

Injuries among World Cup ski and snowboard athletes

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There is little information available on injuries to World Cup skiers and snowboarders. The aim of this study was to describe and compare the injury risk to World Cup athletes in alpine skiing, freestyle skiing, snowboarding, ski jumping, Nordic combined and cross country skiing. We performed retrospective interviews with the International Ski Federation (FIS) World Cup athletes from selected nations during the 2006–2007 and 2007–2008 winter seasons and recorded all acute injuries occurring during the seasons. We interviewed 2121 athletes and recorded 705 injuries. There were 520 (72%) time-loss injuries and 196 (28%) severe injuries (absence > 28 days). In freestyle skiing, alpine skiing and

snowboarding, there were 27.6, 29.8 and 37.8 time-loss and 14.4, 11.3 and 13.8 severe injuries per 100 athletes per season, respectively. In Nordic combined, ski jumping and cross country skiing, there were 15.8, 13.6 and 6.3 time-loss and 3.3, 5.6 and 0.7 severe injuries per 100 athletes per season, respectively. In conclusion about 1/3 of the World Cup alpine, freestyle and snowboard athletes sustain a time-loss injury each season, while the risk is low in the Nordic disciplines. A particular concern was the high proportion of severe injuries observed among alpine, freestyle and snowboard athletes, which is in contrast to most other sports.

Skiing and snowboarding are popular sports. According to the International Ski Federation (FIS), 2362 athletes started in World Cup competitions in 2006–2007 and 2177 in 2007–2008 in the different disciplines of alpine skiing, freestyle skiing, snowboarding, ski jumping, cross country skiing and Nordic combined (a combination of ski jumping and cross country skiing).

The sports of skiing and snowboarding are exciting and represent a source of enjoyment, not just for the athletes but for spectators and TV viewers worldwide. However, the spectacular crashes and significant injuries seen regularly remind us of the risks associated with the sports. However, there are only a handful of studies that have examined the risk for injury to the elite skier and snowboarder and these are generally small, often limited to one competition, or not representative for the current level of performance at the World Cup level. In alpine skiing, one study from the 1994 Olympic Winter Games (Ekeland et al., 1996), one from a World Junior Championships (Bergström et al., 2001) and one season-long study from 1985 (Ekeland & Holm, 1985) have estimated the injury rate to be between 1.9 and 4 injuries per 1000 runs. In freestyle skiing, a discipline that has undergone major changes during recent years, a study from 1976 to 1980 has estimated the injury rate to be 2.8 injuries per 1000 skier days (Dowling, 1982). In snowboard, studies on World

Cup athletes and athletes competing at the national level report injury rates of 1.3 and 4 injuries per 1000 runs, respectively (Torjussen & Bahr, 2005, 2006). In ski jumping, we have found only one 5-year study from Lake Placid, USA, reporting 1.2 injuries per 1000 skier days for World Cup competitions and training (Wright et al., 1986). There is no information available on the injury risk associated with elite cross country skiing or Nordic combined. Therefore, except for snowboarding, the risk of being a World Cup athlete in the various FIS disciplines is not known.

FIS therefore established an injury surveillance system (the FIS ISS) before the 2006–2007 winter season. The objective of the FIS ISS is to provide data on injury trends in international skiing and snowboarding at the elite level with the long-term goal of reducing injury risk. The aim of the current paper was to describe the injury risk and injury pattern among World Cup athletes in alpine skiing, freestyle skiing, snowboarding, ski jumping, cross country skiing and Nordic combined based on data from the FIS ISS.

Materials and methods

Study design and population

We conducted retrospective interviews at the end of the 2006–2007 and the 2007–2008 winter seasons. A methodological

study (Flørenes et al., 2009) comparing prospective injury reporting by team medical personnel, prospective injury reporting by FIS technical delegates and retrospective athlete/coach interviews showed that retrospective interviews were the most accurate in this setting. We therefore chose this method to record injuries among World Cup ski and snowboard athletes. We defined the winter season as starting on November 1, or the first race of the season, lasting until the interviews took place. We conducted the interviews in March during one of the final events in each discipline each year. From the official FIS database, we identified athletes who had started in at least one World Cup/World Championship event in each of the sub-disciplines of alpine skiing (downhill, super-G, giant slalom, slalom, combined and super combined), freestyle skiing (moguls, dual moguls, halfpipe, skicross, aerials), snowboarding (halfpipe, snowboardcross, parallel giant slalom, parallel slalom, big air), ski jumping, cross country skiing and Nordic combined. In all disciplines, we included athletes from nine major skiing nations: Germany, Switzerland, Canada, Finland, France, Norway, Italy, Sweden and Austria. These represent large teams in the different disciplines and we expected most athletes to speak English fluently. In freestyle skiing and snowboarding, the athletes rarely compete in more than one of the sub-disciplines (halfpipe, skicross, moguls/dual moguls, aerials, snowboardcross and big air) and the sizes of the teams vary. Therefore, to increase the number of participants, in some disciplines we also included additional World Cup teams from other English-speaking nations, provided that we could cover at least 80% of all team members with the interviews. In this way, we added 11 World Cup teams in freestyle skiing and snowboarding.

At the event, we interviewed all athletes from the selected nations who were present in person. If the athletes were not present (due to injury or for other reasons), we interviewed their coaches. Some coaches directed us to their team physician/physical therapist to obtain the information needed. We also asked all team coaches to control and complete the list of athletes from their nation. Athletes not defined as being on the World Cup team roster by the coaches were excluded (e.g. national athletes starting in races in that country on the national quota).

Injury recording and injury definition

We explained the purpose and procedures of the interviews at the team captain's meetings, where head coaches from all nations are required to be present. At these meetings, we also encouraged the coaches to inform their athletes of the interviews. A letter describing the interviews was distributed by e-mail to all head coaches/team leaders before the 2007–2008 registration. Research teams from the Oslo Sports Trauma Research Center consisting of physicians, physical therapists and medical students conducted the interviews. The research teams performed the interviews in the finishing area in connection with official training or competition, or in some cases, at the team's hotel. Athletes from the freestyle skiing sub-discipline halfpipe and the snowboard sub-disciplines big air, parallel giant slalom/slalom were not interviewed at the end of the 2006–2007 winter season due to event cancellations and scheduling conflicts. There is no World Cup in ski jumping for women, and we therefore included the Continental Cup (the highest level) for the 2007–2008 winter season. There are only male participants in Nordic combined. To facilitate athlete recall of participation and time loss due to injury, we used a form outlining the week-by-week schedule of the current World Cup program for each discipline. We asked whether they had started in each of the events from the first week of the

season to the next for the whole season (Flørenes et al., 2009). For each injury the athlete reported, we completed an injury form with information on where and when the injury had occurred, what kind of injury it was (body part, injury type and injured side) and how long they were out of training and/or competition. We also asked for a specific diagnosis for each injury. For the interviews with the coaches for athletes not present, we used the same method. Each coach is responsible for a limited number of athletes. The World Cup teams travel and live together for almost the entire competitive season and a methodological study found the coaches to have a good recall of injuries to their racers (Flørenes et al., 2009).

The injury definition was "All injuries that occurred during training or competition and required attention by medical personnel." This definition as well as the classification of the type of injury and body part injured was based on a recent consensus document on injury surveillance in football (Fuller et al., 2006). We classified the severity of injury according to the duration of absence from training and competition as slight (no absence), minimal (1–3 days), mild (4–7 days), moderate (8–28 days) and severe (>28 days) (Fuller et al., 2006). If multiple injuries resulted from the same accident, we described all of these on the same injury form. We also recorded information of where the injury happened, during World Cup/World Ski Championship competition/official training, other competitions/official training, other training activity on snow (i.e. regular training) or basic training not on snow (i.e. running, weightlifting, soccer, etc.). For describing the injury rate, we use all recorded injuries, while only "on-snow" injuries (including competitions, official training and regular training on snow) are included when describing the injury severity, injury type and injured body part.

The study was approved by the Regional Committee for Medical Research Ethics, Region Sør-Norge and by the Norwegian Social Science Data Services.

Statistics

To estimate the risk of injuries to World Cup athletes and allow a comparison between the different World Cup disciplines, we have used the number of injuries per 100 athletes per season with their corresponding 95% confidence intervals (95% CI) to report the injury rate. We based our calculation on the Poisson model and used a *Z*-test for comparing injury risk between disciplines and computing the corresponding 95% CI. We computed the relative risks (RR) with their corresponding 95% CI to compare the injury risk between male and female athletes, as well as the risk of the most severe injuries and knee injuries between the different disciplines. A two-tailed *P*-level of ≤ 0.05 was considered statistically significant.

Results

Of the 2149 World Cup athletes eligible, 2121 (98.7%) were interviewed during the 2006–2007 and 2007–2008 winter seasons (Table 1). Fifteen and 11 athletes from two teams in the sub-disciplines of freestyle skiing and snowboarding, respectively, were excluded because of low team response rates (47% and 9%, respectively). Of the 2121 interviewed athletes, 1145 (54%) were interviewed with the athletes in person and 976 (46%) with the coach/medical staff (Table 1).

World Cup skiing and snowboarding injuries

Table 1. The number of athletes included in the study (All) and the number of athletes where information was obtained through interviews (T) either with the athletes themselves (A) or their coaches or medical staff (C/M)

	Male						Female						Total							
	2006–2007 season			2007–2008 season			2006–2007 season			2007–2008 season			Both seasons							
	All		Interview	All		Interview	All		Interview	All		Interview	All		Interview					
	A	C/M	T	A	C/M	T	A	C/M	T	A	C/M	T	A	C/M	T					
Alpine skiing	144	47	97	144	148	78	70	148	116	38	78	116	113	44	69	113	521	207	314	521
Freestyle skiing	107	70	37	107	192	67	110	177	46	33	13	46	86	38	48	86	431	208	208	416
Snowboarding	91	61	30	91	198	106	80	186	50	39	11	50	95	66	28	94	434	272	149	421
Ski jumping*	67	30	37	67	76	46	30	76					70	38	32	70	213	114	99	213
Nordic combined [†]	57	39	18	57	63	45	18	63									120	84	36	120
Cross country skiing	134	70	64	134	124	75	49	124	90	56	34	90	82	59	23	82	430	260	170	430
Total	600	317	283	600	801	417	357	774	302	166	136	302	446	245	200	445	2149	1145	976	2121
(% interviewed)				(100.0)				(97)				(100.0)				(99.8)				(98.7)

*Ski jumping includes two World Cup seasons for men and one Continental Cup season (2007–2008) for women.

[†]There are only male participants in Nordic combined.

Table 2. Description of activity during which injuries occurred for World Cup athletes in alpine skiing, freestyle skiing, snowboarding, ski jumping, Nordic combined and cross country skiing.

	Alpine skiing	Freestyle skiing	Snowboarding	Ski jumping*	Nordic combined	Cross country skiing	Total
World Cup and World Championship events	86 (45.0)	50 (31.3)	64 (27.0)	5 (11.1)	6 (26.1)	15 (30.6)	226 (32.1)
Official training to WC/WSC	31 (16.2)	40 (25.0)	41 (17.3)	6 (13.3)	2 (8.7)	1 (2.0)	121 (17.2)
Other competitions	3 (1.6)	26 (16.3)	37 (15.6)	2 (4.4)		1 (2.0)	69 (9.8)
Other FIS comp	20 (10.5)	5 (3.1)	19 (8.0)	2 (4.4)	2 (8.7)	6 (12.2)	54 (7.7)
Official FIS training	1 (0.5)	3 (1.9)	5 (2.1)	2 (4.4)			11 (1.6)
Other training activity on snow (regular training)	48 (25.1)	33 (20.6)	67 (28.3)	15 (33.3)	7 (30.4)	25 (51.0)	195 (27.7)
Basic training not on snow	2 (1.0)	3 (1.9)	4 (1.7)	13 (28.9)	5 (21.7)	1 (2.0)	28 (4.0)
Information missing					1 (4.3)		1 (0.1)
Total	191 (100)	160 (100)	237 (100)	45 (100)	23 (100)	49 (100)	705 (100)

Combined data from the 2006–2007 and 2007–2008 winter seasons expressed as the number of injuries (percentages in parentheses).

*Ski jumping includes two World Cup seasons for men and one Continental Cup season for women.

Of the 705 injuries recorded, there were 676 (95.9%) “on-snow” injuries (occurring during competitions, official training or regular training on snow). As many as 49.3% of all injuries occurred during World Cup/World Championship events including official training (Table 2). For alpine skiing, freestyle skiing, snowboarding and Nordic combined, the majority of injuries occurred during World Cup/World Championship events, while training on snow was the activity where most injuries occurred for ski jumping and cross country skiing (Table 2). Only 4 % of all injuries occurred during basic training not on snow; however, for ski jumping and Nordic combined, this was the second and third most common activity during which an injury occurred (28.9% and 21.7%, respectively).

As many as 121 of 448 injuries among males (27.4 %) and 75 of 257 among females (29.2 %) were severe injuries (time loss >28 days) (Fig. 1). A

similar proportion of injuries reported by males (125 of 448, 28.0%) and females (68 of 257, 26.5%) did not lead to any absence from training and competition. For all injuries, we found no difference in the injury rate between males and females (female vs male RR: 1.05, 95% CI 0.89–1.25).

The injury rate during the World Cup season, estimated as the number of injuries per 100 athletes, is shown in Table 3. For time-loss injuries, there was a higher rate in snowboarding compared with the other disciplines (RR: 1.27, 95% CI 1.02–1.58 vs alpine skiing; RR: 1.37, 95% CI 1.08–1.74 vs freestyle skiing; RR: 2.77, 95% CI 1.87–4.12 vs ski jumping; RR: 2.39, 95% CI 1.48–3.84 vs Nordic combined; RR: 6.02, 95% CI 4.00–9.05 vs cross country skiing). We also observed a lower rate in cross country skiing compared with all the other disciplines (RR: 0.21, 95% CI 0.14–0.32 vs alpine skiing; RR: 0.23, 95% CI 0.15–0.35 vs freestyle

Table 3. Injuries per 100 athletes per season (with 95% confidence intervals) for injuries recorded during the 2006–2007 and 2007–2008 winter seasons in alpine skiing, freestyle skiing, snowboard, ski jumping, Nordic combined and cross country skiing

	Injuries per 100 athletes per season		
	All injuries	Time-loss injuries (≥ 1 day absence)	Severe injuries (>28 days absence)
Alpine skiing	36.7 (31.5–41.9)	29.8 (25.1–34.4)	11.3 (8.4–14.2)
Freestyle skiing	38.5 (32.5–44.4)	27.6 (22.6–32.7)	14.4 (10.8–18.1)
Snowboarding	56.3 (49.1–63.5)	37.8 (31.9–43.6)	13.8 (10.2–17.3)
Ski jumping*	21.1 (15.0–27.3)	13.6 (8.7–18.6)	5.6 (2.4–8.8)
Nordic combined	19.2 (11.3–27.0)	15.8 (8.7–23.0)	3.3 (0.1–6.6)
Cross country skiing	11.4 (8.2–14.6)	6.3 (3.9–8.6)	0.7 (–0.1–1.5)

*Ski jumping includes two World Cup seasons for men and one Continental Cup season for women.

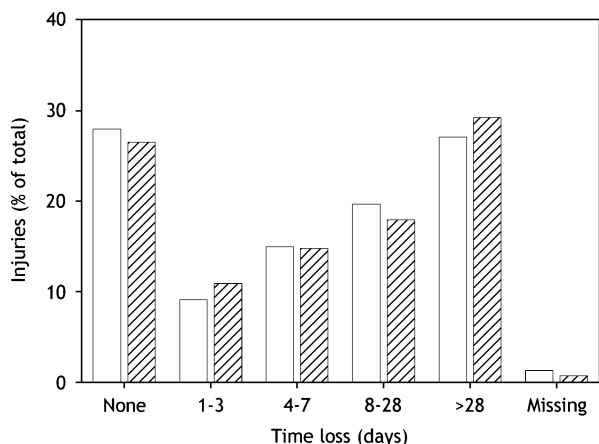


Fig. 1. Injuries according to severity (expressed as the number of days of absence from training and competitions) for all recorded injuries ($n = 705$) among males ($n = 448$; open bars) and females ($n = 257$; hatched bars).

skiing; RR: 0.46, 95% CI 0.27–0.78 vs ski jumping; RR: 0.40, 95% CI 0.22–0.71 vs Nordic combined). For severe injuries, there was a higher rate for alpine skiing, freestyle skiing and snowboarding compared with the three Nordic disciplines of ski jumping, Nordic combined and cross country skiing (alpine skiing vs ski jumping RR: 2.01, 95% CI 1.08–3.74; alpine skiing vs Nordic combined RR: 3.40, 95% CI 1.23–9.35; alpine skiing vs cross country skiing RR: 16.2, 95% CI 5.09–51.8; freestyle skiing vs ski jumping RR: 2.56, 95% CI 1.38–4.76; freestyle skiing vs Nordic combined RR: 4.33, 95% CI 1.57–11.9; freestyle skiing vs cross country skiing RR: 20.7, 95% CI 6.48–65.9; snowboarding vs ski jumping RR: 2.45, 95% CI 1.31–4.55; snowboard vs Nordic combined RR: 4.13, 95% CI 1.50–11.4; snowboard vs cross country skiing RR: 19.7, 95% CI 6.19–63.0). We also observed a higher rate for severe injuries in ski jumping than cross country skiing (RR: 8.08, 95% CI 2.28–28.6), and Nordic combined compared with cross country skiing (RR: 4.78, 95% CI 1.07–21.3).

The distribution of injury severity for “on-snow” injuries in each discipline is shown in Table 4. Time-loss injuries accounted for 486 (71.9%) of all

“on-snow injuries” reported and 189 (28.0%) were severe injuries. There was no difference in the risk for a severe injury between alpine skiing, freestyle skiing and snowboarding (freestyle skiing vs alpine skiing RR: 1.25, 0.87–1.80, freestyle skiing vs snowboarding RR: 1.03, 0.72–1.48, snowboarding vs alpine skiing RR: 1.22, 0.85–1.75), while the risk for the severe injuries was lower in cross country skiing than the other disciplines (RR ranging from 0.05 to 0.06). Ski jumping also had a higher risk of severe injuries compared with cross country skiing for the severe injuries (RR: 5.38, 1.43–20.3). We also observed a higher risk for severe injuries in freestyle skiing, alpine skiing and snowboarding compared with ski jumping and Nordic combined (freestyle skiing vs ski jumping RR: 3.78, 1.80–7.90; freestyle vs Nordic combined RR: 8.51, 2.08–34.8; alpine skiing vs ski jumping RR: 3.02, 1.44–6.31; alpine skiing vs Nordic combined RR: 6.80, 1.66–27.8; snowboarding vs ski jumping RR: 3.67, 1.75–7.68; snowboarding vs Nordic combined RR: 8.27, 2.02–33.8).

For injuries incurred on snow (including competitions, official trainings and regular training on snow), the most common injury type for all disciplines was joint and ligament injuries (37.5–52.9%), except in cross country skiing, where the most common injury type was muscle and tendon injuries (Table 5). Fractures were the second most common in alpine and freestyle skiing, contusions in ski jumping, muscle and tendon injuries in Nordic combined, while joint and ligament injuries were the second most common in cross country skiing. In snowboarding, fractures/bone stress and contusions were equally the second most common injury types. (Table 5).

Overall, 26% of the injuries incurred on snow were knee injuries and the knee was the most frequently injured body part in all disciplines (18.9–36.0 %), except for cross country skiing, where injuries to the lower back/pelvis/sacrum were the most common (Table 6). There was no difference in the rate for knee injuries between alpine skiing, freestyle skiing and snowboarding (alpine skiing vs freestyle skiing RR: 1.18, 0.81–1.72; alpine skiing vs snowboarding

World Cup skiing and snowboarding injuries

Table 4. Injury severity distribution for “on-snow” injuries (including competitions, official training and regular training on snow) for alpine skiing, freestyle skiing, snowboarding, ski jumping, Nordic combined and cross country skiing during the 2006–2007 and 2007–2008 winter seasons expressed as the number of injuries (percentages in parentheses)

Time loss	Alpine skiing	Freestyle skiing	Snowboarding	Ski jumping*	Nordic combined	Cross country skiing	Total
No time loss	35 (18.5)	42 (26.8)	71 (30.5)	12 (37.5)	2 (11.8)	20 (41.7)	182 (26.9)
1–3 days	16 (8.5)	15 (9.6)	22 (9.4)	3 (9.4)	3 (17.6)	9 (18.8)	68 (10.1)
4–7 days	28 (14.8)	19 (12.1)	38 (16.3)	6 (18.8)	4 (23.5)	6 (12.5)	101 (14.9)
8–28 days	51 (27.0)	20 (12.7)	40 (17.2)	3 (9.4)	5 (29.4)	9 (18.8)	128 (18.9)
> 28 days	59 (31.2)	59 (37.6)	58 (24.9)	8 (25.0)	2 (11.8)	3 (6.3)	189 (28.0)
Not available		2 (1.3)	4 (1.7)		1 (5.9)	1 (2.1)	8 (1.2)
Total	189 (100)	157 (100)	233 (100)	32 (100)	17 (100)	48 (100)	676 (100)

*Ski jumping includes two World Cup seasons for men and one Continental Cup season for women.

Table 5. Injury type per discipline for “on-snow” injuries (including competitions, official training and regular training on snow) recorded during the 2006–2007 and 2007–2008 winter seasons expressed as number of injuries (percentages in parentheses) for each discipline ($n = 676$)

Injury type	All injuries						
	Alpine skiing	Freestyle skiing	Snowboarding	Ski jumping*	Nordic combined	Cross country skiing	Total
Fractures/bone stress	35 (18.5)	34 (21.7)	41 (17.6)	3 (9.4)	1 (5.9)		114 (16.9)
Joint/ligament	84 (44.4)	68 (43.3)	90 (38.6)	12 (37.5)	9 (52.9)	15 (31.3)	278 (41.1)
Muscle/tendon	20 (10.6)	19 (12.1)	27 (11.6)	1 (3.1)	3 (17.6)	18 (37.5)	88 (13.0)
Contusion	23 (12.2)	16 (10.2)	41 (17.6)	8 (25.0)	2 (11.8)	7 (14.6)	97 (14.3)
Skin/laceration	7 (3.7)	2 (1.3)	2 (0.9)	1 (3.1)	1 (5.9)		14 (2.1)
Nervous system/concussion	14 (7.4)	15 (9.6)	29 (12.4)	4 (12.5)		3 (6.3)	65 (9.6)
Other	6 (3.2)	3 (1.9)	3 (1.3)	3 (9.4)	1 (5.9)	4 (8.3)	20 (3.0)
Total	189 (100)	157 (100)	233 (100)	32 (100)	17 (100)	48 (100)	676 (100)

*Ski jumping includes two World Cup seasons for men and one Continental Cup season for women.

Table 6. Body part injured for each discipline expressed as number of injuries (percentages in parentheses) for “on-snow” injuries (including competitions, official training and regular training on snow) during the 2006–2007 and 2007–2008 winter seasons

Body part injured	All injuries						
	Alpine skiing	Freestyle skiing	Snowboarding	Ski jumping*	Nordic combined	Cross country skiing	Total
Head/face	16 (8.5)	20 (12.7)	30 (12.9)	7 (21.9)		1 (2.1)	74 (10.9)
Neck, cervical spine		2 (1.3)	1 (0.4)		1 (5.9)	1 (2.1)	5 (0.7)
Shoulder, clavicle	13 (6.9)	16 (10.2)	31 (13.3)	2 (6.3)	3 (17.6)	7 (14.6)	72 (10.7)
Upper arm	1 (0.5)	1 (0.6)					2 (0.3)
Elbow	3 (1.6)	5 (3.2)	9 (3.9)	2 (6.3)		4 (8.3)	23 (3.4)
Forearm	1 (0.5)	3 (1.9)	6 (2.6)	1 (3.1)		1 (2.1)	12 (1.8)
Wrist	3 (1.6)	3 (1.9)	13 (5.6)		1 (5.9)		20 (3.0)
Hand, finger, thumb	17 (9.0)	11 (7.0)	12 (5.2)		1 (5.9)	1 (2.1)	42 (6.2)
Chest (sternum, ribs, upper back)	4 (2.1)	10 (6.4)	6 (2.6)	1 (3.1)		2 (4.2)	23 (3.4)
Abdomen		1 (0.6)	3 (1.3)				4 (0.6)
Lower back, pelvis, sacrum	21 (11.1)	11 (7.0)	24 (10.3)	1 (3.1)	3 (17.6)	12 (25.0)	72 (10.7)
Hip, groin	4 (2.1)	10 (6.4)	10 (4.3)	1 (3.1)		3 (6.3)	28 (4.1)
Thigh	4 (2.1)	3 (1.9)	7 (3.0)	1 (3.1)	1 (5.9)	2 (4.2)	18 (2.7)
Knee	68 (36.0)	46 (29.3)	44 (18.9)	8 (25.0)	6 (35.3)	4 (8.3)	176 (26.0)
Lower leg, Achilles tendon	21 (11.1)	6 (3.8)	7 (3.0)	3 (9.4)	1 (5.9)	5 (10.4)	43 (6.4)
Ankle	10 (5.3)	7 (4.5)	22 (9.4)	3 (9.4)		3 (6.3)	45 (6.7)
Foot, heel, toe	3 (1.6)	2 (1.3)	8 (3.4)	1 (3.1)		2 (4.2)	16 (2.4)
Not available				1 (3.1)			1 (0.1)
Total	189 (100)	157 (100)	233 (100)	32 (100)	17 (100)	48 (100)	676 (100)

*Ski jumping includes two World Cup seasons for men and one Continental Cup season for women.

RR: 1.25, 0.86–1.83; freestyle skiing vs snowboarding RR: 1.06, 0.70–1.60). The risk for knee injuries was higher in alpine skiing (RR: 3.48, 1.67–7.23) and freestyle skiing (RR: 2.94, 1.39–6.24) compared with

ski jumping. In alpine skiing, the second most commonly injured body parts were the lower back/pelvis/sacrum and the lower leg in freestyle skiing and ski jumping head/face, while the second most commonly

injured body part in snowboarding, Nordic combined and cross country skiing was the shoulder/clavicle.

Discussion

This study is the first large cohort study to examine the injury risk and pattern in elite skiing and snowboarding and also the first to compare the different World Cup disciplines. The principal finding was that the risk of injuries in snowboarding, freestyle skiing and alpine skiing is high, with a high frequency of the most severe injuries. The knee was the most commonly injured body part across all disciplines, except cross country skiing.

As outlined by Torjussen and Bahr (2006), choosing the appropriate method to report the risk of injury in skiing and snowboarding is a challenge if the objective is to compare the risk between different skiing populations or disciplines where exposure may differ considerably. Epidemiological studies on recreational skiers and snowboarders typically report the number of injuries per 1000 skier days. If we assume that World Cup skiers and snowboarders during the season (4.5 months from November through mid-March) on average have 2 travel days each week and train and compete during the remaining 5 days, we find that there were 4.1, 4.3 and 6.3 injuries per 1000 days for alpine skiing, freestyle skiing and snowboarding. These estimates are probably low, as we have not corrected for missed exposure for injury or other reasons. Nevertheless, it appears that the injury risk is two to three times as high as that reported from previous studies on recreational alpine skiers (ranging from 1.1 to 3.2 across different studies) (Laporte et al., 2000; Ekeland et al., 2005; Langran, 2005; Johnson et al., 2009) and snowboarders (2.3–4.1) (Langran & Selvaraj, 2002; Greenwald et al., 2003; Ekeland et al., 2005), if the injury rate is expressed per 1000 skier/snowboarder days.

Most of the few previous studies available on elite skiing and snowboarding have reported injury incidence as the number of injuries per 1000 runs (Ekeland et al., 1985, 1996; Bergström et al., 2001; Torjussen et al., 2005, 2006), as this has been argued to be the most accurate measure of injury risk. In alpine skiing and snowboarding, 1 to 4 injuries per 1000 runs has been reported (Ekeland et al., 1985, 1996; Bergström et al., 2001; Torjussen et al., 2005, 2006). However, when comparing the injury risk between different disciplines, run distance and the number of runs during a competition differ widely. For example, one run in ski jumping, snowboard-cross and halfpipe is much shorter than a run in downhill skiing, and a cross country skiing race can be up to 50 km long. In addition, while there are four runs in freestyle halfpipe, five runs in snowboard-cross and

two in ski jumping, there is only one in downhill skiing. It has previously been argued that the most precise measure for injury risk estimation for snow sports is per distance skied (Ronning et al., 2000). One limitation of this approach is that it may be difficult to collect precise data on the number of runs and the length of each run performed by each skier over the course of the season, at least during training. Moreover, the question is whether it is appropriate to correct for such exposure differences when comparing the injury risk across disciplines, for example to compare the risk between a downhill skier and a ski jumper.

In team sports such as football and rugby, injury incidence is usually reported as the number of injuries per 1000 h of training or match exposure (Fuller et al., 2006, 2007). However, compared with other sports, e.g. football, where athletes are active more or less continuously during an entire training and match, alpine or snowboard athletes spend considerable time in the ski lift or waiting to start during training and they are active for only a short period of time during a competition. Froholdt et al. (2009) recently discussed the importance of using both relative injury risk (i.e. where the injury risk is expressed as a rate corrected for exposure) as well as the absolute injury risk (i.e. expressed as the total number of injuries during a season for a team or a player/athlete) when comparing the injury risk between different levels of play in football. We would argue that absolute injury risk is highly relevant, and in this study, we have therefore chosen to express injury risk as the number of injuries per 100 athletes per season. This allows us to compare the overall risk of being injured for top-level skiers and snowboarders between the different disciplines directly, as this seems more relevant than comparing the RR associated with one ski jump to one downhill race. Most of these athletes are full-time professionals and during the season they perform the maximal amount of training and competition possible within the constraints of their discipline.

We found that the risk for injury in alpine skiing, freestyle skiing and snowboarding was high, while there was a lower risk associated with the Nordic disciplines ski jumping, cross country skiing and combined. This does not come as a surprise when we consider the high speed on icy surfaces, spectacular jumps and the combination of speed and jumps with minimal protection these athletes are exposed to during training and competition. However, the question is, how high is high? One interesting consequence of expressing injury rate in absolute terms is that the data may be compared with non-snow sports such as professional football, where the injury risk has been documented to be unacceptably high when compared with other occupations (Drawer & Fuller, 2002). We used data from two studies on male elite football to estimate the number of injuries per 100

athletes per season, one (Ekstrand et al., 2009) where injuries was reported for seven seasons among 23 Champions League teams and one (Hägglund et al., 2009) covering 11 teams in the Swedish premier league. Based on these, we estimated that there were 187 and 205 acute time-loss injuries per 100 athletes per season, respectively. Similar calculations based on studies in female elite players from Sweden (Hägglund et al., 2009), Germany (Faude et al., 2005) and Norway (Tegnander et al., 2008) yielded estimates of 108, 122 and 94 injuries per 100 athletes per season. In other words, the injury risk in elite football appears to be much higher than our estimates of 30, 28 and 38 acute time-loss injuries per 100 athletes per season in alpine skiing, freestyle skiing and snowboarding, respectively, even if we account for the fact that the competitive season is about twice as long in football as in the World Cup.

A consistent finding across most sports is that the frequency of injuries decreases with severity. In other words, slight injuries are the most common, followed by minor and moderate, with severe injuries the least common. It should be noted that our results were the reverse; severe injuries were the most frequent. Almost 1/3 of all injuries to male and female World Cup skiing and snowboarding athletes were severe, leading to an absence for >28 days, similar to a previous study among World Cup snowboarders (Torjussen et al., 2006). Cross-sectional studies among active World Cup snowboard and freestyle athletes have also reported a high prevalence of severe knee injuries (Dowling, 1982; Torjussen et al., 2006). The majority (57–88%) of top-level skiers reported to have suffered at least one serious injury during their career (Margreiter et al., 1976; Raas, 1982; Ekeland et al., 1997). A study on French world-class alpine skiers showed that 50% had sustained at least one anterior cruciate ligament (ACL) injury (Pujol et al., 2007). We found that the risk for sustaining a severe injury was the highest in alpine skiing, freestyle skiing and snowboarding, mainly because of knee ligament injuries. Compared with cross country skiing, these disciplines had a 16- to 20-fold increased risk of such injuries.

Hence, although it seems that the overall injury rate is higher in professional football than on the World Cup circuit, what about the risk for severe injuries? We estimate that among male players on Champions League teams and Swedish premier league teams, there were 31 and 20 severe injuries (>28 days) per 100 athletes per season, respectively (Ekstrand et al., 2009; Hägglund et al., 2009). For female elite players in Sweden, Germany and Norway (Faude et al., 2005; Tegnander et al., 2008; Hägglund et al., 2009), we estimate that there were 16, 19 and 20 severe injuries per 100 athletes per season, respectively. Our findings from alpine skiing, freestyle

skiing and snowboarding show that there were 11, 14 and 14 severe injuries per 100 athletes per season, respectively. If we take into account that the football season is about twice as long as the World Cup season, it seems as if the annual risk for severe injuries is about the same for professional skiers, snowboarders and footballers.

There are some limitations that must be kept in mind when interpreting the results from this study. First, when using retrospective interviews as the method for recording injuries, recall bias is a challenge (Bahr & Reeser, 2003). However, in a methodological study, we found that retrospective athlete interviews gave the most complete picture compared with prospective injury recording by team medical personnel or FIS technical delegates (Flørenes et al., 2009). Nevertheless, there is a possibility that some injuries have not been captured through the injuries. If so, the injury risk would have been underestimated. Having athletes and coaches record injuries prospectively is potentially an alternative way of recording injuries more accurately. However, as performance is the primary focus of elite athletes, it may be unreasonable to expect them to comply fully with an injury-recording protocol, especially as substantial numbers are needed to obtain valid results.

A second limitation is that we have only interviewed the athletes for injuries occurring during the competition period of the winter season and we have no data regarding injuries that they may have sustained during pre-season training on snow or basic training the rest of the year. This limitation needs to be kept in mind when comparing with other sports with a longer competitive season, like football.

Perspectives

Surveillance systems established at the elite level in sports such as football, athletics, handball and the Olympics (Junge et al., 2006; Dvorak et al., 2007; Langevoort et al., 2007; Alonso et al., 2009) have provided important information of injury risk and injury patterns, which in turn has helped researchers direct their focus to develop methods to prevent injuries. Limited data have been available to quantify the risk of injury to our best skiers and snowboarders. This study found that about 1/3 of the athletes in World Cup alpine skiing, freestyle skiing and snowboarding sustain a time-loss injury during the competitive winter season, while the rate is low in the Nordic disciplines. Although the overall risk is much lower among professional skiers and snowboarders compared with professional footballers, the high proportion of severe injuries, mainly knee injuries, is a concern. This is where future research to prevent skiing and snowboarding injuries should be directed.

Key words: skiing, snowboarding, athletic injuries, epidemiology.

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