of injuries for both recreational (10-13) and professional snowboarders (5, 6, 14). Zygmuntowicz & Czerwinski (15) suggested that jumping-related injuries among national freestyle riders was a result of technical mistakes by the rider, such as losing control, catching an edge, recklessness and taking risks.

Videos of real injury situations contain important injury information. Previous studies in team sport and alpine skiing have provided detailed description of the playing situation, athlete-opponent interaction and joint biomechanics for non-contact anterior cruciate ligament (ACL) and ankle injuries through systematic analyses of video recordings (16-18). The purpose of this study was therefore to describe mechanisms of injury, in terms of the riding situation and rider’s behaviour, in WC SBX based on systematic analyses of video recordings (8, 19).

2.0 History of snowboarding and SBX

The sport of snowboarding was originally influenced by wave surfers and street skateboarders in the USA. In the early 60`s surfers first started to attach wheels to their surfboards and tried to copy the movements they performed among the waves of the sea on the street. These early street surfboards were later developed into commercial skateboards, with the first commercial skateboard produced in 1963 (20). Street skateboarding became massively popular in the 1980`s. In skateboarding the rider's use naturally occurring street obstacles such as steps, street curbs, rails and ramps. Later the riders started to build their own jumps and ramps and this developed into a genre of skateboarding. The skateboarding cult of the 1980`s formed the snowboarding movement (21). Sherman Poppen is credited with inventing the first snowboard, the "Snurfer" (combining the words snow and surf) in 1965 in Michigan, USA (22). During the 1970`s and 1980`s as snowboarding became more popular, the pioneers Jake Burton, Dimitrije Milovich and Tom Sims came up with new designs for boards and mechanisms that slowly developed into the snowboards and other related equipment that we know today (22-24).

The ideas skateboarders brought with them to the ski slopes led to snowboarders building their own Half Pipes (HP) modelled after skateboarding ramps, and using fences and other materials as rails on which to perform board slides and jumps (21). Snowboarding has since its introduction especially attracted the younger population. It is estimated that 25 % of participants are under the age of 25 worldwide (25). From originally being forbidden on ski slopes (24), most ski areas today have snow/terrain parks. These parks are specific areas of the slopes where terrain is modified to accommodate acrobatic manoeuvres (12, 13, 26). Models such as rails, boxes, tables, jumps or HP can be found in snow/terrain parks (26).

2.1 Competitive Snowboarding

The first official snowboard competition was held in 1982 near Woodstock, Vermont in USA. In 1983 the first World Championship HP competition was held at Soda Springs, California in USA. Two years later the sport spread to Europe and the first WC was held in Zürs, Austria (27). However, snowboard was not accepted as an official competitive sport until a decade later. The FIS Snowboard WC was first held during the 1994/1995 season and included the freestyle discipline HP and alpine discipline Giant Slalom and Parallel Slalom. These disciplines were new event for the 1998 Olympic Winter Games (OWG) in Nagano (28). SBX was added as a FIS WC event in the 1996/1997 season and as a new event at the 2006 OWG in Turin. Snowboard as a competitive sport is still developing, and new freestyle disciplines as Big Air and Slope Style is now been added to the FIS WC (28).

3.0. Snowboard Cross (SBX)

3.1 Race structure

The concept in SBX is simple: The first athlete that crosses the finish line wins. The race structure consists of 2 parts, qualification runs and the finals. There are 2 individual preliminary timed qualification runs where the aim is to achieve the fastest time. The best ranked athlete from the qualification runs advances to the final heats. Finals are based on either 48 men and 24 ladies with six athletes per heat, or 32 men and 16 ladies with 4 athletes per heat. In FIS WC, there are usually 4 athletes per heat. The first 2 advances to the next round. For an athlete to reach the final, the total number of runs is usually 6 for males and 5 for females (29).

3.2 SBX course

A SBX course is typically quite narrow and includes features as bank turns (crescent shaped turns), jumps of varying size and designs, steep and flat sections along with rollers, gates and drops. All designed to challenge the riders' ability to stay in control (Figure 1)(3, 29). Because there are several obstacles and the optimum line into the obstacles is very narrow, crashes are frequent (3, 21). Courses are normally 500-900 meter long and have a running time between 40 to 70 seconds. The average speed during SBX competition has been found to be 50 km/h for men and 47 km/h for ladies. The same course is used for both men and women (29, 30). In FIS WC, the vertical drop should be a minimum of 100 m and a maximum of 240 m. The slope should preferably be of a medium inclination (14º–18º on average) with varied terrain, and courses should be a minimum of 40 m wide. In special cases, the course width may for short sections (50 m or less) be a minimum of 20 m. During the first 80 m, the course should be straight and relatively flat and designed to separate the riders as quickly as possible after start with 3-5 rollers or other terrain features to the first turn (29).

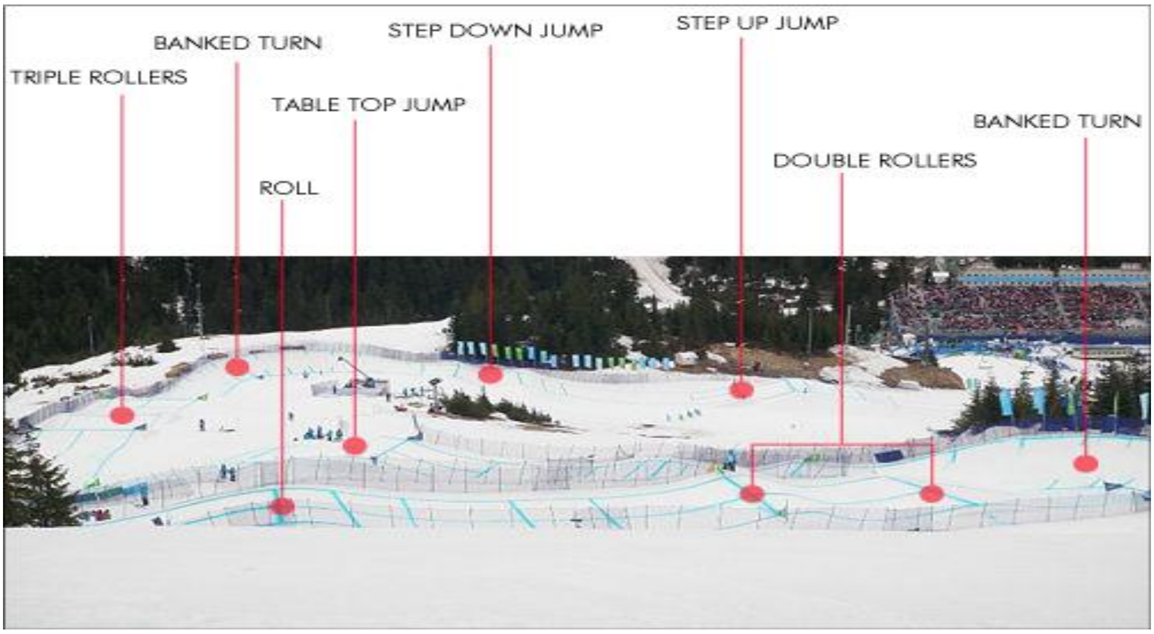

Figure 1. *Part of a SBX course at the 2010 Winter Olympic Games in Vancouver, February 2010, showing some of the features (Downloaded from www.fis-ski.com 23.09.11, reproduced with permission from Rikka Rakic, FIS Communications Manager)*

An ideal SBX slope should allow for the construction of all or some of the terrain features in Figure 1 and 2. The total number and the combination of terrain features and jumps are at the discretion of the course designer, but should incorporate as many different possibilities as practical. Medium or long giant slalom type turns are included only when building a feature is not possible. Blind jumps or terrain features where a competitor is unable to see the landing from the take-off should be avoided. Gap jumps are not permitted under any circumstances and the course should not contain a corner jump as the last feature. The course and obstacles/feature should naturally control the competitors' speed down the course so that the riders do not have to break before each obstacle. The entrances to the obstacles are marked with triangular gate flags and are set so that the competitors can distinguish between them clearly and quickly even at high speed (29).

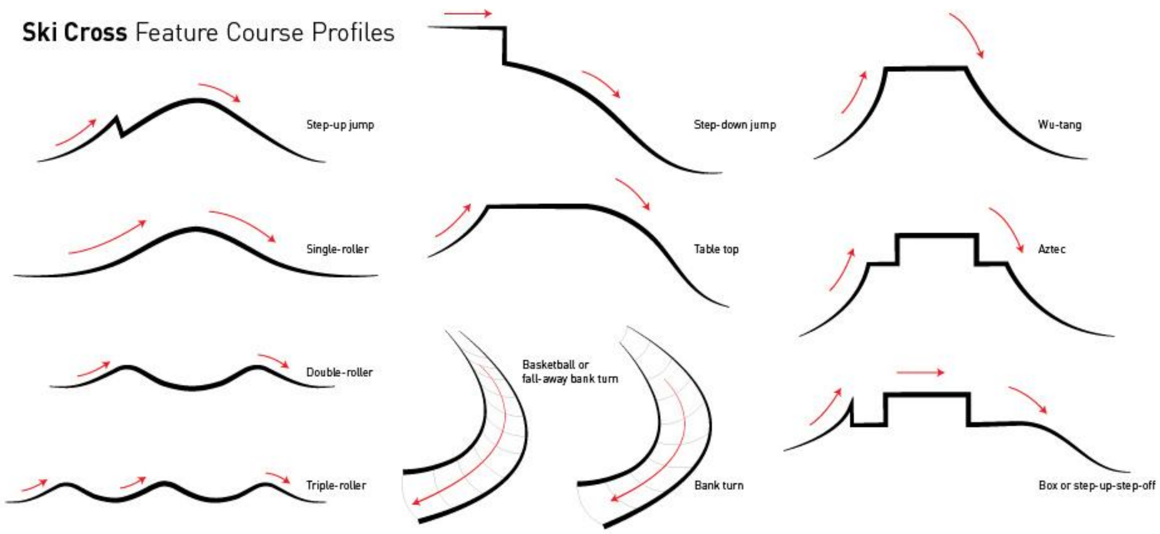

Figure 2. *SBX/SX course features. The same features are used in a SX and SBX course (1). (Downloaded from www.alpinecanada.org 22.09.11, reproduced with permission from Keith Bradford, Canada Ski Cross/ Alpine Canada).*

3.3 Equipment

In SBX the minimal width of the board is restricted. For a gliding surface length up to 135 cm the minimal width is 14 cm whereas a minimal width of 16 cm is required for a gliding surface length of more than 135 cm. There is, however, no restriction on the type of board allowed (29). Riders use either a freestyle board or a giant slalom type of board (alpine board) and this is at a rider's choice of preference. In difference to a freestyle board used in HP, the SBX freestyle board is slightly longer and a stiffer model to generate more straight-line speed (31). Soft boots and soft bindings are used with a freestyle board allowing freedom to adjust quickly to the obstacle on the course. The alpine board is designed to promote carving turns and can offer more speed on fast section of the course. Hard boots are being used on the alpine board (31). According to the FIS Competition rules (29) the boots cannot overlap each other and the bindings must be fixed diagonally on the long axis of the board. Plate systems that connect both bindings are not allowed, however individual plate system on each binding are permitted. Safety lashes are optional (29).

In SBX the competitors are not allowed to wear anything on the hands besides gloves or to use any kind of devices to additionally support their balance, reduce or accelerate their speed (poles or sticks etc). The competition suits are required to be two-piece (pants and separate top). No form fitting speed or downhill suites are allowed. Body protectors (hip, wrist, arms etc) are optional but recommended and usually worn under the snowboard suit. Helmets and back protection are mandatory during all official FIS WC training and competitions (29).

3.4 Riding technique

Jumps and bank turns compose the majority of a SBX course (32). Bank turns, if negotiated correctly, are an opportunity to gain speed. The key is to recognise the shortest line and know how to pump for speed (32). Similarly, at jumps the aim is for the riders to gain or not to loose speed. In contrast to other freestyle snowboard events, SBX riders are seeking as little airtime as possible with a jump trajectory following the course profile as closely as possible, by keeping low and compact when jumping (32). In order to tackle the jump correctly, the rider must gauge speed to be able to dampen the jump. Speed-check (brake by skidding the board) is a common technique to gauge speed. If the jump is dampened incorrectly it will result in either a too long jump and flat landing or a too short jump. Either way the rider will take impact and may be injured (32). Rollers are considered one of the most technical parts of the course. The most efficient and fastest way to tackle this obstacle is generally to keep the board on snow and dampen/absorbing the rollers. However, a good pumping technique is required (32).

3.5 Physical characteristics of the riders

The physiological requirements in SBX are diverse. Besides riding technique, equipment and psychology, riders need strength, aerobic fitness, coordination and more to prevail in a contest and over an entire season (21).

Platzer et al. (21) compiled a physical test battery to evaluate if this test battery could predict snowboard performance in Austrian national and WC team riders. The test battery consisted of a bicycle ergometry test, a countermovement jump, isokinetic leg power test, isokinetic core test, bench press and bench pull, a one-legged static balance test and an indoor SBX start simulator (21). The results showed that the test battery correlated significantly with FIS points for SBX women to all tests but countermovement jump. In men, however, no significant correlations were found. The authors discussed that performance in SBX competition depends on several factors such as psychology, equipment and coordination, and these factors may have as much or more influence on performances than physical fitness. In addition, they hypothesised that in international snowboarding men may be more homogenous in general fitness than the women and this could possibly explain their results. Nevertheless, the authors concluded that maximum push off speed (starting speed at the start gate), leg power, core power and aerobic capacity were important in the ability to negotiate obstacles or colliding with other contestants, and explained 98 % of physical performance in females, but not in men (21).

3.6 Rules

Considering the format of SBX, the rules for contact during the competition is important and especially relevant for this thesis. According to the FIS competition rules pp 121: "*intentional contact by pushing, pulling or other means which causes another competitor to slow down, fall or exit the course is not allowed and is an automatic disqualification sanction. Unavoidable "casual contact" may be acceptable. All contact infractions will be at the discretion of the course Judges and competition Jury*" (29).

4.0 Injuries in snowboard and SBX

4.1 Recreational snowboarding

Most of the studies on snowboarding injuries cover injuries sustained by recreational snowboarders on the slope. Several studies have described the injury incidence and injury pattern for all kind of snowboarding activities on the slope over the last 10 years (Table 1). Injuries are mainly reported by ski-patrols and medical staff at ski resorts in Northern America, Europe and Japan and the injury incidence is usually expressed as the number of injuries per 1000 skier-days (33-40).

In the recent years, a few studies have described the injury rate and injury pattern on recreational snowboarders in terrain/snow parks (Table 1). These parks contain similar terrain features as in SBX, however designed for the riders to perform aerial manoeuvres. A study from Alberta in Canada has reported the total injury incidence and on the different features in terrain parks. Similar to studies on injury rate in WC competition (5, 6), this study recorded injuries per 1000 runs (12). They reported a total injury rate of 0.75 per 1000 runs, where jumps had the highest injury rate of 2.56 per 1000 runs (12).The injury pattern found in terrain parks is similar to other studies on recreational riders where injuries to the upper extremity dominate (Table 1). The wrist is the most commonly injured body part (38, 41, 42). With the increasing skilled snowboarders and the number of terrain parks, an increase in spinal and head injuries have been reported (13, 40).

SBX, however, is purely a competitive sport. The literature regarding injuries from these studies, may therefore not necessarily apply to WC SBX riders.

Table 1. *Epidemiological studies on injury incidence and injury pattern in recreational snowboarders*

Author, year, country (reference)	Study design	Population	Injury recording and definition	Duration	Incidence (per 1000 SD)	Injury pattern
Machold et al. 2000 Austria (38)	Retrospective cohort	2 579 school children snowboarding during their sports week	Self-reported snowboard days; medically reported injuries	1996-97	10.6	Wrist: 32%, hand: 20%, head: 11%
Rønning et al. 2000 Norway (35)	Prospective study	1411 SB from one skiing area	Hospital recording for injuries treated at local hospital	Feb - Mar 1997	4.0	Not studied
Langran & Selvaraj 2002 Scotland (33)	198 Prospective case control	1243 SB from three skiing areas	Injury reports from Ski patrol/physician attended ski patrol services or local medical practice.	1999-00	3.7	Fracture: 24.9%, Sprain: 28.6% Head/face: 19.7%, Upper Ex: 46%, Lower Ex.: 21.6%
Made & Elmqvist 2003 Sweden (34)	Prospective study	568[a] SB from two skiing areas	Medical report from physician for medical attention injuries treated at the local medical centre within 48 hours	1989-99	3.0	Fracture 34%, Contusions 27%, Sprains 26% Upper Ex.: 54.4%, Lower Ex.: 19.2%
Wakahara et al. 2006 Japan (37)	Case series	15320 SB from one skiing area	Hospital reports on spinal cord injuries, but total numbers of SB injuries given	1995-05	1.5*	Not studied
Sakamoto & Sakuraba 2008 Japan (39)	Descriptive epidemiological	2220 SB from two ski resort	Injuries presented to local clinics at the Ski resorts	2000-05	840*** (1994-95) 170*** (2000-02) 180*** (2003-05)	Fracture: 28%, Contusion 31% Upper Ex.: 50%, Trunk: 15%, Lower Ex.: 21%
Wasden et al 2009 USA (36)	Retrospective cohort	348 SB from one ski area	Injury registration of SB injuries treated at Medical Centre	2001-06	Not stated	Head: 27.3%, Spine: 20.69%, Upper Ex.: 11.78%, Lower Ex.: 26.15%, Thorax: 11.49%, Abdomen/pelvis: 22.41%
Ogawa et al. 2010 Japan (40)	Descriptive epidemiological	19 539 SB from one ski area	Injured SB admitted to local hospital emergency department; filled out questionnaire	1996-08	Not stated	Fractures: 37.3%, Bruises: 20.8%, Contusions: 13.5%, Upper Ex.: 41.6%, Trunk: 20.8%, Head/face: 19.1%, Lower Ex.: 12.5%

Studies on terrain/snow parks versus ski slopes						
Goulet et al. 2007 Canada (26)	Case-control	50593 SB/Ski riding in terrain park or ski slope in one ski area	Injuries reported to Ski Patrol at a ski station	2001-05	Not stated	Head/neck: 22.7%(Park), 21.9% (Slope) Trunk: 12.8% (Park), 10.2% (Slope) Upper Ex.: 53.3%(Park), 52.4% (Slope) Lower Ex.: 20.0% (Park), 22.2% (Slope)
Brooks et al. 2010 USA (13)	Cross sectional	9273 SB riding in terrain park or normal slope in two ski areas	Injuries receiving medical care from the Ski Patrol.	2000-04	2.68#	Fracture: 38.6% (Slope), 41.3% (Park) Sprain: 48.3% (Slope), 38.6% (Park) Concussion: 7.8% (Slope), 14.5% (Park), Back/chest: 9.9% (Slope) 17.2% (Park), Lower Ex.: 23.4% (Slope), 19.5% (Park), Upper Ex.: 56.1% (Slope), 49.8% (Park)
Russell et al. 2011 Canada (12)	Case-control study with exposure estimation	334 SB riding in terrain park from one Ski resort	Injuries presented to the ski patrol or local emergency departments	Two winter seasons	Total: 0.75** Jumps: 2.56** HP: 2.56** Kickers: 0.61**	Not studied

SD: *Skier days,* [a] *Only snowboarding injuries analysed in the study,* ***Upper Ex.:*** *upper extremity,* ***Lower Ex.:*** *lower extremity,* ***SB:*** *snowboarder,* ***** *Injuries per 1000 snowboard visits (SV),* ****** *Injuries per 1000 runs,* ***SB:*** *snowboarders,* ***HP:*** *halfpipe, # Total injury incidence for both skiers and snowboarders on slopes and terrain parks,* ******* *Injury incidence per 100 000 lift tickets*

4.2 WC snowboarding

There are only 4 recent studies that have described the injury incidence and injury pattern in WC snowboarding (Table 2). Torjussen & Bahr (6) reported 135 acute time-loss injuries among 258 WC snowboarders corresponding to an injury rate of 1.3 per 1000 runs from 1 WC season. The injury risk for the different disciplines was found high for big air, SBX and HP, and lower for parallel giant slalom and giant slalom. An injury rate of 2.1 per 1000 runs was reported for SBX (6). A similar recent study on FIS WC snowboarders found that during the 5-month WC season, there were 37.8 time-loss injury and 13.8 severe injuries per 100 athletes per season (5). Flørenes et al., concluded that on average 1/3 of the WC riders sustained a time-loss injury each season (5). In comparison, newly published data on the rate of injuries during the 2010 OWG, reported that the injury risk in SBX was the highest of all the Olympic events (4). Engebretsen et al. found that in the two weeks of OWG, 23.1% of the SBX riders sustained a time-loss injury, and reported an injury rate of 20 per 1000 registered athlete (4).

Steenstrup et al. (accepted October 25, BJSM 2011) recently investigated the injury incidence in individual qualification runs vs. final runs of SBX riders during 4 WC seasons (Table 2). They reported 48 time-loss injuries among 345 SBX riders. A total injury rate of 8.5 per 1000 runs was reported, and the injury rate was found higher in final runs (12.1 per 1000 runs) compared to qualification runs (6.1 per 1000 runs).

The injury pattern among competitive WC snowboarders across disciplines differs from those seen in recreational snowboarders, with fewer wrist injuries and more knee and back injuries (Table 2). Flørenes et al. found that joint and ligament injuries were the most common injury types among WC snowboarders, while contusions and fractures/bone stress were equally the second most common injury types (5).

Table 2. *Epidemiological studies on the injury incidence and injury pattern in WC SBX/Snowboard*

Author, year (reference)	Study design	Population	Injury recording and definition	Duration	Incidence	Injury pattern**
Torjussen & Bahr 2006 (6)	Retrospective athlete interview	258 SB	Acute injuries resulting in missed participation and overuse injuries influencing performance	April 2002-March 2003	**SBX: 2.0/1000r** BA: 2.3/1000r HP: 1.9/1000r PGS: 0.6/1000r PS: 0.3/1000r	Knee: 18% Shoulder: 13% Back: 13% Wrist: 8%
Flørenes et al. 2010 (5)	Retrospective athlete interview	421 SB	All injuries occurred on snow (training or competition) and requiring attention by medical personnel	2006-2008 WC season (Nov-Mar)	All injury: 56.3/100A Time-loss: 37.8/100A Severe: 13.8/100A	Joint/ligament: 38.6% Fractures/bone stress: 17.6% Knee: 18.9% Shoulder/clavicle: 13.3% Head/face: 12.9% Back/pelvis/sacrum: 10.3%
Engebretsen et al. 2010 (4)	Retrospective injury registration	57 SBX	All injuries requiring attention by medical personnel and resulting absence from competition or training.	12-28 Feb 2010 Olympic Winter Games	SBX total: 20/1000rA SBX female: 16/1000rA SBX male: 4/1000rA	All alpine/snowboard: Sprain: 28 (27.5%) Contusion: 28 (27.5%) Face/Head/neck: 22 (21.6%) Knee: 24 (23.5%)
Steenstrup et al. (accepted October 25, BJSM 2011)	Descriptive epidemiological	SBX (F: 120; M: 225)	All injuries occurred in SBX qualification and finals, and requiring attention by medical personnel; resulting in absence from competition or training	2006-2010 SBX WC season	Total: 8.5/1000r Qualification: 6.1/1000r Finals: 12.1/1000r Female Total: 9.7/1000r Qualification: 9.3/1000r Finals: 10.5/1000r Males Total: 7.8/1000r Qualification: 4.4/1000r Finals: 12.9/1000r	Not studied

SB: *Snowboard,* ***SBX:*** *Snowboard Cross,* ***BA:*** *Big Air,* ***HP:*** *Half pipe,* ***PGS:*** *Parallel giant slalom,* ***PS:*** *Parallel slalom,* ***F:*** *females,* ***M:*** *males;* ***/1000r****: incidence per 1000 run,* ***/100A:*** *incidence per 100 athlete with all disciplines included* ******** *data based on all Snowboard disciplines (SBX, HP, BA, PGS and PS).* ***/1000rA:*** *incidence per 1000 registered athlete.*

5.0 The injury prevention process

The long-term goal of epidemiological sports injury research is to prevent injuries. The injury prevention process has been described by van Mechelen et al. (7) as a 4-step sequence. First, the magnitude of the problem must be identified through injury surveillance and described in terms of the incidence and severity of sports injuries. Next, the risk factors and injury mechanisms that play a part in the occurrence of sport injury have to be identified. Main questions of interest are: What are the causes for the injuries? And why and how do injuries occur? The third step is to introduce measures that are likely to reduce the future risk and/or severity of sports injuries. This measure should be based on the aetiological factors and the mechanism as identified in the second step. Finally, the effect of the measures must be evaluated by repeating the first step (7). Finch introduced an addition to this sequence, a 6-stage model that incorporates the implementation of effective prevention strategies into real life (43).

5.1 Injury causation

Understanding the causes of injuries is a critical step in the 4-step sequence of injury prevention (9). This means that we have to examine all the factors involved, including obtaining information on why a particular athlete may be at risk in a given situation (risk factors) and how the injuries occur (injury mechanisms) (8). Firstly, one must identify those factors associated with an increased risk of injury. These factors are termed internal or external risk factors (9). Internal (intrinsic) risk factors are part of the riders' constitution that may make them predisposed to injury. Riders are exposed to external (extrinsic) risk factors when they participate in training or competitions, which may make them susceptible to injury (9). Internal risk factors can be age, gender, body composition, health, physical fitness level, anatomy and snowboarding skill level. External risk factors can be opponents on a SBX course, use of protective equipment (helmets, back guards), equipment such as the snowboard, and the environment (weather, visibility, height/steepness of jumps or banks or other features, snow and ice conditions).

The sum of these risk factors and the interaction between them make the athlete susceptible for injury, but an inciting event is necessary to cause an injury (9). The inciting event is usually referred to as the "injury mechanisms" in epidemiological studies of sport injuries. The term, however, is widely used and not well defined (8). Bahr & Krosshaug introduced a detailed description of the injury mechanism, including aspects of specific sports situations, the athlete's behaviour and movement as well as detailed biomechanical characteristics of anatomical structures (Figure 3) (8). A precise description of the injury mechanism is essential to understand the multi-factorial cause of injury. To understand which component of the apparent mechanisms that is actually responsible for an injury, it is important to distinguish between "mechanisms of injury" and "mechanisms of no injury". In this way we may have uncovered the critical component of the inciting event that ultimately causes an injury (44).

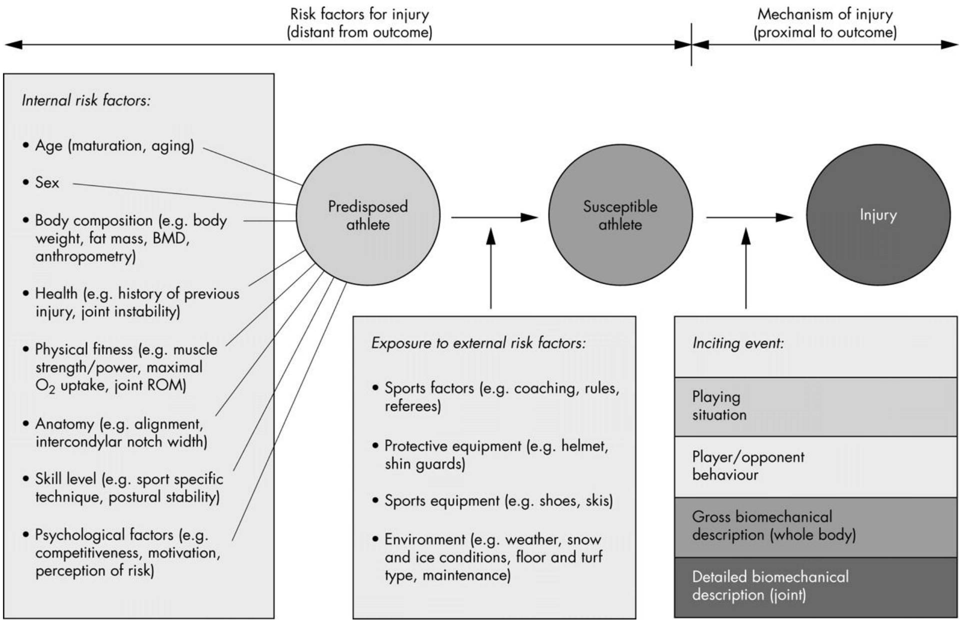

Figure 3. *Comprehensive model of injury causation. The figure is retrieved from Bahr & Krosshaug (2005). Reproduced with permission from Roald Bahr 2011.*

5.2 Risk factors in SBX

Although this study aimed at describing the injury mechanism in SBX, it is important to have knowledge about the risk factors. A risk factor may be part of or a collection of factors that together produce a sufficient cause for an injury to occur (19). In SBX, it is hypothesised that riding in heats of 4 or 6 athletes increases the risk of injury. Engebretsen et al. reported that the possible reason for the high injury risk in SBX during the 2010 OWG could be attributed to the riding format (4). They suggested that to compete for the front position while manoeuvring past multiple obstacles combined with high speed (external factors) (21), may contribute to an increased injury risk. In addition, loss of control from accidental body contact could lead to high-risk situations (4). Recently, 1 study has described a significantly higher injury incidence in final runs compared to qualification runs from 4 WC season (Steenstrup et al., accepted October 25, BJSM 2011) (Table 2). Taking the observations of Engebretsen et al (4) and the result of the aforementioned study into account, it seems likely that riding in multiple is an risk of injury in SBX. However, whether this injury risk is a result of accidental body and/or board contact among the riders or only as a disturbance of the riding strategy and tactics is still unknown. We will convey this question in this study.

In general, there is little available data on risk factors among recreational and professional snowboarders. In addition to the 2 studies mentioned among professional SBX riders, a few epidemiological studies have attempted to identify potential risk factors in recreational riders (Table 3). In these studies, an intentional jump over 1 meter, speed and rider error are reported as the most common risk factors for recreational riders (11, 15, 22, 45-47).

Table 3. *Potential risk factors among recreational and national snowboarders*

Reference	Study sample	Approach	Study period	Risk factors
Davidson & Laliotis 1996 (22)	931 SB	Prospective questionnaire	1989-1990	Human error (60%), equipment failure (0.54%), speed (4.4%), jumping (15%)
Gajdzinska et al. 2006 (46)	100 SB	Retrospective questionnaire	2004/2005	Excess speed (37%), insufficient skills (28%), Other people (18%), Bad weather conditions (8%), poor route preparation (6%), Faulty equipment (3%)
Zygmuntowicz & Czerwinski 2007 (15)	211 SB	Retrospective questionnaire	2006/2007	Technical errors (81%) Tiredness (14%) Icy slope (13%) Other people (4%) Faulty equipment (1%)
Tarazi et al. 1999 (45)	22 SB	Medical records	1994-1996	Intentional jump over 2 meter
Yamakawa et al. 2001 (11)	238 SB	Retrospective athlete interview	1988-2000	Intentional jump over 1 meter
Hasler et al. 2010 (47)	306 injured SB 253 controls	Case-control	2007-2008	Low readiness for speed, Bad weather/visibility, Old snow. Not wearing a helmet, icy slopes.

SB: *snowboarders*

6.0 Injury mechanism

Understanding the mechanism of injuries is essential for their prevention (7, 8, 44). Little is known about the injury mechanisms in snowboarding. Mostly, the method used to describe the injury mechanism are based on self-reports by the injured rider, and the injury information has first of all been extracted from ski patrol, national trauma registries and hospital medical reports (48). Therefore, the description of injury mechanisms is mainly limited to the injury situation.

6.1 Injury mechanism in snowboarding

6.1.1 Riding situation

Epidemiological studies have found that the injury rates and injury patterns between recreational snowboarders and professional riders differ. Thus, it is reasonable to believe that different injury mechanisms apply at the professional vs. recreational level. The primary mechanisms of injuries in recreational snowboarders are falls and collisions (48). However, jumping is reported to be a common cause for injuries both in recreational (10-13) and professional snowboarders (5, 6, 14), and a fall from a failed jump is reported as the specific cause (15, 49). Epidemiological studies on self-rated expert recreational snowboarders have reported that head, spinal and shoulder injuries are predominately caused by jumping (11, 37, 45, 49-53) (Table 3). This injury pattern has also been found among professional riders (Table 2). Thus, a description of the mechanism of these injury types will be presented.

6.1.2 Head and spine injuries

Koo & Fish reported that the most common mechanism of spinal injury among recreational snowboarders was an axial loading following a failed jump (49). This was based on a review of 10 snowboard-related spinal injuries through interview with the athletes and radiological review during 1 winter season in 5 ski resorts in British Columbia, Canada (49). This view is supported by 3 similar studies from Japan (11, 37, 53). These studies suggested that the absence of poles predisposes the snowboarder to backwards falls when a snowboarder makes a poor landing after jumping, thereby shearing force is exerted on the spine (11, 37, 53).

Fukuda et al investigated snowboarding-related and skiing-related head injuries during 5 ski seasons at 1 resort area in Japan (51). This study included 1076 subjects, and 634 riders were injured while snowboarding who was treated at a hospital in the period of 1994-1999. The majority of the patients were beginners and intermediate skilled riders. They were examined clinically at the hospital and interviewed about the injury situation. The most frequent cause of injury was falls on a middle-steep slope. Almost half of the snowboarders were injured while jumping. Of the 634 head injuries in snowboarding, there were 304 occipital injuries, 119 frontal, 57 temporal, 6 parietal, and 148 injuries in which the area was unknown. Occipital injuries were associated with a backward fall (51). A similar mechanism was also reported by Nakaguchi & Tsutsumi (52). They found that the “opposite-edge phenomenon” were involved in the majority occipital head injuries in a study of 38 snowboard-related head injuries treated at a hospital in Japan in the period of 1995-2001. In addition to the clinical examination, the subjects were also interviewed about the injury situation (52). The phenomenon of opposite edge is where a strong ventro-dorsal rotation is created when a rider catches snow with the valley-side edge and causes the rider to stop rapidly and fall (52).

6.1.3 Shoulder/upper extremity injuries

While the “opposite edge phenomenon” (as described above) is reported as the main mechanism of upper extremity injuries in recreational riders (54), Torjussen & Bahr suggested that WC snowboarders athletes do not injury their upper extremity as frequently because they have greater edge control and do not fall backwards onto their upper extremity (6). On the contrary, 3 reviews (Table 3) about the epidemiology on shoulder injuries in skilled recreational riders, have reported that a fall during jumping is the main injury mechanism (50, 55, 56). Deady & Salonen (56) reviewed the literature on shoulder injuries with a focus on the injury mechanisms. They reported that the most common mechanism for shoulder injuries were falls during jumping with either a direct blow, axial loading from an outstretched arm, or eccentric muscle contraction associated with shoulder abduction during a fall (56). And the most common shoulder injuries were glenohumeral dislocations, clavicle fractures, acromioclavicular separations, rotator cuff strains and proximal humerus fractures (56).

6.1.4 Knee injuries

Injuries to the knee are more common in WC riders compared to recreational snowboarders (Table 1 and 2) (5, 25). However, recently, an increase in knee injuries in recreational snowboarding is also been reported (57). It is previously assumed that the fixation of both feet is protective against knee injuries (25), but Torjussen & Bahr suggested that it is likely that this effect will be reduced as the impact energy and torsion forces increase with the higher and more spectacular jumps seen among both elite and recreational riders (6, 57). There is only 1 study that has attempted describing the injury mechanism of knee injuries in snowboarders. Davies et al (57) studied the injury mechanism of ACL among self-rated expert recreational riders based on retrospective athlete interviews. They concluded that the 37 ACL injuries studied, resulted from a jump with a flat landing on flexed knee with significant knee compression. Further, they hypothesised that the ACL rupture was caused by a maximal eccentric quadriceps contraction as the rider resists a compressive landing (57).

Table 4. *Relevant articles on injury mechanism in snowboarding*

Reference	Injury type	Approaches	Mechanisms
Koo & Fish 1999(49)	Spinal injuries	Interview + MRI/CT	Fall during jump
Tarazi et al 1999 (45)	Spinal injuries	Medical and ski patrol records	Jumping
Fukuda et al 2001(51)	Head injuries	Interview	Fall during jump
Yamakawa et al 2001(11)	Spinal injuries	Interview	Jumping
Nakaguchi & Tsutsumi 2002 (52)	Severe head injury	Interview + CT	Simple fall on slope (58%), Fall during a jump (21%), Collision (21%)
Wakahara et al 2006 (37)	Spinal injuries	Interview + MRI/CT	Jumping (83.3%), Fall (16.7%)
Seino et al 2001 (53)	Spinal injuries	Interview.	Backward fall from jump
Matsumoto et al 2002	Upper Extremity injuries	Questionnaire	Fall (59%), jumping (31%)
Kocher et al 1998 (50)	Shoulder injuries	(Review)	Backward fall from jump or aerial manoeuvres
McCall & Safran 2009 (55)	Shoulder injuries	(Review)	Jumping or aerial manoeuvres
Davies et al 2009 (57)	ACL	Questionnaire	Flat landing from jump/ max.ecc.quad contraction
Zygmuntowicz & Czerwinski 2007(15)	-	Questionnaire	Fall during landing after a jump
Ogawa et al. 2010 (40)	-	Questionnaire	Falls (49.7%), Jumping (26.3%)
Deady & Salonen 2010 (56)	Shoulder, spinal/head, lower extremity injuries	(Review)	Falls, jumps

MRI: *magnetic resonance imaging,* ***CT****: computed tomography*

6.2 Injury mechanism in SBX

There are to our knowledge no previous studies that have specifically investigated the injury mechanisms in SBX. Torjussen & Bahr (6) reported falling at an obstacle and collisions as the main injury mechanisms based on retrospective interviews of WC SBX riders. However, these injury mechanisms were not described in greater detail. Considering the race format and riding style in SBX is distinct different from the other disciplines of WC snowboarding and recreational snowboarding, the injury mechanism described above may not necessarily apply to SBX riders. However, jumping is an important feature of SBX and performing jumps at high speeds are suggested as particularly difficult elements on the SBX course, in addition to riding on rollers (32). Zygmuntowicz & Czerwinski (15) suggested that jumping-related injuries among national freestyle riders was a result of technical mistakes and rider errors, such as losing control, catching an edge, recklessness and taking risks.

7.0 Methodological theory

A complete description of the mechanisms for sports injuries includes aspects of the injury situation, specific athlete/opponent behaviour, as well as description of whole body and joint biomechanics at the time of injury (Figure 3) (8). Therefore, a number of different methodological approaches are used to describe the mechanism of injuries (19, 58, 59). These include interview of injured athletes, video analysis of actual injuries, clinical studies (study of joint damage through MRI or CT scans), laboratory motion analysis, cadaver studies and mathematical stimulations (19, 59).

Retrospective interviews and questionnaire are the most commonly used approach to study injury mechanisms in sports (19). By this approach, it might be possible to describe the inciting event preceding the injury, at the time of injury, as well as after the injury. The advantage of this approach is that the data is relatively easy to obtain through personal interview or questionnaire with the injured rider, coach, medical personnel or others who witnessed the accident (19). To our knowledge, this is the only method used to describe injury mechanism both in recreational and professional snowboard. Torjussen & Bahr reported that injuries in SBX occurred from falling at an obstacle and collision based on retrospective interviews (6). However, a collision in SBX may involve several opponents where the rider colliding with the injured rider may have lost balance and/or forced to change riding strategy due to a 3rd rider. Therefore, interviews may be influenced by recall bias or simply the fact that these injuries happen so quickly and at such high speed that the rider may not even be able to comprehend what actually took place when they were injured (19, 60). In addition, the description given may be influenced by what he/she was told by others witnessing the event (19).

Visual analysis from videos is another approach that may describe the injury situation, athlete/opponent behaviour as well as the whole body and joint biomechanics of an injury (19). By utilising video recordings, it is possible to describe the injury mechanisms of real injury situations in more detail than by retrospective interviews and questionnaires (18, 19). The aim of this study was to analyse the events leading up to the injury in terms of the riding situation and rider behaviour. Therefore, in the following section the methodological approach used in this study will be presented with the focus on the advantages and limitations in relation to injury situation and athlete/opponent behaviour.

7.1 Video analysis

Videos of actual injuries contain important information on what took place when the injury occurred. Video analysis has not previously been used in describing the mechanisms of injury in neither recreational nor professional snowboarding. However, previous studies in team sport and alpine skiing have provided detailed description of the playing situation, athlete-opponent interaction and joint biomechanics for non-contact ACL and ankle injuries through systematic analyses of video recordings (16-18, 61, 62). Information gathered from video analysis has, in turn, made it possible to point out situations with a high risk of injury (19, 63). Another advantage of video analysis is that it is possible to compare injury versus no-injury situations. In SBX final heats for example, the other riders can act as matched controls and by analysing these situations one may be able to distinguish between "mechanisms of injury" and "mechanisms of no injury". Thus, we can identify the critical component of the inciting event that ultimately causes an injury (44).

Bere et al. (18) recently identified 3 main mechanisms for ACL injuries among WC alpine skiers from the analysis of video recordings, which they termed "the slip-catch", "landing back-weighted and "the dynamic snowplow". However to fully understand the mechanisms of these 20 ACL injuries, a description of the events leading to the injury situation was needed (8, 19). Therefore, Bere et al. conducted a similar study aimed at describing the skiing situation leading to ACL injuries. Based on this systematic video analysis of 20 ACL injury situations, factors related to skier technique, skier strategy and specific race conditions were identified as main contributors to the injury situations (Bere et al., accepted BJSM 2011). They suggested to train ski racers to recognise the risk situations and, if possible, avoid these altogether or respond by "bailing out" in time to prevent ACL injuries. Similarly, an earlier study by Ettlinger et al. (64) developed an awareness program to prevent ACL injuries based on the information gathered from video analysis of 10 ACL injuries among recreational skier. By educating skiers on how to avoid dangerous behaviour, they were able to reduce the injury rate of ACL injuries by 62%. This study by Ettlinger et al. (64) was also one of the first to employ the method of video analysis to investigate the injury mechanism in sport.
Another study by Andersen et al. (16) employed the analysis of video recordings to examine the mechanism of ankle injuries among elite Norwegian and Icelandic football players. The

main finding was an inversion trauma. However, in most of the incidents the indirect cause of the injuries were an external medial force of the ankle (late tackle from the side) which brought the player out of balance, causing unexpected foot motion just before landing (16). This and the 2 aforementioned studies illustrate that to fully understand the injury mechanism, it is important to describe the playing/riding situation as well as the joint specific biomechanics.

Although remarkably consistent patterns can be readily identified by visual analysis of video recordings, there are some limitations to this method (19). One limitation is the quality of the video recording, the image quality, camera angle and the number of views available (19). In order to improve the quality of the videos Olsen et al. digitised and enhanced the videos by creating still, slow motion, and enlarged picture sequences to clearly show the incident in the study of the injury mechanism of ACL in team handball player (17). Additionally, in Bere et al. (18) the videos were deinterlaced which increased the effective frame rate from 25 to 50 Hz.

Another limitation of the analysis of video recording is the ability of the observer to describe the event and that these assessments are subjective and qualitative (59). Both in the studies of Bere et al. (accepted BJSM 2011) and (18), and Andersen et al (16) a panel of experts in the field of sports medicine and football/alpine skiing analysed the video recordings. However, one cannot exclude that the review of the injury situation may have been influenced by the perspectives of the experts (Bere et al., accepted BJSM 2011). Additionally, one cannot in all cases be sure of the exact moment of injury. Although the individual estimates of the index frame were remarkably consistent between the experts in most cases in the study of ACL injury mechanism in WC alpine skiers by Bere et al. (18), there were a few cases where the initial estimates were less consistent prior to the consensus meeting. Therefore, in 4 cases they analysed more than 1 plausible injury time point. However, the alternative injury situation appeared less likely than the primary injury moments, and the first plausible injury situation made the basis for the analysis in this study.

Nevertheless, keeping these limitation in mind a systematic analysis of injury situations from video would seem to be the obvious approach toward a more detailed understanding of the mechanisms of sport injuries, providing more reliable information than retrospective interviews and questionnaire (16).

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Article: Mechanisms of Injuries in World Cup Snowboard Cross: A Systematic Video Analysis of 19 Cases

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1. Introduction

A study from the 2010 Vancouver Olympic Games reported that the injury risk in Snowboard Cross (SBX) was the highest of all the Olympic events.[1] Recent data from the International Ski Federation (FIS) Injury Surveillance System (ISS) show that during the 5-month FIS snowboard World Cup (WC) season, on average 1 in every 3 riders sustained a time-loss injury.[2] In WC competition, the incidence was reported as 2.1 time-loss injuries per 1000 runs from 1 WC season, [3] whereas data from the FIS ISS from 4 WC season suggests a rate as high as 8.2 injuries per 1000 runs (Steenstrup et al., accepted October 25, BJSM 2011). Thus, attention needs to be directed at how to prevent SBX injuries.

Understanding the mechanism of injuries is essential for their prevention.[4-6] In SBX, riders are required to manoeuvre past multiple obstacles (jumps, narrow crescent-shaped turns, kickers, gates and rollers) in two individual qualification runs, then in heats of 4 or 6.[7, 8] It is not uncommon for riders to collide as they compete for the front position in heats.[9] It is hypothesised that these potential external risk factors, combined with high speed, may contribute to injury. In addition, loss of control from accidental body contact may lead to high-risk situations.[1] However, little is known about the injury mechanisms in SBX. Torjussen & Bahr[3] reported falling at an obstacle and collisions as the main injury mechanisms based on retrospective interviews of WC SBX riders. Jumping, which is an important feature of the SBX discipline, is thought to be another common cause of injuries for both recreational[10-13] and professional snowboarders.[2, 3, 14] Zygmuntowicz & Czerwinski[15] suggested that jumping-related injuries among national freestyle riders was a result of technical mistakes and rider errors, such as losing control, catching an edge, and risk taking.

Videos of actual injuries contain important injury information. Previous studies in team sport and alpine skiing have provided detailed description of the playing situation, athlete-opponent interaction and joint biomechanics for non-contact anterior cruciate ligament (ACL) and ankle injuries through systematic analyses of video recordings.[16-18] Our aim was to describe mechanisms of injuries, in terms of the riding situation and rider behaviour, in WC SBX riders based on systematic analyses of video recordings.[5, 19]

2. Methods

2.1 Injury and video recording

We obtained video recordings of injuries reported through the FIS ISS for 4 WC seasons (2006-2010). The FIS ISS was based on retrospective interviews with all athletes, coaches and medical staff from 20 snowboard WC teams.[2, 20] Only injuries leading to absence from competition or training for at least 1 day were included in this study. In total, 63 injuries were reported, 51 of these occurred during WC competition, World Snowboard Championships (WSC) and Olympic Winter Games (OWG) (Figure 1).

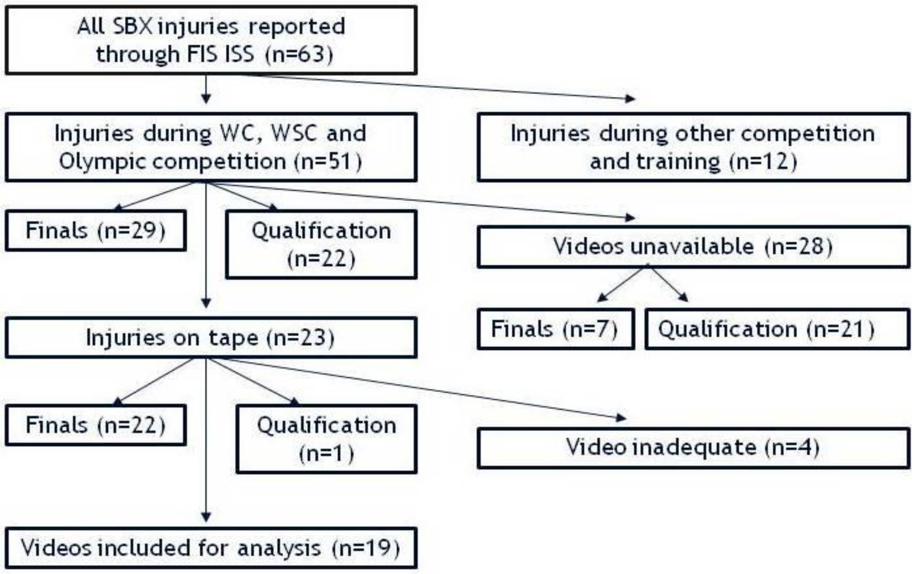

Figure 1. *Flow chart showing the process to identify videos of injuries in SBX in WC, WSC and OWG based on injury registration through the FIS ISS (2006-2010).*

In collaboration with the TV producer, Infront (Italy), we obtained recordings of the entire run of 22 injuries from WC competition, all from final runs. Four were excluded. In 1 case, the rider did not start in the run obtained on video whereas in the other 3 no injuries were identified or not visible (heavy fog). Additional footage of injuries from the OWG was obtained directly from the International Olympic Committee (IOC). Out of 5 injuries reported through FIS ISS, we captured 1 one injury from a qualification run on video. In total, we managed to obtain 19 injuries for video analysis, 18 from final runs and 1 from qualification run. Fourteen of these were captured from 1 camera angle and 6 from 2 camera angles.

2.2 Video processing

The 19 videos were mainly received as analogue video files on BetaCam SP (n=18). One version of each video was edited in Final Cut Pro version 6.06 (Apple, Cupertino, California) to include the rider situation from 1 or 2 obstacles prior to the injury situation and until the rider came to a full stop. In addition, the starting position was included to allow easy identification of the rider for the analysis. One video was received in digital .avi-format from the IOC TV producer. Analogue files were digitized to PAL-DV 48 KHz. All files were then transcoded to QuickTime (.mov) files in 4:3 formats, which enabled us to analyse the files using Quick Time Player (version 7, Apple, Cupertino, California). In 2 cases, we deinterlaced the videos in order to improve the quality for the analysis by increasing the effective frame rate from 25 to 50 Hz using Adobe Photoshop (CS2 Adobe System Inc, San Jose, California, USA).

2.3 Video analysis

We developed a specific analysis form for SBX based on previous forms for alpine skiing, handball and football.[16-18] The form included open and closed questions regarding a) the circumstances of injury, b) the rider situation, and c) rider behaviour (Table 1). Five experts in the fields of sports medicine, snowboard and biomechanics formed the analysis team. First, they independently reviewed the injury tapes to estimate the time of the injury, referred to as the index frame. During this phase, the experts were blinded to the opinion of the others, but we provided them injury information on each case (sex, specific diagnosis, injured side and riding style). The videos were then reviewed in a group session to reach a consensus on the index frame. Following the consensus meeting, the experts analysed each video independently to complete the form. Additionally, if experts judged the injury to occur in conjunction with jumping (take-off or landing), they were asked to draw an estimated optimal course line and the actual course line taken by the injured rider on topographical sketches of the course/obstacle profile, which we prepared in advance for each case using CAD software (Microstation V8i, Bentley Systems, Pennsylvania, USA).

The final analyses were done in group meetings where the experts carefully reviewed each case based on their completed forms and sketches to reach consensus on the circumstances and mechanisms of injury. Each video was examined as many times as needed to obtain a consensus on all categorical variables. If less than 3 experts could agree, the variable was reported as “no consensus”.

2.4 Statistical analysis

As a measure of the accuracy of the index frame estimates, we reported the mean absolute deviation (in ms) of the individual estimate from the index frame determined in the consensus meeting.

Table 1. *Variables and categories used in the analysis form to describe the injury situation of each injury case*

Variable	Categories
General/Environment	
Visibility	Good, reduced, unsure
Snow condition	Icy, hard, soft, unsure
Weather condition	Clear, foggy, snowy, unsure
Type of terrain	Flat, medium, steep, flat to steep, steep to flat/compression, dosed, unsure
Piste condition	Smooth, rough/bumpy, changes frequently, unsure
Preceding the injury (one/two obstacles before the index frame)	
Riding situation	Jumping, bank turning, giant slalom turn, riding on rollers, gliding/straight riding, unsure
If jumping, what type	Single, double, triple jump, spines, step up, step down, table top, unsure
If turning, which phase	Initiation, middle, end, change of turns, change of turn to jump, change of turn to roller, unsure
Loss of control	Yes, no, unsure
Gate contact	Yes, no, unsure
Security net	Yes, no, unsure
Is the rider riding an inappropriate course line	Yes, no, unsure
If yes, caused by	Timing, opponent, inappropriate strategy, previous obstacle, unsure
Regains control from previous obstacle	Yes, no, unsure
Technique	On edge forward, on edge backward, flat loaded, unsure
Balance	In balance, out of balance
Weight distribution	Equally, mainly on leading leg, mainly on back leg, unsure
If jumping (questions in relation to the sketches)	
Speed in relation to course setting	High, normal, unsure
Speed influence of controlling the jump	Yes, no, unsure
Course line influence on the injury	Yes, no, unsure
Technical error influence ability to control jump	Yes, no, unsure
Contact	
Any contact	Yes, no, unsure
Type of contact	Intentional, unintentional, unsure
Influence on rider control	Yes, no, already lost control, unsure
Influence on injury	Yes, no, unsure
What is in contact	Board, trunk, arms, head/neck, unsure
Who causes contact	Injured rider, opponent, unsure
Position of the rider who causes contact	In front, behind, beside, unsure, other please describe
Course at contact	Wide, narrow, unsure
Course of influence on contact	Yes, no, unsure
Attention (i.e. what is the rider focusing on)	Opponent, the piste, unsure, other please describe
Open question	Please describe the rider situation leading to the injury in your own words

3. Results

3.1 Injury characteristics

The majority of injuries were to the knee (n=6) and upper extremity (n=6) (Figure 2). The most severe injuries occurred when landing from a jump; 5 of the knee injuries and the 2 back injuries occurred after landing, and in another case the rider sustained multiple injuries to the thorax, abdomen and shoulder (Table 2).

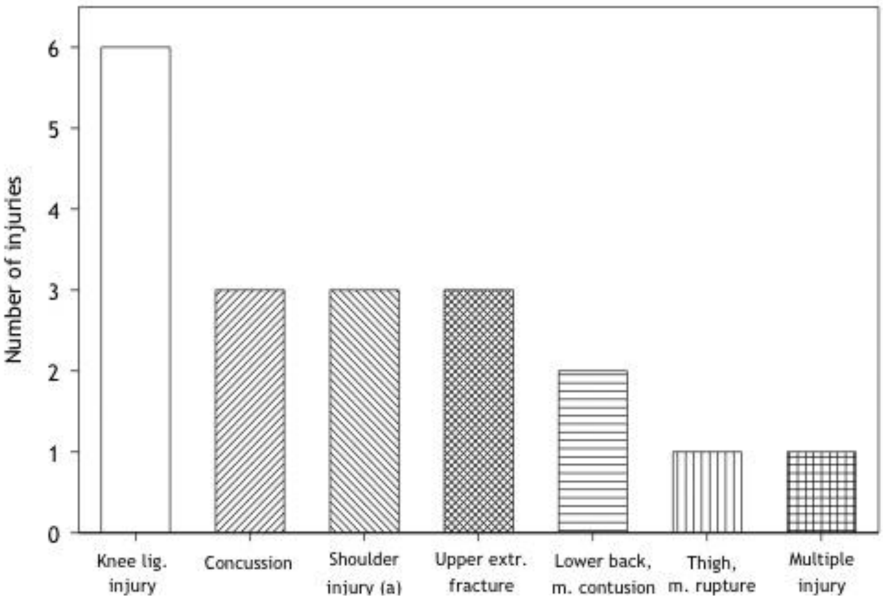

Figure 2. *Injury type and location of the injuries included in the video analysis based on injury registration through the FIS ISS. [a]The category shoulder injury includes dislocation, fracture and ligament injury.*

Table 2. *Results from video analysis of the riding situation preceding the injury in SBX*

				Riding situation					Contact				
											Influence on		
Case #	Specific diagnosis	Sex[1]	Accuracy (ms)[2]	Out of balance	Course line	Speed	Technical error	Location of error	Contact	Injured rider	Rider control	Injury	Position[3]
Jumping													
1	Concussion	M	±30	Lost balance	Inappropriate	Normal	Yes	Take off	No contact				
2	Concussion	F	±160	Lost balance	Appropriate	Normal	Yes	Take off	No contact				
3	Fracture UE[a]/radius	M	±70	Backwards	Inappropriate	Normal	Yes	Take off	Unsure				
4	Contusion low back	F	±110	Lost balance	Appropriate	Normal	Yes	Take off	No contact				
5	Multiple trauma	M	±230*	Lost balance	Inappropriate	Normal	Yes	Take off	No contact				
6	Quadriceps rupture[b]	F	±490***	Lost balance	Appropriate	Normal	Yes	Landing	No contact				
7	Knee injury/ligament	M	±490**	Forwards	Appropriate	Normal	Yes	Landing	No contact				
8	Muscle injury low back/pelvis	M	±200*	Lost balance	Appropriate	Normal	Yes	Landing	No contact				
9	Knee injury/ACL	M	±130	Backwards	Appropriate	Normal	Yes	Unsure	No contact				
10	Knee injury/ACL	M	±160	Lost balance	Inappropriate	Normal	Unsure	Take off	No contact				
11	Knee injury/ACL	M	±125	Lost balance	Appropriate	High	Unsure	Take off	No contact				
12	Knee injury/twisted	F	±30	Lost balance	Appropriate	Normal	No		Board/board Arms/arms	Active	Yes	Yes	Behind
13	Shoulder injury/ligament	M	±80	Lost balance	Appropriate	Normal	No		Board/board	Passive	Yes	Yes	In front
Bank turn													
14	Shoulder injury/AC[c]	M	±110	In balance	Appropriate				Board/board	Both	Yes	Yes	Unsure
15	Fracture UE[a]/forearm	M	±40	In balance	Appropriate				Board/board	Passive	Yes	Yes	In front/ beside
16	Concussion	F	±310*	Lost balance	Inappropriate				Board/board	Active	Yes	Yes	In front
17	Knee injury/MCL[d]	F	±50	In balance	Appropriate				Board/board Trunk/trunk Arms/arms	Passive	Yes	Yes	In front

18	Shoulder injury/ligament	M	±50	Forward	Inappropriate	Unsure				
Rollers										
				Index frame		Alternative index frame				
19	Fracture UE[a]/thumb	M	±340***	Forward	Appropriate	Board/hand	Active	Already lost control	Yes	In front

[1]Sex: male (M), female (F)
[2]Accuracy: Mean of the absolute deviations of the initial, individual estimates from the index frame determined in the consensus meeting (*One outlier relative to consensus, **two outliers, ***consensus based on three experts
[3]Position: position of the rider who caused the contact
[a] UE: Upper extremity
[b]Injury sustained in qualification run (individual run)
[c]AC: Acromioclavicular joint injury
[d]MCL: Medial collateral ligament

3.2 Riding situation and rider behaviour

Thirteen of the 19 injury situations occurred at jumps, 5 while turning in crescent banks and 1 while riding on rollers (Table 2). In 13 cases the rider had already lost control before the time of injury (mainly leading to a fall), in 3 cases due to contact with another rider. In total, 6 of the 19 cases resulted from contact with another rider, whereas in 2 cases this was not possible to judge. All contacts were unintentional, but influenced rider control and the subsequent injury. Most contacts occurred during bank turning (n=4) followed by jumping (n=2) (Table 2).

3.2.1 Jumping-related injuries

Of the 13 jumping-related injuries, 9 were caused by an individual technical error (losing control, catching the edge, timing of jump), 2 by contact with another rider, 1 by an inappropriate course line at take-off and 1 by too high speed at take-off. Out of the 9 technical errors, 5 occurred at take-off, 3 at landing whereas the experts were uncertain in 1 case (Table 2).

The most common technical error at take-off was a too high jump trajectory, which resulted in a flat landing. As a result the rider was unable to recover when landing (compression), leading to a fall and injury (cases #1-5). A similar mechanism was also assumed in 2 other cases. In the first case, the rider chose an inappropriate course line into the jump, which resulted in long air time and a flat landing outside the piste (case #10). In the second case, the rider gained too high speed from an outer position out of a bank turn leading to a high jump trajectory with long air time. The landing in this case was not possible to fully visualise on video, but was assumed to be flat (case #11) (Figures 3-4).

In 3 landing situations, the rider appeared to be in control at take-off and in the air, but lost control and/or caught an edge when landing, leading to a fall and injury (cases #6-8,Figure 5).

The final 2 jumping-related cases were caused by 1 rider losing control and/or caught an edge when landing and consequently caught the board of another rider. The other rider then lost balance, leading to a fall and injury (cases #12-13).

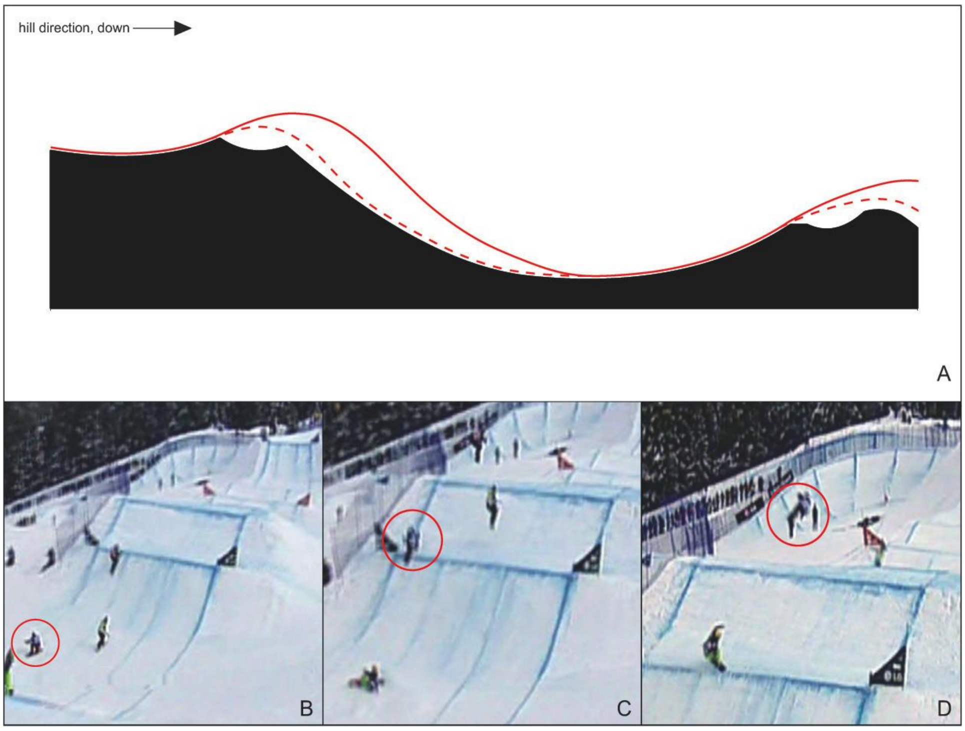

Figure 3. *Injury 4: Technical error at take-off.* **A,** section view of the jump showing the trajectory the injured rider (continuous line is injured rider, broken line is assumed optimal line based on trajectory of other riders). **B**, the injured rider lands flat and leaning backwards after a technical error from previous jump, is unable to recover. **C,** leading to unbalanced position at take-off on following jump (injury site). **D,** as a result, unable to control jump, uncontrolled flight.

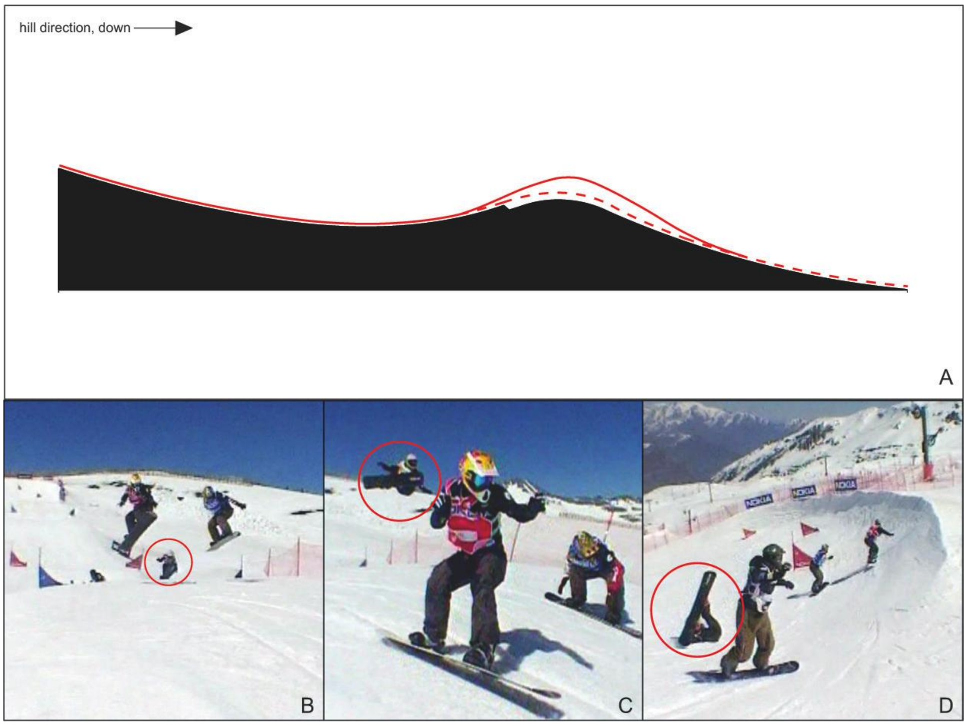

Figure 4. *Injury 2: Technical error at take-off.* **A**, section view of the jump showing the trajectory taken by the injured rider (continuous line is injured rider, broken line is assumed optimal line). **B**, the rider (circled) loses control at take-off. **C,** leading to uncontrolled flight with a high trajectory. **D,** the injured rider lands flat, outside the piste with a head fall (concussion).

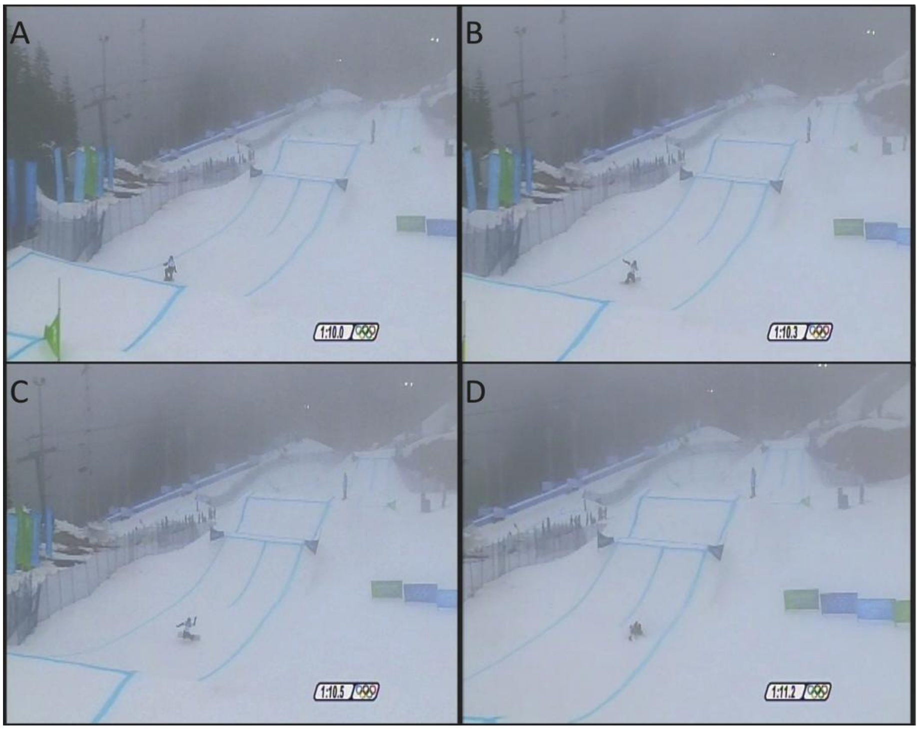

Figure 5. *Injury 7: Technical error at landing.* **A,**the rider lands out of balance backwards. **B**, the rider tries to recover with a heel turn. **C,** catches the edge and **D,** falls backwards.

3.2.2 Bank turn injuries

The second most common injury situation was turning in crescent banks (n=5). In all but 1 case a rider in a balanced position lost control due to contact with another rider (Table 2, cases #14-17). Contact was caused by another rider in 2 cases, by the injured rider in 1 and both in 1 situation. In all situations the rider causing the contact was in front. In 3 of the four contact situations, the rider who caused contact changed position during the turn from inner to outer position riding into the course line of the other rider, and caused contact by catching the board of the other rider. The injured rider then lost control leading to a fall at the time of injury (Figures 6-7). In 1 of these 3 cases, the rider hooked a gate with the board in an unbalanced position after contact with another rider (case #16).

The remaining 2 cases represent mechanisms different from the cases above. During the completion phase of the turn, another rider lost control and fell in front of the injured rider, thereby caused contact (case #17). In the final case no contact occurred. In a change of turn to roller, the rider was forced to take an inappropriate course line by the other rider. The rider came out of balance forward, which led to a fall at time of injury (case #18).

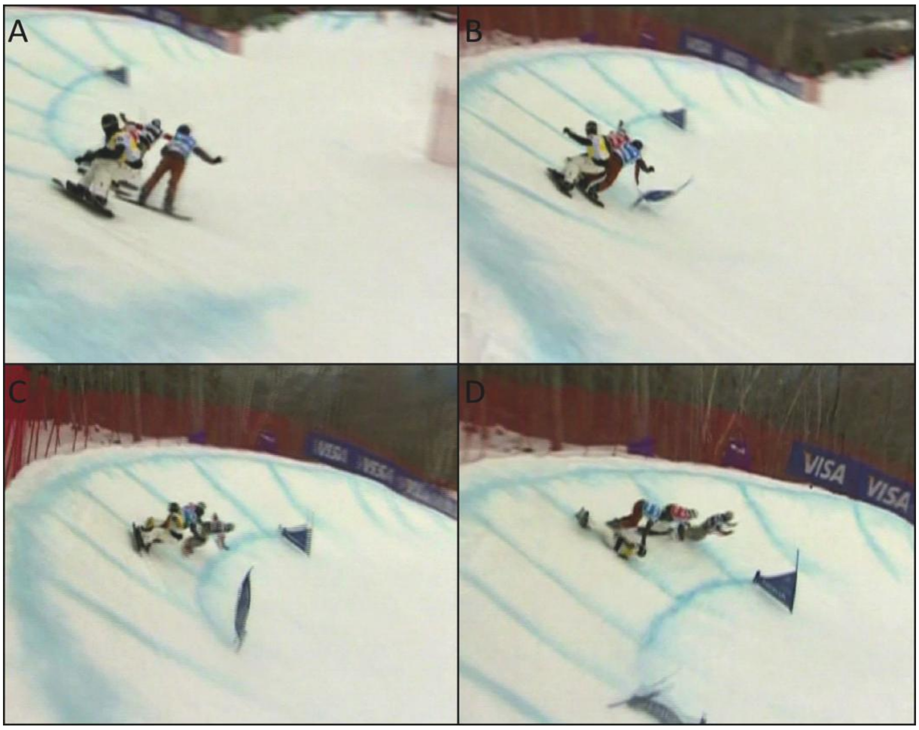

Figure 6. *Injury 16: Bank turn injury, contact*. **A**, the other rider (blue jersey) in an inner position at initial phase of bank turn. **B,** the other rider changes position from inner to outer position, riding into the course line of the injured rider (yellow jersey) and **C,** causing contact by catching the board of the injured rider. **D,** as a result the injured rider loses balance and falls onto the shoulder (index frame).

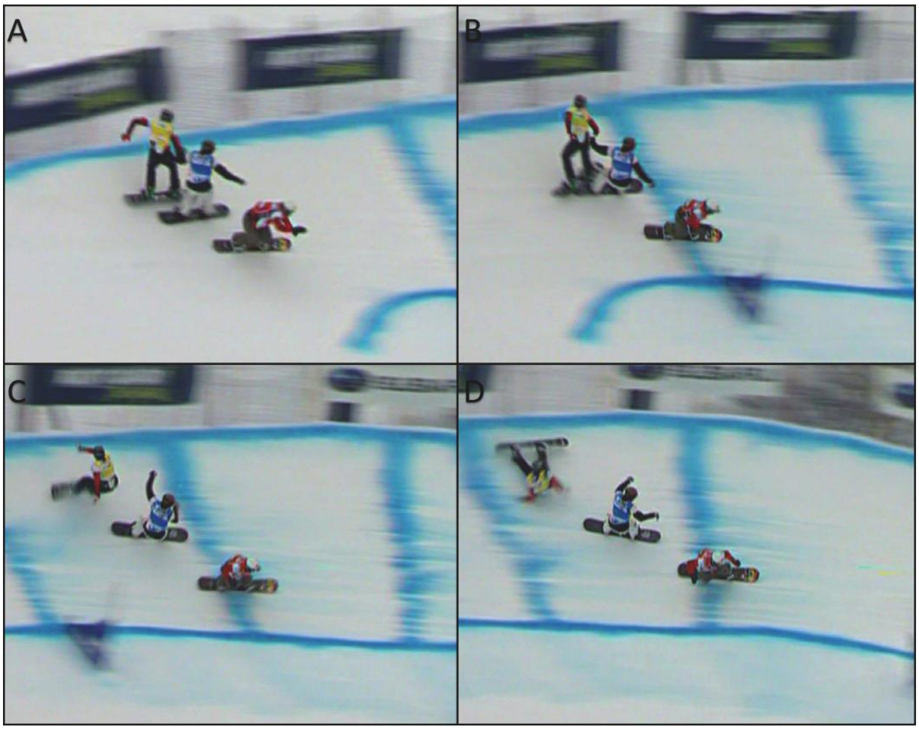

Figure 7. *Injury 15: Bank turn injury, contact.* **A,** the rider in the red jersey has the inner position in the initial phase of a bank turn. **B,** the red rider forces the blue rider to change position from inner to outer, riding into the course line of the injured rider (yellow jersey). **C,** causes contact by catching the board to the injured rider. **D,** as a result the injured rider loses balance and falls onto his outstretched hand and sustains a fracture of the forearm.

3.2.3 Roller injuries

In 1 case the rider lost balance forward on a roller as a consequence of a technical error from the previous roller. In an attempt at regaining balance, the rider leaned on his hand resulting in injury (case # 19).

4. Discussion

This is the first study to examine the injury mechanisms in WC SBX based on systematic video analyses. The principal finding was that most of the injuries resulted from an individual technical error at take-off when jumping. The second most common inciting event was unintentional board contact between riders at bank turning.

4.1 Riding situation

All injuries in this study occurred when jumping, bank turning and at rollers. Jumping accounted for over half of the injury cases. Previous studies on recreational snowboarders have also shown that jumping is associated with high injury rate.[10-13, 21-23] However, in contrast to jumps in snowboard parks, in SBX competition the jumps are designed to facilitate speed and less air time,[7] with a jump trajectory following the course profile as closely as possible. [24] Interestingly, we found in the majority of the cases that the injury was caused by an individual technical error (wrong timing, incorrect damping at take-off, losing control, catching the edge). This is supported by previous findings on national freestyle snowboarders.[15] Furthermore, we identified that half of the technical errors were at take-off, resulting in a too high jump trajectory and a flat landing beyond the intended landing zone. The rider was then unable to recover during the landing phase, which led to a fall at the time of injury. This mechanism corresponds very well with 1 rider's perspectives on how jump injuries occur (Stian Sivertzen, Norwegian team SBX rider, personal communication, May 2011). Although it appeared that the technical errors happened without interference from other riders, he commented that riders often feel stressed by the other riders as they try to maintain their position in the heat, thus forcing errors.

For injuries occurring at bank turns (n=5), 4 happened as a result of an unintentional board contact between riders. We observed a pattern were the rider who caused the contact changed from inner to outer position during the turn, riding into the course line of the other rider. The injured rider lost control due to board contact, which led to a fall. An explanation for these injuries may be the design of the turns. Although the turns were rated as wide in the majority of the cases, the experts pointed out that the actual riding space was narrow, considering that the turns are highly dosed. Combined with high speed, these factors may make the turn technically challenging and provoke contact. Another explanation may be that the riders are not fully aware of the position of the others as they seek the shortest course line to execute the turn, or they may be riding back to back.[24]

4.2 Rider behaviour

We observed that in 13 of the 19 cases the rider was out of balance well before the time of injury. In all of these cases the rider lost control from a technical error either at take-off, landing or at rollers. In the remaining 6 cases the rider lost balance at the time of injury as a result of accidental board contact. In all cases, the contact had a direct influence on the injury and mainly occurred as a board contact between 2 riders, only. In addition to the 4 contact situations identified at bank turns, we found 2 when landing after a jump. In these, the contact situation was distinctly different from the situations described at bank turns. The rider who caused the contact, positioned in front of the other rider, lost control when landing from an individual technical error. In an attempt at regaining balance, the rider then accidentally caught the board of the injured rider. Engebretsen et al.[1] suggested that accidental board and body contact might force the rider to have an unanticipated reaction, loss of control and probably leading to high-risk situations. Taking this view and the results of this current investigation into account, rider contact regularly causes loss of control and high-risk situations.

4.3 Methodological considerations

When interpreting the results from this study, there are some limitations. First, only 1 video from qualification runs was available for analysis. However, recent results from the FIS ISS show that the injury rate is significantly higher in final heats than in qualification runs (12.1 and 6.1 per 1000 runs, respectively) (Steenstrup et al., accepted October 25, BJSM 2011). Whether the mechanism of injuries in qualification and final runs differ is unknown, but there should be no contact injuries in the qualifications, as these are all individual runs. Second, we cannot in all cases be sure of the exact moment of injury. Especially for injuries occurring at jumps, the camera view was often less than optimal. However, as shown in Table 2, the individual estimates of the index frame were remarkably consistent in most cases.
Third, other performance-determining factors, such as psychological, cannot be analysed from video. This factor may have as much influence on injuries as the physical requirements in SBX.[9]

4.4 Further perspectives

In this study jumping was the most challenging obstacle, where technical errors either at take-off or landing caused the injury. But considering that a limited number of videos were available for analysis in this study, prospective systematic collection of injury videos should continue. Also, video recordings of injuries during qualification runs are needed to fully describe the inciting events in SBX injuries.

Nevertheless, we found a consistent pattern where jumping produced the most injuries. In addition, it appears that riding in heats of 4 or 6 is a contributing factor, especially at bank turning. There is, however, according to the FIS WC SBX rules, no standardisation on the height or distance between jumps or the next obstacles except from the start to the first bank.[7] In this study, however, the majority of jumping-related injuries were attributed to a technical error by the rider and not to the design of the jump itself. Nevertheless, if such standards could be developed, it might possibly reduce the energy involved when landing and give the riders more time to prepare for the next obstacle.

5. Conclusion

We identified that most injuries in SBX resulted from jumping, and that a technical error at take-off was the primary cause of the injuries. The second most common inciting event was unintentional board contact between riders at bank turning. In all 19 cases, the error or contact resulted in a rider out of balance leading to a fall at the time of injury.

5.1 Acknowledgements

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5.3 Ethical approval

The study was reviewed by the Regional Committee for Medical Research Ethics, South-Eastern Norway Regional Health Authority, Norway.

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Appendix 1

Oslo Sports Trauma
RESEARCH CENTER

FIS PARTNER
FIS INJURY SURVEILLANCE SYSTEM

Description of Injuries in World Cup Snowboardcross (SBX)

Expert: Date:

A. INJURY INFORMATION

Injury no: Specific diagnosis:

Rider ID (Colour):

Male:
Female:

Side injured:
Left
Right
Not applicable

Qualification
Final

Riding style: Regular ☐ Goofy ☐

At what frame do you think the injury occur?

Alternative index frame number(s):

Corresponding index frame:

The assumed moment of injury (consensus):

B. PRECEDING THE INJURY

Enviroment

Visibility:
- Good ☐
- Reduced ☐
- Unsure ☐

Snow condition:
- Icy ☐
- Hard ☐
- Soft ☐
- Unsure ☐

Weather condition:
- Clear ☐
- Foggy ☐
- Snowy ☐
- Cloudy ☐
- Unsure ☐

Type of terrain:
- Flat ☐
- Medium ☐
- Steep ☐
- Flat to steep ☐
- Steep to flat/compression ☐
- Dosed ☐
- Unsure ☐

Piste condition:
- Smooth ☐
- Rough/bumpy ☐
- Changes frequently ☐
- Unsure ☐

Riders situation			
The rider is:			
Jumping - take off	☐		
Landing after a jump	☐		
Bank turning	☐		
Giant Slalom turn	☐		
Riding on rollers	☐		
Gliding/straight riding	☐		
Unsure	☐		

If jumping, what type:		If turning, the rider is in:	
Single jump (kicker)	☐	Initiation phase	☐
double jump	☐	Control phase	☐
triple jump	☐	Completion phase	☐
Spines	☐	Change of turns	☐
double spines	☐	Change of turn to jump	☐
Step-up jump	☐	Change of turn to roller	☐
Step-down jump	☐	Unsure	☐
table top jump	☐		
Unsure	☐		

Has the rider lost control (is out of balance) before time of injury?

	Yes	☐
	No	☐
	Unsure	☐
If yes, leading to:	Fall	☐
	Major instability	☐
	Minor instability	☐
	Unsure	☐

Gate contact:

No	☐
Yes	☐

If yes, influence on rider control

-	Yes	☐
-	No	☐
-	Already lost control	☐
-	Unsure	☐

Yes, and influence on the injury

Yes	☐
No	☐
Unsure	☐

Security net

Does the rider hit the security net? :	Yes	☐
	No	☐
If yes: did the security net function adequately	Yes	☐
	No, please describe	
If yes: was it misplaced:	Yes	☐
	No	☐
	Unsure	☐

If jumping:

If at take off, is the rider riding an inappropriate course line:

- Yes ☐
- No ☐
- Unsure ☐

If yes, is this caused by:

- Time pressure ☐
- Opponents ☐
- Inappropriate strategy ☐
- Unsure ☐

Regains control after landing from previous obstacle:

- Yes ☐
- No ☐
- Unsure ☐

If no:

- Falls ☐
- Out of balance ☐
- Unsure ☐

If no: from which previous obstacle:

- Jump ☐
- Bank turn ☐
- Rollers ☐
- Other, please describe
- Unsure ☐

The rider is during take off:

- Out of balance backward ☐
- Out of balance forward ☐
- In balance in the sagital plane ☐
- Unsure ☐

- Out of balance to the right ☐
- Out of balance to the left ☐
- In balance in the frontal plane ☐
- Unsure ☐

If at landing

Does the rider fall?	Yes	☐	If yes:	On piste	☐
	No	☐		Outside piste	☐
	Unsure	☐		Unsure	☐
				Other, please describe:	

Type of terrain at landing

Flat	☐
Steep	☐
Uphill	☐
Unsure	☐
Other, please describe	

The rider is landing:

On board	☐
Head/neck	☐
Back	☐
Trunk	☐
Upper extremity	☐
Unsure	☐

<u>If landing on board, landing is</u>

Normal	☐
On edge forward	☐
On edge bacward	☐
Flat loaded forward	☐
Flat loaded backward	☐
Unsure	☐

<u>Weight distribution on board:</u>

Equally	☐
Mainly on the leading leg	☐
Mainly on the back leg	☐
Unsure	☐

<u>The rider is at landing:</u>

Out of balance backward	☐
Out of balance forward	☐
In balance in the sagital plane	☐
Unsure	☐
Out of balance to the right	☐
Out of balance to the left	☐
In balance in the frontal plane	☐
Unsure	☐

if at jumps (questions in relation to the sketches)

<u>Course line</u>

<u>The course line taken by the injured rider</u>

Is the rider forced to take the chosen line? Yes ☐ No ☐ Unsure ☐

If yes: forced by

- Opponent ☐
- Timing/time pressure ☐
- Inappropriate strategy ☐
- Unsure ☐

Is the course line taken by the injured rider of influence on the injury: Yes ☐ No ☐ Unsure ☐

<u>Speed</u>

Is speed (high) at take off of influence on the injury situation? Yes ☐ No ☐ Unsure ☐

Does speed contribute to the ability to control the jump? Yes ☐ No ☐ Unsure ☐

<u>Jumping technique</u>

Does the rider do a technical error at the jump? Yes ☐ No ☐ Unsure ☐

If yes:

- take off ☐
- in the air ☐
- landing ☐
- unsure ☐

Is a technical error at jumping of influence on the injury situation? Yes ☐ No ☐ Unsure ☐

If turning:					
During the turn, is the rider riding an inappropriate course line?				Yes	☐
				No	☐
				Unsure	☐
If yes, is this caused by:					
Time pressure		☐			
Opponents		☐			
Inappropriate strategy		☐			
Previous obstacle		☐	Please specify:	After jump	☐
Unsure		☐		After bank turn	☐
				After rollers	☐
				Unsure	☐
Rider falls?	Yes	☐			
	No	☐			
	Unsure	☐			
<u>The rider is:</u>					
Out of balance backward		☐			
Out of balance forward		☐			
In balance in the sagital plane		☐			
Unsure		☐			
Out of balance to the right		☐			
Out of balance to the left		☐			
In balance in the frontal plane		☐			
Unsure		☐			
<u>Board is</u>			<u>Weight distribution on board:</u>		
Edge loaded forward		☐	Equally		☐
Edge loaded backward		☐	Mainly on the leading leg		☐
Normal		☐	Mainly on the back leg		☐
Unsure		☐	Unsure		☐
if riding on rollers or if not jumping nor turning					
Does it appear that the rider is riding an inappropriate course line?				Yes	☐
				No	☐
				Unsure	☐
<u>If yes, is this caused by:</u>					
Time pressure		☐			
Opponents		☐			
Innapropriate strategy		☐			
Previous obstacle		☐	Please specify:	After jump	☐
Unsure		☐		After bank turn	☐
				After rollers	☐
				Unsure	☐

The rider is:

Out of balance backward ☐
Out of balance forward ☐
In balance in the sagital plane ☐
Unsure ☐

Board is

On edge forward ☐
On edge backward ☐
Flat loaded ☐
Unsure ☐

Weight distribution on board:

Equally ☐
Mainly on the leading leg ☐
Mainly on the back leg ☐
Unsure ☐

Riders/opponents behaviour

1.Contact

Is there any contact?

Yes ☐
No ☐
Unsure ☐

If yes, what type?

Intensional (pulling, pushing) ☐
Unintensional ☐
Unsure ☐

If yes, influence on rider control

- Yes ☐
- No ☐
- Already lost control ☐
- Unsure ☐

Yes, and influence on the injury

Yes ☐
No ☐
Unsure ☐

What is in contact?

	Board	Trunk	Arms	Head/neck	Unsure
Board					
Trunk					
Arms					
Head/neck					
Unsure					

Comment:

Who causes the contact?

Injured rider	☐
Opponent	☐
Unsure	☐

How many is involved?:

Position in heat:

Injured		Opponent	
No 1	☐	No 1	☐
No 2	☐	No 2	☐
No 3	☐	No 3	☐
No 4	☐	No 4	☐
Unsure	☐	Unsure	☐

Position of the rider who causes contact (in relation to opponent):

In front	☐
Behind	☐
beside	☐
Unsure	☐
Other, please describe	

Riding style of those in contact:

	Injured rider	Opponent 1	Opponent 2	Opponent 3
Leading leg Left	☐	☐	☐	☐
Leading leg Right	☐	☐	☐	☐
Unsure	☐	☐	☐	☐

Course at contact

Wide	☐
Narrow	☐
Steep	☐
Unsure	☐

Is course of influence on the contact:

Yes	☐	If yes:	High influence	☐
No	☐		Slight influence	☐
Unsure	☐		No influence	☐
			Unsure	☐

If contact at a jump, when?

Take off	☐
In the air	☐
At landing	☐
Unsure	☐

if at turning, when?

Initiation phase	☐
Control phase	☐
Completion phase	☐
Change of turns	☐
Change of turn to jump	☐
Change of turn to roller	☐
Unsure	☐

2. Attention (where is the rider´s attention directed to)

- Opponent ☐
- the piste ☐
- Unsure ☐
- Other, please describe

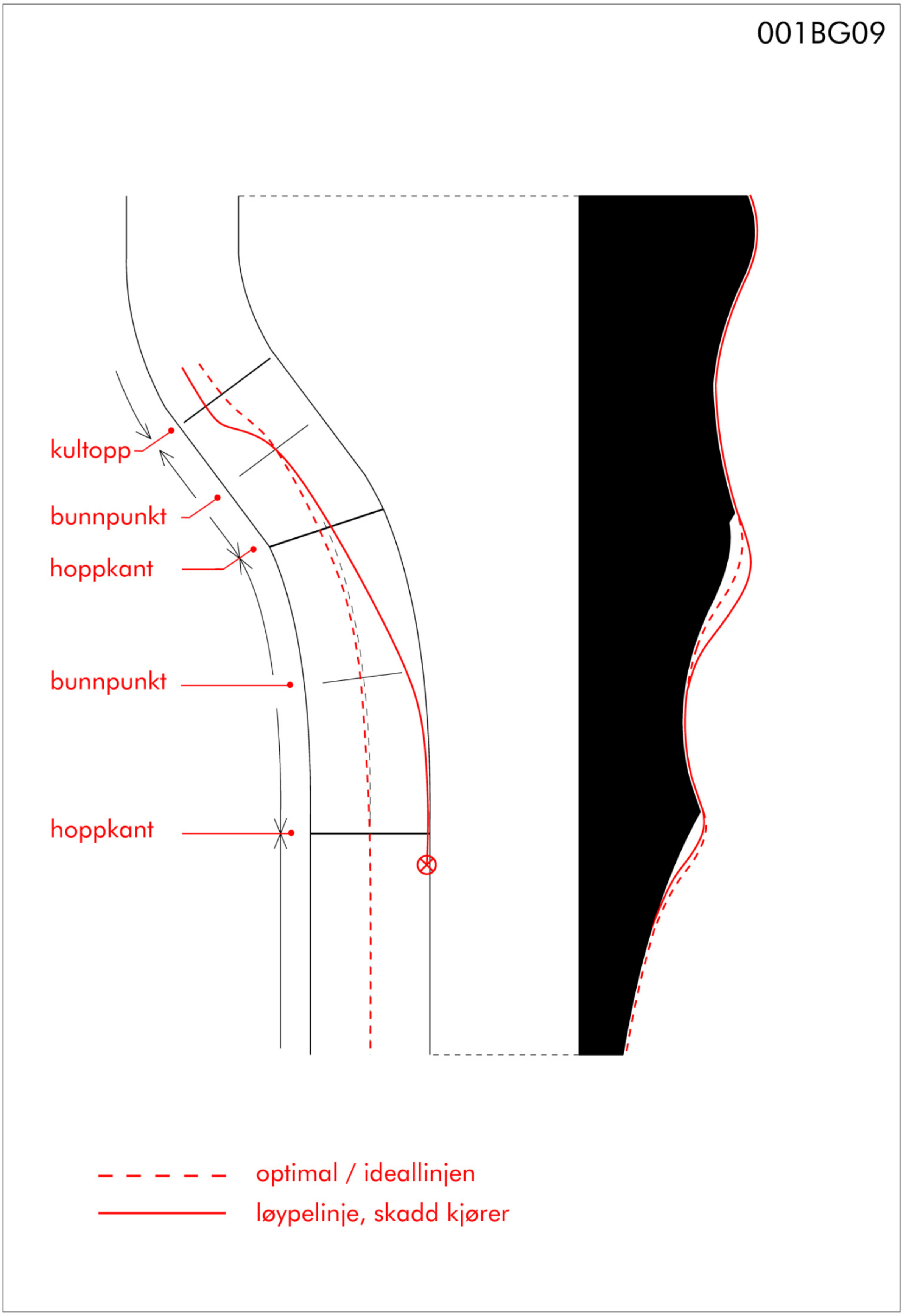
Comments:

Please describe the rider situation leading to injury in your own words, outlining key factors which may have caused the injury situation.

C. THE TIME OF INJURY

Please describe the injury mechanism in your own words.

Appendix 2


001BG09
kultopp
bunnpunkt
hoppkant
bunnpunkt
hoppkant
optimal / ideallinjen
løypelinje, skadd kjører

Appendix 3

Re: Permission to use image of SBX/SX course

9/29/2011

Riikka Rakic
To phbakken@hotmail.com

From: **Riikka Rakic** (rakic@fisski.com)
Sent: Thursday, September 29, 2011 10:14:39 AM
To: phbakken@hotmail.com

Dear Arnhild

we confirm herewith the permission to use the image identified as described below.

Best regards

INTERNATIONAL SKI FEDERATION

Riikka Rakic
FIS Communications Manager

****
Blochstr. 2
CH-3653 Oberhofen/Thunersee, Switzerland
Phone + 41 79 64 34 281
Fax + 41 33 244 61 71
rakic@fisski.ch
www.fis-ski.com

-------- Original-Nachricht --------

Betreff: Permission to use image of SBX/SX course
Datum: Thu, 29 Sep 2011 08:38:52 +0200
Von: Arnhild Bakken <phbakken@hotmail.com>
An: <mail@fisski.ch>

Hi,

I am a Norwegian physiotherapist currently writing a master's thesis about injury mechanisms in World Cup SBX at the Norwegian School of Sports Sciences. I am currently writing a section describing SBX course and features, and I therefore would like to ask permission to use the image of a SBX/SX course and some of its features from your website FIS Competition rules (attachment). The image will be referenced with the name of permission giver and your website address.

If this e-mail does not reach the correct person to answer this question, could you please forward it appropriately?

Thank you for your co-operation.

Best regards,
Arnhild Bakken

Appendix 4

Re: Permission to use image of SX Course features

10/4/2011

Keith Bradford
To Arnhild Bakken

From: **Keith Bradford** (kbradford@alpinecanada.org)
Sent: Tuesday, October 04, 2011 7:55:40 PM
To: Arnhild Bakken (phbakken@hotmail.com)
Hi Arnhild,

That's fine with me but I don't know what the source of that graphic is.

Keith

From: Arnhild Bakken <phbakken@hotmail.com>
Date: Tue, 4 Oct 2011 11:40:41 -0600
To: Keith Bradford <kbradford@alpinecanada.org>
Subject: Permission to use image of SX Course features

Hi,

I am a Norwegian physiotherapist currently writing a master's thesis about injury mechanisms in World Cup Snowboardcross (SBX) at the Norwegian School of Sports Sciences. I am currently writing a section describing SBX course and features. In the search on google images for a picture/image of the different features of a SBX course, I came across your image of a Skicross course. Since the features in SX and SBX are very much the same, I therefore would like to ask permission to use the image of a SX course and features from your website (attachment). The image will be referenced with the name of permission giver and your website address.

If this e-mail does not reach the correct person to answer this question, could you please forward it appropriately?

Thank you for your cooperation

Best regards

Arnhild Bakken
Oslo Sports Trauma Research Center
Department of Sports Medicine
Norwegian School of Sport Sciences
PO Box 4014 Ullevål Stadion
0806 Oslo
NORWAY
www.ostrc.no

Appendix 5

SV: Tillatelse til bruk av figur i masteroppgave

10/24/2011

Roald Bahr
To Arnhild Bakken

From: **Roald Bahr** (roald.bahr@nih.no)
Sent: Monday, October 24, 2011 9:09:40 AM
To: Arnhild Bakken (phbakken@hotmail.com)

ok

____
Fra: Arnhild Bakken [phbakken@hotmail.com]
Sendt: 24. oktober 2011 08:51
Til: Roald Bahr
Emne: Tillatelse til bruk av figur i masteroppgave

Hei Roald.

Jeg ferdigstiller nå min masteroppgave i idrettsfysioterapi: Mechanisms of Injuries in World Cup Snowboard Cross: A systematic Video Analysis of 19 cases. I den forbindelse spør jeg om tillatelse om å bruke din figur: Multifaktorielle modell som beskriver årsaken til skader (vedlagt) i oppgaven?

Arnhild