BJSM Online First, published on October 4, 2013 as 10.1136/bjsports-2013-092573

Injury rate and injury pattern among elite World Cup snowboarders: a 6-year cohort study

D H Major,[1] S E Steenstrup,[1] T Bere,[1] R Bahr,[1] L Nordsletten[1,2,3]

[1]Department of Sports Medicine, Oslo Sports Trauma Research Center, Norwegian School of Sports Sciences, Oslo, Norway
[2]Department of Orthopedic, Oslo University Hospital, Oslo, Norway
[3]University of Oslo, Oslo, Norway

Correspondence to
Daniel H Major, Department of Sports Medicine, Oslo Sports Trauma Research Center, Norwegian School of Sports and Sciences, PO Box 4014, Ullevål Stadion, Oslo N-0806, Norway; daniel@major.no

Accepted 3 September 2013

ABSTRACT

Background There is limited knowledge on the injury rate and injury pattern in the different disciplines among elite snowboarders.

Objective The aim of this study was to describe and compare the injury rate and injury pattern among the different International Ski Federation (Fédération Internationale de Ski, FIS) World Cup (WC) snowboard disciplines.

Methods We conducted retrospective interviews with FIS WC snowboard athletes at the end of each season in the period 2007–2012, to register all acute injuries sustained during training or competition during the competitive season requiring attention by medical personnel. To calculate the exposure, we obtained information from result lists from the FIS competition database for all WC competitions for each of the interviewed athletes.

Results We registered a total of 574 injuries among 1432 athletes, accounting for an overall injury rate of 40.1 injuries/100 athlete/season. A total of 171 injuries occurred during the FIS WC competitions, corresponding to 6.4 injuries/1000 runs. During competition, injury risk was highest in snowboard cross with 11.9/1000 runs, followed by 6.3 in halfpipe, 3.6 in big air and 2.8 in parallel giant slalom/parallel slalom (PGS/PSL). Snowboard cross also had the highest risk of severe injuries (>28 days absence). No differences in injury risk were detected between male and female snowboarders. The most commonly injured body part was the knee (17.8%), followed by the shoulder/clavicle (13.4%) and head/face (13.2%). The risk of knee injury (the most common injury type) and head injury was significantly higher in snowboard cross and halfpipe compared to PGS/PSL.

Conclusions The risk of injuries was higher in snowboard cross than in halfpipe, big air and PGS/PSL. The most commonly injured body part was the knee. Prevention of snowboard injuries among elite snowboarders should focus on knee injuries, severe injuries and snowboard cross athletes.

INTRODUCTION

Snowboarding is a relatively new but popular winter sport. The International Ski Federation (Fédération Internationale de Ski, FIS) organised the first Snowboard World Cup (WC) in 1994, and snowboarding became an Olympic discipline in 1998 in Nagano.[1] The FIS WC snowboard disciplines are halfpipe (HP), snowboard cross (SBX), big air (BA), slopestyle and parallel giant slalom/parallel slalom (PGS/PSL). In total, 634 active snowboarders competed in the FIS WC competitions during the 2012/2013 season.[2]

According to a previous study, as many as 1/3 of all WC snowboarders suffer a time-loss injury during the 5-month winter season.[3] Snowboarders have a higher rate of time-loss injuries compared to other FIS disciplines, 37% higher than freestyle and 27% higher than alpine skiing.[3]

Engebretsen *et al*[4] found that as many as 35% of athletes in SBX, 13% in HP and 4% in PGS sustained an injury during the 2010 Olympic Winter Games (OWG). Only one previous study has compared the injury risk between the different disciplines of snowboarding, documenting a rate of 1.3 injuries (95% CI 1.0 to 1.7) per 1000 runs among snowboarders competing in the FIS WC.[5] The injury rate was significantly higher in BA (2.3), SBX (2.1) and HP (1.9) than in PGS (0.6) and PSL (0.3).[5] However, the findings from this one-season study should be interpreted with caution due to low study power.

Studies on elite snowboarders have suggested that the injury pattern may be different when compared to the injury pattern among recreational snowboarders, with a lower proportion of wrist fractures and a higher proportion of injuries to the knee, chest and back.[3 5 6] However, data on the injury rate and profile among elite snowboarders are limited,[7] as they are based on a low number of competitions without an exact exposure registration (number of started runs). Thus, the aim of this study was to describe the injury rate and the injury pattern among elite snowboarders participating in the FIS WC in the disciplines HP, BA, SBX and PGS/PSL, based on 6-year data from the FIS Injury Surveillance System (ISS).

MATERIAL AND METHODS

Study design and population

We recorded injuries through the FIS ISS based on annual retrospective athlete interviews during six WC seasons (2007–2012). A methodological study has shown that retrospective interviews were the best method to register injuries, compared to prospective injury registration by FIS technical delegates and team medical personnel.[7] Athletes on the WC teams from Austria, Canada, Finland, France, Germany, Italy, Norway and Sweden were interviewed. During the study period, we also included athletes from 23 other teams to increase the study population. The team had to have a response rate of 80% or more to be included. All the athletes included were registered in the FIS database and had started in at least one FIS WC competition.

All interviews were conducted at the end of each season in person by physicians or physiotherapists from the Oslo Sports Trauma Research Center in the finishing area or during organised meetings at

To cite: Major DH, Steenstrup SE, Bere T, *et al*. *Br J Sports Med* Published Online First: [*please include* Day Month Year] doi:10.1136/bjsports-2013-092573

the competitor hotel. We completed a standardised interview form[7] for each athlete, where each athlete was asked to consent to participating in the FIS ISS. If the athlete reported an injury, an injury form[7] was also completed. The injury form consisted of information about the date and place of injury, injury circumstances, body part injured, side (left/right), injury type, injury severity and the specific diagnosis. If an athlete was not present at the event, due to injury or other reason, or if the athlete did not understand English, the team coach, physician or physiotherapist was interviewed. If the athlete was injured at the time of the interview, we used the physician's prognosis to classify the severity of the injury.

Injury definition

We defined injuries as "all acute injuries that occurred during training or competition and required attention by medical personnel."[8] The injury definition and the classification of body parts and injury types used in the injury form was based on a consensus document on injury surveillance in football.[8] We classified the severity of the injuries, according to the duration of absence from training and competition, as follows: slight (no absence), minimal (1–3 days), mild (4–7 days), moderate (8–28 days) and severe (>28 days).[8]

Exposure registration

To calculate exposure, we obtained the exact number of started runs by each of the athletes interviewed from the official FIS competition database (http://www.fis-ski.com) for each of the six seasons (2007–2012). The result list for each of the WC races during the six seasons was extracted one by one from the FIS database online into an Excel file. Specific variables were added to the result for each of the athletes, that is, date, discipline, place and sex. In addition, we created a new variable to calculate the number of started runs for each athlete per competition. The exposure data in the Excel file were transferred to our database (Oracle Database 11g, Oracle Corporation, California, USA) where we linked the exposure data for each of the athletes to the information recorded through the interviews. We calculated total exposure, as well as exposure for males versus females and for each of the different snowboarding disciplines.

Statistical analysis

The injury rate was expressed as the absolute injury rate (injuries per 100 athletes per season) and the relative injury rate (injuries per 1000 runs) with the corresponding 95% CI. When calculating the absolute injury rate we included all recorded injuries, while we only included injuries in official WC, World Snowboard Championship (WSC) and OWG competitions when calculating the relative injury rate, as the number of runs started (exposure) was only available for these events. A total of 15 injuries reported to have occurred in competition could not be attributed to the event reported (HP: n=6, PGS/PSL: n=1, SBX: n=8). We included these in our analysis of the absolute injury rate, as it seems quite likely that these injuries occurred in training prior to the competition rather than in the competition itself. Calculations were based on the Poisson model, and Z tests were used to compare the injury rate and injury pattern between groups. The rate ratio (RR) with 95% CI was computed. A two-tailed p level of <0.05 was considered to be statistically significant.

RESULTS

In total, 1432 interviews were completed, 927 on male snowboarders and 505 on female snowboarders during six winter seasons (table 1). Of these, 621 interviews (43%) were carried

Table 1 Number of injuries and athletes interviewed during six seasons of FIS WC snowboarding (2007–2013) with absolute injury rate (injuries per 100 athletes per season) computed with 95% CI for the specific discipline and the specific seasons

	Big air			Halfpipe			PGS/PSL			Snowboard cross			Total		
Season	Injuries	Athletes	Injury rate	Injuries	Athletes	Injury rate	Injuries	Athletes	Injury rate	Injuries	Athletes	Injury rate	Injuries	Athletes	Injury rate
06/07	4	7	57.1 (1.1–113.1)	32	67	47.8 (31.2–64.3)	3	4	75 (−9.9 to 159.9)	27	64	42.2 (26.3–58.1)	66	142	46.5 (35.3–57.7)
07/08	11	40	27.5 (11.2–43.8)	22	73	30.1 (17.5–42.7)	32	70	45.7 (29.9–61.6)	66	97	68 (51.6–84.5)	131	280	46.8 (38.8–54.8)
08/09	7	15	46.7 (12.1–81.2)	43	88	48.9 (34.3–63.5)	27	77	35.1 (21.8–48.3)	53	89	59.6 (43.5–75.6)	130	269	48.3 (40–56.6)
09/10	0	7	–	15	69	21.7 (10.7–32.7)	20	98	20.4 (11.5–29.4)	51	97	52.6 (38.1–67)	86	271	31.7 (25–38.4)
10/11	3	14	21.4 (2.8–45.7)	32	80	40 (26.1–53.9)	15	101	14.9 (7.3–22.4)	65	119	54.6 (41.3–67.9)	115	315	36.5 (29.8–43.2)
11/12	2	8	25 (-9.7–59.6)	11	33	33.3 (13.6–53)	7	62	11.3 (2.9–19.7)	26	53	49.1 (30.2–67.9)	46	156	29.5 (21–38)
Total	27	91	29.7 (18.5–40.9)	155	410	37.8 (31.9–43.8)	104	412	25.2 (20.4–30.1)	288	519	55.5 (49.1–61.9)	574	1432	40.1 (36.8–43.4)

FIS WC, International Ski Federation (Fédération Internationale de Ski) World Cup; PGS/PSL: parallel giant slalom/parallel slalom.

Table 2 Number of injuries (n) and absolute injury rate (expressed as the number of injuries per 100 athletes per season) with 95% CI for all recorded injuries, time-loss injuries (≥1 day absence) and severe injuries (>28 days) for the different snowboard disciplines

	All injuries		Time-loss injuries (≥1 day)		Severe injuries (>28 days)	
Discipline	n	Incidence	n	Incidence	n	Incidence
Big air	27	29.7 (18.5 to 40.9)	23	25.3 (14.9 to 35.6)	9	9.9 (3.4 to 16.4)
Halfpipe	155	37.8 (31.9 to 43.8)	103	25.1 (20.3 to 30.0)	36	8.8 (5.9 to 11.6)
PGS/PSL	104	25.2 (20.4 to 30.1)	81	19.7 (15.4 to 23.9)	32	7.8 (5.1 to 10.5)
Snowboard cross	288	55.5 (49.1 to 61.9)	216	41.6 (36.1 to 47.2)	101	19.5 (15.7 to 23.3)
Total	574	40.1 (36.8 to 43.3)	423	29.5 (26.7 to 32.3)	178	12.4 (10.6 to 14.2)

PGS/PSL, parallel giant slalom/parallel slalom.

out with the athletes, 158 (11.0%) with medical personnel and 653 (46%) with team coaches.

We recorded a total of 574 injuries (213 among women and 361 among men) and of these, 74% were time-loss injuries (n=423). The majority of the time-loss injuries were severe (n=178, 42%) or moderate (n=111, 26%). There were 80 mild injuries (19%) and 54 were minimal (13%). In 19 cases (3.3%), we did not have data on injury severity.

The overall injury rate was 40.1 (95% CI 36.8 to 43.4) injuries per 100 athletes per season (table 2). For all injuries, the injury risk was significantly higher in SBX than in BA (RR 1.9, 95% CI 1.3 to 2.8), HP (RR 1.5, 95% CI 1.2 to 1.8) and PGS/PSL (RR 2.2, 95% CI 1.8 to 2.8). The injury risk was also significantly higher in HP compared to PGS/PSL (RR 1.5, 95% CI 1.2 to 1.9). For time-loss injuries, the injury risk was significantly higher in SBX than in BA (RR 1.6, 95% CI 1.1 to 2.5), HP (RR 1.7, 95% CI 1.3 to 2.1) and PGS/PSL (RR 2.1, 95% CI 1.6 to 2.7), while for severe injuries, the injury risk was significantly higher in SBX compared to HP (RR 2.2, 95% CI 1.4 to 3.2) and PGS/PSL (RR 2.5, 95% CI 1.7 to 3.7). There were no sex differences in the injury risk within any disciplines or severity categories.

Of all the injuries reported (n=574), 28% occurred during WC/WSC/OWG competitions (n=171), 20% during official training for these competitions (n=117), 27% in regular training on snow (n=152) and 1.7% during basic training not on snow (n=10). In 19%, the injuries occurred during other competitions (n=109), while the remaining injuries (n=15, 2.4%) were not identified. For the WC/WSC/OWG injuries (n=171), we calculated the injury rate (injuries per 1000 runs) to compare disciplines and sexes (table 3). For all these 171 injuries, the injury risk was significantly higher in SBX than in BA (RR 3.3, 95% CI 1.4 to 8.2), HP (RR 1.9, 95% CI 1.2 to 2.9) and PGS/PSL (RR 4.2, 95% CI 2.9 to 6.1). There was also a significantly higher injury risk in HP compared to PGS/PSL (RR 2.2, 95% CI 1.3 to 3.7). For time-loss injuries, there was a significantly higher injury risk in SBX than in HP (RR 2.5, 95% CI 1.4 to 4.5) and PGS/PSL (RR 4.0, 95% CI 2.5 to 6.3), while for severe injuries, the injury risk was significantly higher in SBX compared to HP (RR 2.9, 95% CI 1.0 to 8.4) and PGS/PSL (RR 3.5, 95% CI 1.7 to 7.3). No sex differences in injury risk were detected within any disciplines or severity categories.

Of the 574 injuries reported, 42% (n=241) were located in the lower extremities (figure 1). The most commonly injured body part was the knee (n=102, 17.8%), followed by the shoulder/clavicle (n=77, 13.4%) and head/face (n=76, 13.2%). There were no significant differences between men and women with respect to the body part injured.

Based on injuries from the WC/WSC/OWG (n=171), BA athletes had a significantly higher risk (injuries per 1000 runs) of ankle injuries than PGS/PSL athletes (RR 8.8, 95% CI 1.2 to 62.4). SBX (RR 8.4, 95% CI 2.5 to 8.4) and HP (RR 5.0, 95% CI 1.2 to 20.9) had a significantly higher risk of injuries to the head/face than PGS/PSL. SBX had a significantly higher risk of knee (RR 5.9, 95% CI 2.0 to 17.6), lower back/pelvis/sacrum (RR 4.2, 95% CI 1.3 to 13.0), chest (sternum/ribs/upper back; RR 8.4, 95% CI 1.0 to 69.5) and shoulder/clavicle injuries (RR 2.8, 95% CI 1.1 to 6.9) than PGS/PSL. HP also had a significantly higher risk of knee injuries than PGS/PSL (RR 5.2, 95% CI 1.5 to 17.9).

DISCUSSION

This is the first large cohort study to compare injury risk and injury patterns across WC snowboard disciplines. The study is based on the largest available database on snowboard injuries among elite snowboarders, the FIS ISS, and exact exposure data

Table 3 Number of all injuries (n=171) and exposure (the total number of runs, n=26 691) in the different disciplines during FIS WC, WSC and OWG competitions

	Injuries			Exposure (runs)			Incidence (injuries per 1000 runs)			RR
Discipline	Men	Women	Total	Men	Women	Total	Men	Women	Total	Men versus women
Big air	5	0	5	1402	–	1402	3.6 (0.4 to 6.7)	–	3.6 (0.4 to 6.7)	–
Halfpipe	16	10	26	2597	1518	4115	6.2 (3.1 to 9.2)	6.6 (2.5–10.7)	6.3 (3.9 to 8.7)	0.9 (0.4–2.1)
PGS/PSL	20	15	35	6326	6006	12 332	3.2 (1.8 to 4.5)	2.5 (1.2–3.8)	2.8 (1.9 to 3.8)	1.3 (0.6– 2.5)
Snowboard cross	69	36	105	5981	2861	8842	11.5 (8.8 to 14.3)	12.6 (8.5–16.7)	11.9 (9.6 to 14.1)	0.9 (0.6–1.4)
Total	110	61	171	16 306	10 385	26 691	6.7 (5.6 to 8.1)	5.9 (4.4–7.3)	6.4 (5.4 to 7.4)	1.3 (0.9 to 1.7)*

*Analysis carried out without big air.
FIS WC, International Ski Federation (Fédération Internationale de Ski) World Cup; OWG, Olympic Winter Games; PGS/PSL, parallel giant slalom/parallel slalom; RR, rate ratio;WSC, World Snowboard Championship.

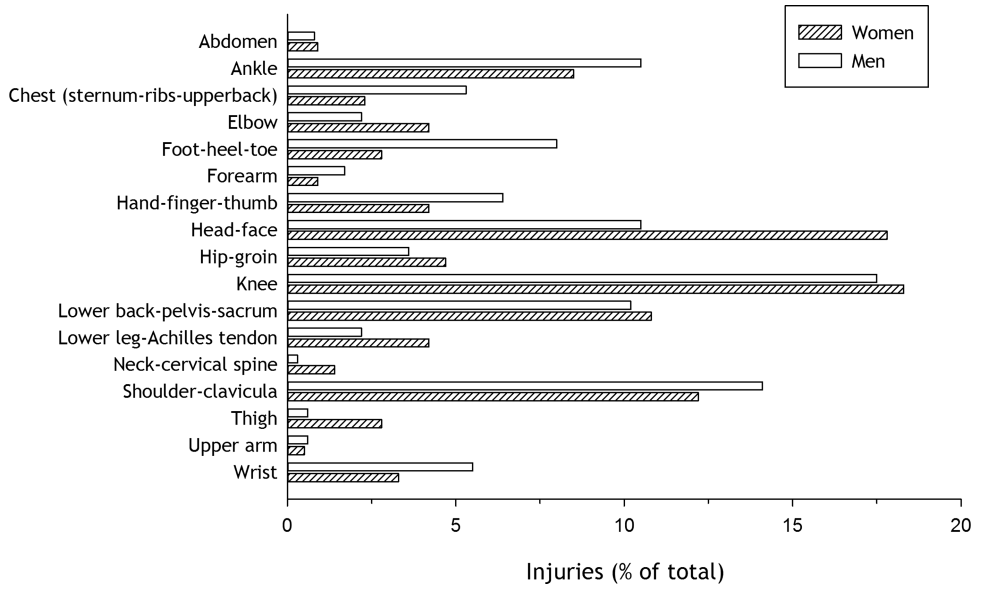

Figure 1 Distribution of all injuries (n=574) by body part for men and women.

for injuries sustained in the FIS WC competitions were obtained from the FIS competition database. The main findings of this study were that the absolute (per season) and relative (per run) injury rates were significantly higher in SBX than in HP, BA and PGS/PSL. SBX also had the highest risk of severe injuries. The risk of knee injury (the most common injury type) and head injury was higher in the jumping disciplines, SBX and HP, compared to PGS/PSL. Interestingly, no difference between male and female snowboarders was detected in the relative or absolute injury rate.

We estimated the injury rate in two different ways, as the absolute rate (the overall risk of injury to an athlete during one season) and the relative rate (the risk of injury per run). Our results show a higher injury rate than the study by Torjussen and Bahr,[5] who reported a total of 1.3 injuries/1000 runs. Because Torjussen and Bahr[5] based their exposure calculations on assumptions of average runs per competition (including warm-up and training runs) for one season (2002–2003), the comparison should be interpreted with caution. Compared to the study by Flørenes *et al*[3] based on a two 2-season sample, our results show a lower overall injury rate (per 100 athlete) for all injuries, time-loss injuries and severe injuries. When we compare our findings in snowboarding with those of other FIS WC disciplines, we find that the injury rate (per 1000 runs) is 1.5-fold and 2.5-fold higher in alpine skiing and freestyle skiing, respectively.[9 10]

Studies have shown that jumping promotes injuries in recreational[11–13] and elite snowboarders.[5 6] This corresponds very well with our results, as we found that the disciplines where jumping is a key element (BA, HP and SBX) had a higher injury rate than the alpine disciplines without jumping (PGS/PSL).

Almost 1/3 of all injuries sustained by FIS WC snowboarders were severe, that is, leading to an absence of more than 28 days. Among this group of elite snowboarders, severe injuries are the most common, followed by slight, moderate, mild and minimal. The high proportion and incidence of severe injuries is similar to that in other winter sports like alpine skiing[9] and freestyle skiing,[10] but different from that in team sports like handball and football, where slight injuries are most common and severe injuries least common.[3 14 15]

The results from this study show that SBX athletes have a higher risk of all injuries, time-loss injuries and severe injuries than those in other disciplines, which differs from the results from the only previous study among FIS WC snowboard athletes.[5] Video analysis has shown that most injuries in SBX resulted from jumping, where a technical error at take-off was the primary cause of the injuries.[16] The second most common inciting event was unintentional contact between riders at the bank turning.[16] An explanation why there is a higher injury rate and more severe injuries in SBX than in other FIS WC snowboard disciplines could be that SBX is the only discipline where the athletes race simultaneously in the same course combining high speed, jumping and turning around gates. It seems quite likely that there are external risk factors involved that need to be modified to reduce the risk of injury (eg, rules, number of competitors, course setting and high speed). It has been suggested that space constraints in the course and competition for the ideal line cause injuries.[17] SBX may also promote a risk-taking attitude for competitors to stay on top of their sport.[5]

A difference between recreational and elite snowboarders is the relatively higher proportion of knee injuries[3–6] and fewer wrist injuries.[12 18–20] Previous studies have shown that the knee is the most commonly injured body part among elite snowboard athletes with 16–19% of all injuries.[3 5 6] Our results confirm this finding; knee injuries represented 17.8% of all injuries. Some studies have discussed that fixation of both feet protects against knee injuries,[21–24] because it is assumed to protect knee ligaments from twisting injuries[25] and valgus stress.[26] It is quite likely that the protective effect of having both feet fixed will be reduced as the impact energy and torsional forces increase with higher and more spectacular aerials.[5] Our results show that there are higher rates of knee injuries in HP, BA and SBX than in PGS/PSL. This strengthens the hypothesis that the disciplines where jumping is performed (BA, HP and SBX) lead to more knee injuries than the alpine disciplines (PGS/PSL). Knee injuries, including anterior cruciate ligament (ACL) injuries, are typically sustained when landing from a height onto a flat landing.[13 27]

Shoulder and clavicle injuries are the second most common and account for 13.4% of all injuries, which is similar to other

studies.[3 5 6] It has been suggested that the lower extremity restrictions, caused by fixation of both feet, predispose the athlete to falls and upper extremity injuries.[21] SBX athletes had a significantly higher risk of sustaining a shoulder/clavicle injury than PGS/PSL athletes. This could be caused by technical errors at take-off when jumping or unintentional contact between riders.[16]

Even though a helmet is mandatory in all FIS WC snowboard competitions and should be designed specifically for each discipline,[28] the head/face is the third most frequently injured body part with 13.2% of all injuries. This finding is supported by previous studies.[3 5] Because the disciplines where jumping is performed (BA, HP and SBX) have a higher relative rate of head injuries than PGS/PSL, we assume that jumping is a potential risk factor for head injuries. Previous studies among recreational snowboarders have shown that jumping may lead to head injuries.[13 22 29] Because our results show that there are many head injuries in FIS WC snowboard competitions, it will be important to investigate if the helmet standards in each discipline are adequate to minimise the risk of head injuries and severe head injuries from crashes.

Snowboarding continues to evolve towards more extreme performances, leading to higher physical demands of the athletes, possibly tempting athletes to push themselves beyond their limits. BA and HP athletes can prepare new tricks in safe environments, on 'big air bags' or trampolines that provide a soft landing, which might be essential when trying new tricks without sustaining an injury. However, there is little protection if something goes wrong when performing extreme tricks during competition.

Researchers and snowboarders have discussed that the features might have become too difficult for some athletes and that the features "should be more adequately adapted to the age, musculoskeletal development and skill level" of the athlete, because a study revealed in the youth OWG that young snowboard athletes had the highest injury risk.[30] Because our results assume that jumping increases the risk of injuries, especially knee and head injuries, focusing on adequate construction of jumps is important. Torjussen and Bahr[5] also suggest that regular maintenance of jumps, HPs and other features is important to prevent injuries. In snowboarding, women and men compete in the same courses, and even though there are no significant differences in injury rates between the sexes, some argue that women should have their own courses as they do for alpine skiing. Because of the high velocities and impact forces in snowboarding, there is a need for appropriate levels of strength, endurance and conditioning.[31] Preventive training, such as strength training, may reduce the risk of snowboard injuries.[32] Based on the injury pattern observed, snowboard athletes should focus preventive training on knee injuries, as this is the most frequent injury and, according to Flørenes *et al*,[3] the main reason for severe injuries in snowboarding. Thus, future research and injury prevention should first of all focus on severe injuries in SBX. There is a need to obtain high-quality videos of snowboard injuries to describe the mechanisms involved in all disciplines.[33]

There are some limitations to this study, which must be kept in mind when interpreting the results. Recall bias is always a challenge with retrospective interviews, although a methodological study found retrospective interviews to be the best available method to record injuries among WC skiers and snowboarders.[7] Even though we interviewed the athletes/coaches/medical personnel at the end of each of the six seasons, minor injuries might have been under-reported because the interviewee could not remember them. We did not collect descriptive information such as age, experience and previous injuries, which could potentially help explain some of the findings. Another limitation is that it may be a challenge to obtain the correct diagnosis.[10] We do not know how many of the 574 injuries were diagnosed by medical personnel, and because of this uncertainty, we have not reported specific diagnoses (eg, ACL-rupture) in our results. It should also be mentioned that we only recorded injuries from the WC season and do not have information about injuries during training for the rest of the year. This must be kept in mind when comparing the results to other sports with a longer competitive season, like football.[3]

CONCLUSION

The absolute (per season) and relative (per run) injury rates were significantly higher in SBX than in HP, BA and PGS/PSL. SBX also had the highest risk of severe injuries. The risk of knee injury (the most common injury type) and head injury was higher in SBX and HP compared to PGS/PSL. There were no differences in the relative or absolute injury rate between male and female snowboarders.

What are the new findings?

- This is the largest study until now on injury rate and injury pattern among elite snowboarders based on 6 years data from the International Ski Federation (Fédération Internationale de Ski, FIS) Injury Surveillance System.
- Snowboard cross has the significantly highest relative (per 1000 runs) and absolute (per 100 athletes per season) injury rates compared to halfpipe, big air and parallel giant slalom/parallel slalom, as well as the highest rate of severe injuries.
- Snowboard cross and halfpipe athletes have a significantly higher risk of knee and head injuries compared to parallel giant slalom/parallel slalom athletes.

How might it impact on clinical practice in the near future?

Prevention of snowboard injuries among elite snowboarders should focus on knee injuries, severe injuries and snowboard cross athletes.

Acknowledgements The authors thank the International Ski Federation staff and officials for all practical support in collecting the injury data, as well as the athletes, coaches and medical staff involved. The authors would also like to thank Tonje Wåle Flørenes, who was responsible for establishing the International Ski Federation (Fédération Internationale de Ski, FIS) Injury Surveillance System (ISS).

Contributors DHM, TB, SES, RB and LN contributed to the study conception, design, and methodology. TB and SES coordinated the study and managed the data collection. DHM wrote the first draft of the manuscript and all authors contributed to the final manuscript. DHM and RB are the guarantors.

Funding The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through generous grants from the Royal Norwegian Ministry of Culture, the South-Eastern Norway Regional Health Authority, the International Olympic Committee, the Norwegian Olympic Committee and Confederation of Sport and Norsk Tipping AS. The FIS Injury Surveillance System is

supported by the International Ski Federation and was established through a grant from DJO.

Competing interests None.

Ethics approval The study was reviewed by the Regional Committee for Medical Research Ethics, South Eastern Norway Regional Health Authority, Norway and approved by the Norwegian Social Science Data Services.

Provenance and peer review Not commissioned; externally peer reviewed.

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