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ORIGINAL ARTICLE

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Background: Although snowboarding is already established as an Olympic sport, it is still a developing sport, with new disciplines, more demanding snow installations, and spectacular tricks. A recent study on subjects at Norwegian national elite level showed that injury risk is high and that injuries among competitive snowboarders differ from those seen in recreational snowboarders, with fewer wrist injuries and more knee and back injuries.

Objective: To describe the incidence and type of injuries among female and male snowboarders at international elite level.

Method: At the last race of the Fédération Internationale de Ski Snowboard World Cup, acute injuries resulting in missed participation and overuse injuries influencing performance, were recorded during a retrospective interview (91% response rate). The registration period was from April 2002 (end of season) until March 2003. Exposure was recorded as the number of runs in all disciplines, and the incidence was calculated as number of injuries per 1000 runs.

Results: The 258 athletes interviewed reported 3193 competition days (n = 46 879 runs) in all disciplines. In total, 135 acute injuries were recorded; 62 (46%) during competition in the official disciplines. Of the 135 acute injuries, the most common injury locations were knee (n = 24; 18%), shoulder (n = 18; 13%), back (n = 17; 13%), and wrist (n = 11; 8%). The overall incidence during competition was 1.3 (95% confidence interval 1.0 to 1.7) injuries per 1000 runs; 2.3 (0.9 to 3.8) for big air (n = 10), 1.9 (1.1 to 2.8) for halfpipe (n = 21), 2.1 (1.2 to 3.0) for snowboard cross (n = 20), 0.6 (0.2 to 1.0) for parallel giant slalom (n = 8), and 0.3 (0.0 to 0.7) for parallel slalom (n = 3). The severity of injuries was graded based on time loss (27% lost >21 days) and score on the Abbreviated Injury Scale (AIS) (38% AIS 1, 61% AIS 2 and 1% AIS 3). There were 122 overuse injuries, 38 (31%) of these to the knee.

Conclusion: The injury risk for big air, snowboard cross, and halfpipe disciplines is high, while that for the snowboard slalom disciplines is lower. The injury pattern is different from recreational athletes, with a greater share of knee injuries and fewer wrist injuries. Compared with national level, the injury risk appears to be lower at World Cup level.

Snowboarding represents a new sport on the international sports scene, especially at the elite competitive level, and many changes have taken place over a brief time period. The International Snowboard Federation first established a Snowboard World Cup in 1991, while the International Ski Federation (Fédération Internationale de Ski; FIS) Snowboard World Cup was started in 1994, and snowboarding became an Olympic discipline in 1998 at Nagano. Recent developments include the motocross inspired discipline, snowboard cross, which is a new addition to the Olympic programme for the 2006 Winter Olympic Games in Turin, and the introduction of the "super pipe", a halfpipe with larger dimensions than the traditional halfpipe. We have recently shown that the pattern of injuries in competitive athletes at national level differs from recreational snowboarders, with fewer wrist injuries and more knee and back injuries.[1] In addition, previous studies suggest that the halfpipe and big air events carry a higher risk of injury than the other disciplines.[1 2] However, there are few studies on the injury pattern and injury risk related to snowboarding disciplines, especially at international elite level. Therefore, the aim of this study was to investigate each of the official snowboarding disciplines to describe the injury pattern and injury incidence among competitive athletes at World Cup level.

METHODS

This study is a retrospective survey based on interviews with athletes at the final FIS Snowboard World Cup event for the season held in Arosa, Switzerland in March 2003. This event included competitions in the four main disciplinesb (half-pipe, big air, snowboard cross, and parallel giant slalom), and 282 snowboarders took part. All athletes and team captains were required to attend a technical meeting, where they were informed about the purposes and procedures of the study. They were encouraged to contact the investigators for a 5–10 minute interview during the day. They were informed that participation was voluntary and assured that information provided could not be traced back to the individual or team.

For each athlete, all injuries, acute or overuse, and the detailed competition programme for the 12 month period from the end of the previous season to 1 April 2003 were recorded during a structured interview. In addition to World Cup and World Championship events, riders had taken part in national, regional, and international competitions, which were also recorded, including competitions in unofficial disciplines (named quarterpipe and slope style). A standard form was used, which included data on injuries during competition and training, and competition exposure. Training exposure was not reported. We also recorded sex, stance, safety equipment used, and years of competitive experience.

An injury report was completed for each injury the athlete had sustained. An acute injury was defined as any injury

Abbreviations: ACL, anterior cruciate ligament; AIS, Abbreviated Injury Scale; FIS, Fédération Internationale de Ski

Table 1 Exposure, number of injuries and incidence (with 95% confidence intervals) of acute time loss injuries occurring during competition and official training in the different disciplines during the 2002–2003 season (n = 62)

	Exposure (runs)		Injuries		Incidence (injuries/1000 runs)	
	Women	Men	Women	Men	Women	Men
Halfpipe	4691	6123	11	10	2.3 (1.0 to 3.7)	1.6 (0.6 to 2.6)
Big air	476	3808	2	8	4.2 (0.0 to 10.0)	2.1 (0.6 to 3.6)
Snowboard cross	3874	5563	9	11	2.3 (0.8 to 3.8)	2.0 (0.8 to 3.1)
Parallel giant slalom	6211	7221	4	4	0.6 (0.0 to 1.3)	0.6 (0.0 to 1.1)
Giant slalom	4035	4877	2	1	0.5 (0.0 to 1.2)	0.2 (0.0 to 1.6)

with a sudden onset causing cessation of the athlete's participation in competition or training for at least o1 day following the day of the incident. An overuse injury was defined as any injury with a gradual onset, which influenced performance during competition or training. All injuries corresponding to these definitions were recorded using a standard form containing the following information: (*1*) date of injury; (*2*) when the injury occurred ((*a*) during competition or official training runs (training and warm up runs performed as part of the official competition format), (*b*) during snowboard training (on snow), (*c*) during other forms of training (strength, conditioning or other activity not on snow)); (*3*) if the injury was new or a recurrence; (*4*) if the athlete continued the race after the incident or not; (*5*) discipline executed during the incident, and the injury mechanism; (*6*) injury type (concussion, contusion, sprain, strain, dislocation, fracture, skin abrasion/wound, other); (*7*) anatomical location and side; (*8*) protective gear used; and (*9*) diagnosis and who examined the injury (physician, physiotherapist, other, not examined). In addition, the time to return to activities was recorded as the time it took until the athlete was fully able to participate in training and competition. Injury severity was graded according to the duration of time loss from training and competition as minor (1–7 days), moderate (8–21 days) and serious (>21 days). Severity was also recorded using the Abbreviated Injury Scale (AIS) as 1 (minor), 2 (moderate), 3 (severe, not life threatening, 4 (serious, life threatening), 5 (critical, survival uncertain), 6 (maximum, currently untreatable).

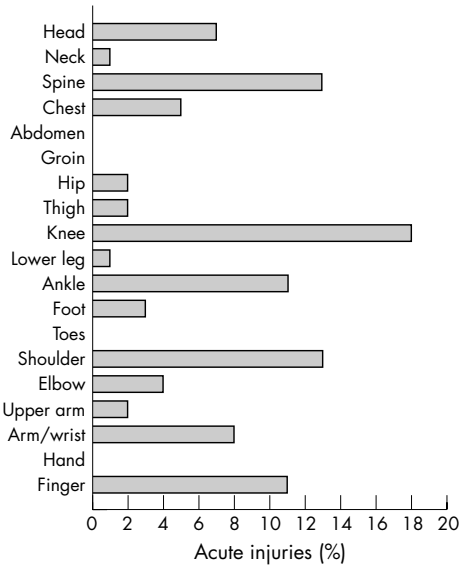

Figure 1 Distribution of all acute time loss injuries by body region for men and women (n = 135).

We recorded the number of events attended by the athlete in each of the official disciplines throughout the season, including World Cup and other races. Competition exposure was calculated as the number of events multiplied by a fixed number of runs for each discipline. This factor was determined on the basis of a prospective registration of the number of runs performed in each the official disciplines as part of the official competition format (training and warm up runs, qualification and competition runs), which was carried out by the race directors and technical delegates during selected World Cup events (4–5 events for each discipline). The average exposure factors determined based on this registration were: 19.6 runs per athlete for each halfpipe, 13.6 for big jump, 13.7 for snowboard cross, 13.7 for parallel giant slalom, and 13.6 for parallel slalom. No attempt was made to estimate training exposure outside competition.

Statistics

Injury incidence was calculated as the number of time loss injuries during competition or official training per 1000 runs, and results were reported with their corresponding 95% confidence intervals (CI). To enable comparison with data on recreational skiers and snowboarders, injury incidence was also reported as the number of injuries per 1000 skier days. A Z test for person–time data was used to compare injury incidence between disciplines and sexes, and the relative risk (RR) was reported with 95% confidence intervals in the results. An α level of 0.05 was considered as statistically significant.

RESULTS

Of the 282 registered competitors at the FIS Snowboard World Cup, 258 (61% mens) took part in the interview (response rate 91%). The average age for both sexes was 23 years, and 84% reported participation in snowboard competitions for five or more seasons. No competitors had fewer than two seasons of competitive experience, and 88% reported >50 days of practice on snow per year. Apart from mandatory competition use, 75 athletes (30%; 45% women, 20% men) reported always wearing a helmet, 90 (35%; 42% women, 32% men) sometimes wore a helmet, while 88 (35%; 13% women, 48% men) reported using a helmet only in competition (five did not respond to this question). Women snowboarders reported a higher frequency of helmet use during training than did men ($p<0.001$ women *v* men, Pearson χ^2). Only five competitors (2%) reported using wrist guards, while 159 (62%; 65% women, 61% men) wore back protection (non-significant between sexes).

In total, 135 acute time loss injuries were reported during the season. Of these, 67 (50%) occurred during training and 68 (50%) during competition (including official warm up and training runs), 62 in the official disciplines (halfpipe, big air, snowboard cross, giant slalom, and parallel giant slalom) and 6 in the unofficial disciplines (quarterpipe and slopestyle). Of the 67 training injuries, 57 occurred while training on snow

Table 2 Injury type for the 135 acute time loss injuries that occurred either during training or in competition

	Discipline						
Site of injury	HP	SC	BA	PGS	PS	Other	Total, n (%)
Head	2	2	2	1	0	3	10 (7)
Neck/throat	0	0	0	0	0	1	1 (1)
Shoulder/clavicle	2	4	2	1	2	7	18 (13)
Upper arm	0	1	0	1	0	0	2 (1)
Elbow	1	1	3	0	0	1	6 (4)
Lower arm/wrist	5	3	1	0	0	2	11 (8)
Fingers	3	0	0	9	2	1	15 (11)
Chest	3	0	3	0	0	1	7 (5)
Spine	6	4	2	4	1	0	17 (13)
Hip	1	1	0	0	0	0	2 (1)
Thigh	0	0	0	1	0	1	2 (1)
Knee	7	5	6	0	0	6	24 (18)
Lower leg	1	0	0	0	0	0	1 (1)
Ankle	3	2	0	1	0	9	15 (11)
Foot	2	1	1	0	0	0	4 (3)
Total	36	24	20	18	5	32	135

HP, halfpipe; SC, snowboard cross, BA, big air; PGS, parallel giant slalom; PS, parallel slalom; Other: injuries during freeriding or other training (not on snow).

(of which 41 could be related to the official disciplines) and 10 during other types of training.

The athletes reported taking part in 3193 competitions in the official disciplines, of which 2040 were World Cup races. Hence, the total competition exposure was estimated to 46 879 runs (table 1), based on the fixed exposure factors estimated for each discipline. The total injury incidence during official warm up and competition in the five official disciplines (n = 62 injuries) was 1.3 (95% CI 1.0 to 1.7) injuries per 1000 runs; 1.5 (0.9 to 2.0) for women and 1.2 (0.8 to 1.6) for men (risk ratio (RR) 0.85; 95% CI 0.52 to 1.40 for men versus women; non-significant). The incidences for the different disciplines were; big air 2.3 (95% CI 0.9 to 3.8), halfpipe 1.9 (1.1 to 2.8), snowboard cross 2.1 (1.2 to 3.0), parallel giant slalom 0.6 (0.2 to 1.0), and parallel slalom 0.3 (0.0 to 0.7) (table 1). Thus, the incidence was generally higher in the big air, halfpipe, and snowboard cross disciplines than in parallel giant slalom (RR 3.9 (95% CI 1.6 to 9.9) *versus* big air, 3.3 (1.4 to 7.4) *versus* halfpipe and 3.5 (1.6 to 8.1) *versus* snowboard cross) and parallel slalom (RR 6.9 (1.9 to 25.2) *versus* big air, 5.8 (1.7 to 19.3) *versus* halfpipe and 6.3 (1.9 to 21.2) *versus* snowboard cross).

When reported as the number of injuries per 1000 skier days, the injury incidence on competition days was 15.9 for big air, 12.7 for halfpipe, 11.6 for snowboard cross, 2.7 for parallel giant slalom, and 1.5 for parallel slalom. The overall competition injury incidence was 7.0 injuries per 1000 skier days.

Of the 135 acute time loss injuries reported during the season, 55 were minor, 42 moderate, and 38 serious. The diagnosis was made by a physician in 86% of the cases, while 6% had been evaluated by a physiotherapist. Knee injuries were the most frequent (table 2), and there was no difference in the distribution of injuries between men and women ($p = 0.22$, Pearson χ^2) (fig 1). There were 26 re-injuries (19%), of which most (73%) were joint sprains, mainly of the knee, shoulder, or wrist. The main injury type was sprains (43%), but fractures (22%) and contusions (20%) were also common. The most severe injury reported was a shoulder dislocation (AIS 3) that had occurred in a woman during halfpipe training. She had also had an elbow dislocation (AIS 3) some months prior to the incident during the same type of activity. The rest of the injuries were graded AIS 1 (51) or AIS 2 (82).

The main mechanisms of injury reported were falling when landing in the halfpipe discipline (97%), falling at obstacle in snowboard cross (52%), and falling when landing in big air (100%). Not surprisingly, collisions with competitors were quite frequent in snowboard cross (44%), while falling between the gates was common in the parallel slalom and parallel giant slalom (57%).

In total, 122 overuse injuries were reported by 94 (36%) of the 258 World Cup athletes, with knee (31%), back (18%), and lower leg injuries (18%) being the most frequent (table 3).

DISCUSSION

There are some limitations to this study, which must be kept in mind when interpreting the results from the retrospective interviews. One is recall bias; the athletes may not have remembered all of the injuries they had suffered during the previous season. In particular, minor injuries may have been under-reported. Another significant caveat is that injured athletes who were not able to compete during the last race of the season were not available for interview; we surveyed the "survivors." This approach may have lead to an under-estimation of severe, season ending injuries, such as anterior cruciate ligament (ACL) injuries and serious fractures. In fact, during three of the 21 World Cup events, technical delegates recorded injuries prospectively assisted by medical staff, and they reported two ACL ruptures, both in women participating in snowboard cross. Otherwise, the injury pattern reported by the technical delegates closely resembled the interview data.

Another limitation is that some athletes who participated in the snowboard World Cup did not take part in the final event for reasons other than injury. However, the response

Table 3 Body location of the 122 overuse injuries reported during the 2002–2003 season

	Women	Men	Total, n (%)
Back	8	14	22 (18)
Hip/thigh	3	5	8 (6)
Knee	11	27	38 (31)
Lower leg	11	11	22 (18)
Foot	6	11	17 (14)
Arm/shoulder	3	11	14 (11)
Other	0	1	1 (1)
Total	42	80	122

rate during the event was very high. Other than those who were sidelined because of injury, there is no reason to believe that athletes who were not available for interview differed in their injury risk from those who attended. It therefore seems reasonable to conclude that the injury rates reported probably underestimates the rate of major, season ending injuries.

Recording exposure and reporting injury incidence represents a challenge in the skiing and snowboarding disciplines. In a previous study on snowboarders at the national elite level,[1] we chose to report the injury incidence per 1000 runs instead of per 1000 skier days, and the same procedure was chosen for the current study. In epidemiological studies on recreational skiers and snowboarders, injuries are usually reported per 1000 skier days. The most precise measure would be an estimate of injury risk per distance skied, as distance varies considerably between the various skiing and snowboarding disciplines, but this would require a more sophisticated recording system. However, we would argue that among competitive athletes, expressing injury rate relative to the number of runs provides a more relevant risk estimate than skier days, because it more accurately considers the time during which the athlete runs the risk of injury. We could not get an exact measure of the number of runs for each athlete during the interview. Therefore, we based our exposure estimates for each discipline on a prospective registration from several World Cup events during the season, and used official results records and direct counts to estimate the average number of runs per rider during each race.

Using these estimates, we found an overall incidence during competition (including official training runs) of 1.3 injuries per 1000 runs among elite international competitors. In our previous study from the national elite level, the overall incidence was approximately threefold higher.[1] The estimate was 3.4–4.0 injuries per 1000 runs, but it should be noted that the exposure estimate differed considerably between the international and the national levels. The average number of runs per athlete per event was 2–8 for the various disciplines on the Norwegian national tour, compared with 13–20 for the World Cup level events. This means that exposure per athlete per event was roughly three times higher at international than national level. This seems reasonable, reflecting the way these events are organised, with a more complex competition format and 1–2 days of official training runs prior to each World Cup competition.

Two previous studies from elite international alpine skiing are available that have used a similar approach to estimate exposure and report injury incidence. They report an injury incidence of 1.9 per 1000 runs[3] and 4.0 per 1000 runs,[4] but as both studies were based on single events with very few injuries, they should be interpreted with caution. Larger studies from a similar competitive level are needed to compare injury incidence between the snowboarding and alpine skiing disciplines.[1] If the injury incidence is expressed as the number of injuries per 1000 skier days, which is the standard used in epidemiological studies on recreational studies, our data suggest that the incidence is 2–3 times higher among elite international snowboarders (7 per 1000 skier days) than recreational alpine skiers (2–3 per 1000 skier days),[17 21] or recreational snowboarders (4 per 1000 skier days).[8 13 16]

The most likely explanation for the relatively high injury incidence is the development of the sport in a direction of more extreme performance and more extreme snow constructions. The combination of speed and jumps seen in the freestyle disciplines (halfpipe, big air, slope style, quarterpipe) and in the motocross inspired discipline of snowboard cross may promote a risk taking attitude for participants to stay at the top of their sport.[5–7] In particular, this is the case in the halfpipe and big air disciplines, where jumping is the essence of the sport, and the judging criteria reward height and rotations. This is also reflected by the typical mechanisms of injury reported; falling when landing in the halfpipe and big air disciplines, and falling at obstacles in snowboard cross. Not surprisingly, collisions with competitors were quite frequent in snowboard cross, while falling at the gates was common in the alpine disciplines. The injury risk can also be assumed to increase from changes in the other disciplines, such as snowboard crossm where new obstacles, higher jumps, and greater speed are likely to characterise the sport in the future.

While we found no sex difference in injury incidence, the results indicate that the injury risk differs between disciplines. The incidence for the parallel slalom and parallel giant slalom disciplines is far lower than for the other three disciplines, in which jumping is a characteristic trait. However, these results should be interpreted with caution, as the number of injuries and exposure recorded for each discipline is low. For the same reason, care should be taken when comparing the injury patterns between disciplines. Nevertheless, when examining the overall injury pattern, the results are somewhat different from previous investigations on recreational snowboarders, with a lower proportion of wrist fractures and a higher proportion of knee, chest, and back injuries.[5 6 8–12] Injuries to the wrist accounted for 8%, which is similar to the national elite level,[1] but is low compared with studies on recreational snowboarders.[6 9 12 21] It is likely that the reason is the experience of the World Cup snowboarders. Edge control and general skills prevent them from falling backwards and thus causing injuries to the wrist,[6 9 12 13] while novice snowboarders unintentionally catch the snow on the down valley edge and fall backwards or forwards (described as the opposite edge phenomenon).[14 15]

Another difference between recreational and competitive snowboard athletes is a relatively higher proportion of knee injuries;[5 6 8–12] 17% of all acute injuries in the five official disciplines in our study. However, a direct comparison with the alpine skiing disciplines is not possible, as we do not know how many serious knee injuries (such as ACL injuries) occur during the season. We would not find these in competitors who had already been eliminated from competition due to ACL injuries. Nevertheless, based on the relatively high proportion of knee injuries, snowboarding at the World Cup level is similar to national elite snowboarding[1] and alpine skiing,[16] where knee injuries account for 20–36% of injuries among both elite and recreational skiers.[17–20] Studies have shown that jumping promotes knee injuries in both recreational[7 9 21 22] and professional snowboarders.[2 23] Fixation of both feet is assumed to protect against knee injuries,[5 10–13 21] but it is likely that this effect will be reduced in elite performers as the impact energy and torsion forces increase with the higher and more spectacular jumps taken by contestants.

Back and chest injuries together account for 22% of all acute injuries. Unsurprisingly, most of these injuries occurred in halfpipe, snowboard cross, and big air, which accords with previous findings showing that jumping promotes injuries to the chest and spine.[24] One suggestion is that the fixed position of the lower extremities restricts movement in a way that predisposes to chest and spine injury.[11]

Head injuries were infrequent (7% of all acute injuries). As head injuries represent up to 26% of all injuries among recreational participants,[5 6 8 10 11 14 19 21 25] these figures are low. One explanation may be that helmet use is mandatory in the FIS World Cup events in all disciplines except parallel slalom and parallel giant slalom. FIS International Competition rules state that the helmet should be manufactured specifically for snowboarding or ski racing. However, the proportion of athletes reporting regular helmet use was low, especially among men. That there was only one head

What is already known on this topic

- The injury risk in recreational snowboarding is high, with a high proportion of wrist injuries

What this study adds

- The injury pattern among international elite snowboarders is different from recreational athletes with a greater share of knee injuries and fewer wrist injuries
- The injury risk for the snowboard jumping disciplines (big air, snowboard cross, and half pipe) is higher than for the slalom disciplines

injury (collision at gate, head contusion) in the slalom disciplines supports the suggestion that jumping is an important injury mechanism for head injuries.[14 21]

Several actions have been suggested to prevent injuries among recreational snowboarders. Proper fitting of equipment with attention to the angle and position of bindings, and choice of boots and board length are thought to be important.[8] Soft boots have been claimed to be beneficial for beginners.[8] Technical training programmes are widely recommended,[5 7 8 10 21 26–29] although studies on skiers have concluded that regular ski instruction does not reduce injury risk.[17 30–32] Safety equipment is widely recommended, especially helmets[6 11 14 23 25 27] and wrist guards.[12]

Competitive snowboarders should be prepared to cope with the increasing demands for strength, endurance, and general fitness through appropriate training. A pre-season assessment of physical condition can be beneficial.[28] Furthermore, specific training for each discipline to improve movement skills, balance and coordination is recommended. Gymnastics, including trampoline exercises, is essential to prepare for the big jump and halfpipe disciplines. Video recordings can increase awareness and ability to correct bad technique. Snowboard facilities should be properly maintained and adequate construction of the pipe, jumps, and other obstacles is important. Recently, improved safety equipment has become available, providing more comfortable helmets that are less heavy and bulky, back protectors, elbow pads, wrist guards, padded gloves, and hip, knee, and shin pads. Even padded jackets and sweaters, similar to those used in motocross, are available. Based on the injury patterns and mechanisms reported, it seems reasonable to suggest that such safety equipment should be used. However, there is no evidence proving their efficacy at the elite level, and further research is therefore needed.

In conclusion, the injury risk for the big air, snowboard cross, and halfpipe disciplines is high, while that for the snowboard slalom disciplines appears to be lower. The injury pattern is different from recreational athletes with a greater share of knee injuries and fewer wrist injuries, and a higher injury incidence. Compared with the national level the injury risk is lower at the World Cup level, and similar to previous studies from elite alpine skiing.

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