

Recording injuries among World Cup skiers and snowboarders: a methodological study

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No long-term injury surveillance programs exist for competitive skiing or snowboarding. The objective of this study was, therefore, to compare different methods to record injuries among World Cup athletes in alpine, freestyle, and cross-country skiing, snowboarding, ski jumping and Nordic combined. Information regarding injuries sustained during the 2006–2007 winter season was recorded through three separate and independent systems: prospective injury reports by technical delegates (TD) from the International Ski Federation, prospective medical team registration by selected teams, and retrospective athlete interviews at the end of the season. A total of 100 unique injuries to 602

World Cup athletes were identified from any of the three recording methods. Of these, 91% were registered through the athlete interviews, 47% by the medical team registration and 27% by the TD reports. Only 20 injuries (20%) were captured by all three methods. A total of 64 time-loss injuries were registered. The interviews captured 60 (94%), the medical team registration 39 (61%), and the TD reports 23 (36%) time-loss injuries, while 18 (28%) were registered by all three systems. Retrospective interviews with athletes/coaches regarding injuries during the last 6 months gave the most complete picture of injuries to World Cup skiers and snowboarders.

Skiing and snowboarding are popular sports and it has been estimated that there are approximately 200 million skiers worldwide (Hunter, 1999). Skiing and snowboarding are also popular as competitive sports and the different disciplines of alpine skiing, freestyle skiing, snowboarding, ski jumping, cross-country skiing, and Nordic combined (combination of cross-country skiing and ski jumping) account for more than half of all participants in the winter Olympic Games. According to the International Ski Federation (FIS), 5393 FIS races were held during the 2006–2007 winter season in these disciplines (FIS, personal communication, April 2008). Of these, 298 races were at the World Cup level.

However, in contrast to recreational alpine skiing and snowboarding, where there are several regional (Johnson et al., 2000; Dohjima et al., 2001; Langran & Selvaraj, 2002; Made & Elmqvist, 2004) and even national (Laporte et al., 2000; Ekeland & Rødven, 2006) prospective ski injury recording systems, no long-term injury surveillance programs exist for competitive skiing or snowboarding. Therefore, we only have limited data available on the injury profile

of the elite skier or snowboarder. Although there are some studies from competitive alpine skiing (Ekeland & Holm, 1985; Ekeland et al., 1996; Bergstrom et al., 2001), snowboarding (Torjussen & Bahr, 2005, 2006), freestyle skiing (Dowling, 1982), and ski jumping (Wright, Jr. et al., 1986; Yamamura et al., 1993), these are generally small and often limited to one competition. Except for snowboarding, there are no recent studies available reflecting the current performance level of elite athletes in these disciplines. No data is available from elite cross-country skiing or Nordic combined. Consequently, as prospective injury recording systems do not exist, the risk of being injured for top-level skiers or snowboarders is unknown.

Establishing reliable systems for injury surveillance is a key risk management tool. Such recording systems also represent the important first step in the sequence of injury prevention research (van Mechelen et al., 1992). Prospective cohort studies are recommended to monitor injury patterns and risk over time (Fuller et al., 2006). To date, injury surveillance systems have been established for major

sports events such as World Championships in individual sports like athletics (Alonso et al., 2009) and team sports such as football (Junge et al., 2004) and rugby (Stephenson et al., 1996), as well as multi-sport competitions such as the Olympic Games (Junge et al., 2006, 2008) and the US college sports (National Collegiate Athletic Association Injury Surveillance System) (Dick et al., 2007).

Before the 2006–2007 winter season, FIS took an initiative to establish a continuous injury reporting system for all FIS events. In recreational skiing and snowboarding different methods, reports from ski patrols, physicians at base-lodge clinics, hospital reports or self-reports have been used to record injuries. However, as it was not known which method would yield the most complete and accurate record of injuries to elite ski and snowboard athletes, we wanted to evaluate what would be the best method to register injuries in this population of athletes. The information sources potentially available were the athletes themselves, their medical staff or FIS personnel responsible for running the event, namely the technical delegate (TD) and his local staff, including the official race doctor. Thus, the aim of this study was to compare three different methods to record injuries among World Cup skiers and snowboarders, prospective reporting by the TD, prospective reporting by the medical staff of selected World Cup teams and retrospective interviews with World Cup athletes at the end of the World Cup season.

Materials and methods

Study design and population

Injuries to World Cup athletes in the different 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 were registered through three independent and separate methods during the 2006–2007 winter season (November 1 until the end of the respective World Cup season): (1) prospective injury reports by the TD from FIS (TD reports), (2) prospective injury reporting throughout the season by medical staff from selected World Cup teams (“Medical team registration”), and (3) retrospective athlete interviews at the end of the season (“Athlete interviews”). Athletes from one of six major skiing nations who had participated in at least one World Cup event during the season were eligible for inclusion in this study. The study was approved by the Regional Committee for Medical Research Ethics, Region Øst-Norge and by the Norwegian Social Science Data Services.

Injury definition

The injury definition communicated to all parties involved in the three registration methods was: “All injuries that occurred during training or competition and required attention by medical personnel.” Training included activities on snow


and basic training not on snow. The three registration systems used an injury form containing the same information regarding event and injury (Fig. 1). The classification of the type of injury and body part injured were based on a recent consensus document on injury surveillance in football (Fuller et al., 2006). Severity of injury was classified 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). Expected time loss was recorded in the TD reports, as the actual time loss was not known at the time of registration. A specific diagnosis was also recorded. If multiple injuries resulted from the same event, all of these were described on the same form.

Injury registration by the TD reports

A TD is the official FIS representative and is always present at FIS races, with the responsibility of ensuring that the athletes, coaches and organizers are satisfied with the outcome of the competition (FIS, 2005). The primary duties of the TD are to make sure that the rules and directions of the FIS are adhered to, to see that the event runs smoothly, to advise the organizers within the scope of their duties and to be the official representative of the FIS (FIS, 2008). TDs were asked to report injuries to any athlete participating in all events of the World Cup and World Championships (including official training). We informed those responsible for TD training in the different disciplines how to complete the injury forms during information meetings at the annual FIS spring and autumn meetings before the start of the season. We also produced a brochure with information about the project, as well as description of roles and responsibilities and this brochure was distributed at the same meetings. Information was also distributed through the official FIS website as well as a sub site of the Oslo Sports Trauma Research Center website dedicated to the project. To report an injury, TDs were asked to complete a specific injury form (Fig. 1). The injury form described each injury in detail with regards to the injury type, body part injured, the injured side, specific diagnosis, and expected duration of time loss from training/competition. The TDs were asked to enlist the help of a medically trained person at the event, preferably the official race doctor, to complete the specific medical information. The TDs completed the forms manually or electronically and faxed or sent them by e-mail or regular mail to the FIS office.

Medical team registration

The second registration method was a prospective reporting by the medical staff for six selected World Cup teams. The federations of Switzerland, Germany, France, Finland, Canada and Norway agreed to participate in this study during a meeting in the FIS Medical Committee in September 2006. Each of these federations nominated a contact person for each World Cup team in the disciplines of alpine, freestyle, snowboard, ski jumping, Nordic combined and cross-country skiing, preferably the doctor or physical therapist working and travelling with the team. We sent a letter describing the purposes and procedures of the medical team registration to the team contacts. The team contacts were asked to ensure that all injuries to their World Cup athletes during team activities and competitions were documented by their medical personnel. The team contacts were asked to pass on information material to all athletes, trainers, medical personnel and other support staff to inform about the registration. In addition, written consent was obtained from the athletes. The team contacts were physicians, physical therapists or



F I S
PARTNER
FIS INJURY
SURVEILLANCE
SYSTEM

Injury Surveillance Study - Interview

Oslo Sports Trauma
RESEARCH CENTER

FIS World Cup Alpine, male, 2006/07

Athlete Name: _____

Nation: _____ Discipline: _____

Contact (e-mail/cell): _____

| Week | Date | Site | Race / Competitio n | Start: Yes | Injury: Yes | If "yes" on injury, fill out form Other notes |
|--------------------|--|---|--------------------------------------|--|--|--|
| 44 | 1.-5./11 | | | | <input type="checkbox"/> | |
| 45 (6.-12./11) | 12.11.2006 | Levi, FIN | SL | <input type="checkbox"/> | <input type="checkbox"/> | |
| 46 | 13.-19/11 | | | | <input type="checkbox"/> | |
| 47 (20.-26./11) | 25.11.2006 26.11.2006 | Lake Louise, CAN Lake Louise, CAN | DH SG | <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> | |
| 48 (27.-3./12) | 30.11.2006 30.11.2006 01.12.2006 02.12.2006 03.12.2006 | Beaver Creek, USA Beaver Creek, USA Beaver Creek, USA Beaver Creek, USA Beaver Creek, USA | SC (DH) SC (SL) DH GS SL | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | |
| 49 (4.-10./12) | 10.12.2006 10.12.2006 | Reiteralm, AUT Reiteralm, AUT | SC (SG) SC (SL) | <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> | |
| 50 (11.-17./12) | 15.12.2006 16.12.2006 17.12.2006 | Gardena/Groeden, ITA Gardena/Groeden, ITA Alta Badia, ITA | SG DH GS | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | |
| 51 (18.-24./12) | 18.12.2006 20.12.2006 21.12.2006 | Alta Badia, ITA Hinterstoder, AUT Hinterstoder, AUT | SL SG GS | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | |
| 52 (25.-31./12) | 28.12.2006 29.12.2006 | Bormio, ITA Bormio, ITA | DH DH | <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> | |
| 1 (1.-7./1) | 06.01.2007 07.01.2007 | Adelboden, SUI Adelboden, SUI | GS SL | <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> | |
| 2 (8.-14./1) | 13.01.2007 14.01.2007 14.01.2007 | Wengen, SUI Wengen, SUI Wengen, SUI | DH SC (DH) SC (SL) | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | |

Fig. 2. Example of an interview form with week-by-week schedule. Part of the form from alpine skiing.

Athlete interviews

The third registration method was a retrospective interview with World Cup athletes and/or their team managers/doctors/

physical therapists at the end of the 2006–2007 winter season regarding injuries the athletes had sustained during the season. Athletes having started in at least one World Cup/World Championship event in each of the disciplines of alpine,

Recording injuries in skiing and snowboarding

freestyle, snowboard, ski jumping, Nordic combined and cross-country skiing from the same six nations participating in the medical team registration were identified from the official FIS database. The interviews were carried out at one of the season-ending World Cup events for each discipline. At these events, all athletes who were present from the selected nations were interviewed in person. For those athletes who were not present (due to injury or other reasons), their coaches and/or team physicians/physical therapists were interviewed. Information regarding the purpose and procedures of the interviews was given at the team captain's meeting, where head coaches from all nations are required to be present, and they were asked to inform their athletes. Research teams from the Oslo Sports Trauma Research Center (physicians, physical therapists and medical students) conducted the interviews, normally in the finishing area in connection with official training or competition for the different disciplines, in some cases at their hotel. Athletes from the freestyle discipline halfpipe and the snowboard disciplines big air, parallel giant slalom and parallel slalom were not interviewed because of event cancellations and scheduling conflicts. The interviews were structured based on a form outlining the week-by-week schedule of the World Cup program for each respective discipline, to facilitate athlete recall of missed participation due to injury (Fig. 2). If an injury was recorded, an injury form was completed.

During the registration period, neither the TDs nor the team medical staff was aware that we would perform athlete interviews at the end of the season.

Data analyses

To compare the accuracy and completeness of the three registration methods, injuries recorded to any athlete from the six nations covered by all three methods were compared. The comparison was limited to injuries occurring during World Cup/World Championships (including official training), as the TD reports did not cover training injuries outside these events. Injuries reported during the season-ending event were not included in the comparison between the different methods. We defined the information reported by the athletes themselves regarding injury type and the duration of absence from competition and training as the reference to which the other methods were compared. If an injury was not reported in the athlete interview, we then used the report from the team medical personnel as the reference.

Statistics

Kappa (κ) correlation coefficients were calculated for agreement between methods (Altman, 1991). Coefficients of 0.81–1.00 are generally interpreted as very good, 0.61–0.80 as good, 0.41–0.60 as moderate, 0.21–0.40 as fair and <0.20 as poor (Altman, 1991).

Results

During the 2006–2007 winter season, 3297 athletes competed in the FIS World Cup according to the official FIS database; 455 in alpine skiing, 1475 in cross-country skiing, 79 in Nordic combined, 459 in freestyle skiing, 141 in ski jumping and 620 in snowboarding. Of these, 612 were from the World Cup teams of the six countries covered by all three

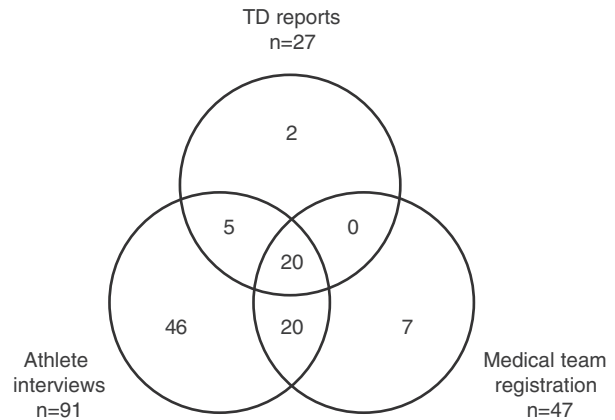


Fig. 3. Venn diagram of injuries reported through the three registration methods within the cohort covered by all three methods ($n = 100$).

registration methods and we were able to obtain interview information about 602 athletes (98%); 141 from alpine skiing, 153 from cross-country skiing, 41 from Nordic combined, 117 from freestyle skiing, 50 from ski jumping and 100 from snowboarding.

A total of 100 unique injuries, which potentially could have been reported in all three registrations were identified (injuries to the 602 athletes interviewed occurring in World Cup/World Championship events until the date of the interviews). Of these, 91 injuries were recorded through the athlete interviews, 47 by the medical team registration and 27 by the TD reports. Only 20 injuries were recorded by all three registration methods (Fig. 3).

For the time-loss injuries (injuries leading to an absence of ≥ 1 day), a total of 64 unique injuries were identified from at least one of the three recording systems. Sixty injuries were reported from the athlete interviews, 39 by the medical team registration and 23 through the TD reports. Eighteen injuries were recorded by all three registration methods (Fig. 4).

Of the 100 unique injuries recorded through the three recording systems, 29 were in alpine skiing, 12 in cross-country skiing, four in Nordic combined, 25 in freestyle skiing, six in ski jumping and 24 in snowboarding. Among the 29 alpine skiing injuries, 10 (34%) were detected by the TD reports and 21 (72%) through the medical team registration. The corresponding figures for cross-country skiing were 0 and 4 (33%), for Nordic combined 0 and 3 (75%), for freestyle skiing 11 (44%) and 10 (40%), for ski jumping 2 (33%) and 4 (67%) and for snowboarding 4 (17%) and 5 (21%) for the TD reports and medical team registration, respectively.

As shown in Table 1, 44 (60%) of the 73 injuries that the TDs did not record were minor injuries with no absence or a 1–3 day time loss from training and

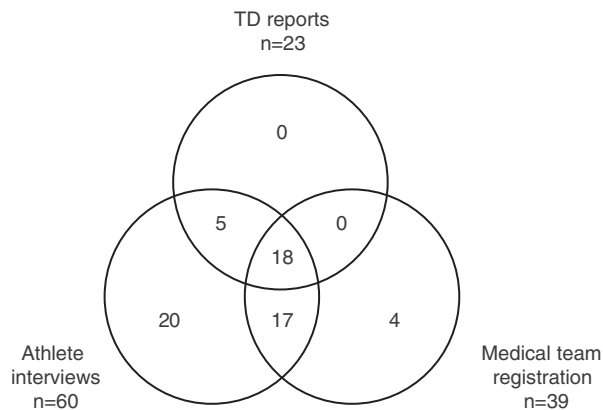


Fig. 4. Venn diagram of time-loss injuries (absence ≥ 1 day) reported through the three registration methods within the cohort covered by all three methods ($n = 64$).

Table 1. Comparison of reported severity between technical delegates (TD) reports and all recorded injuries ($n = 100$)

| TD reports | All recorded injuries | | | | | | Total |
|--------------|-----------------------|----------|----------|-----------|----------|----------|-------|
| | 0 | 1–3 days | 4–7 days | 8–28 days | >28 days | Un-known | |
| 0 | 3 | | | 1 | | | 4 |
| 1–3 days | | | 1 | | | | 1 |
| 4–7 days | 1 | 1 | | 1 | 2 | | 5 |
| 8–28 days | | | | | 2 | | 2 |
| >28 days | | | | 1 | 5 | | 6 |
| Unknown | | 1 | 1 | 1 | 6 | | 9 |
| Not recorded | 32 | 12 | 3 | 14 | 11 | 1 | 73 |
| Total | 36 | 14 | 5 | 18 | 26 | 1 | 100 |

Results are shown as the number of cases in each severity category, classified according to the number of days of absence from training and competition (0: no time loss, 1–3 days, 4–7 days, 8–28 days and >28 days).

Table 2. Comparison of reported severity between medical team registration and all recorded injuries ($n = 100$)

| Medical team registration | All recorded injuries | | | | | | Total |
|---------------------------|-----------------------|----------|----------|-----------|----------|----------|-------|
| | 0 | 1–3 days | 4–7 days | 8–28 days | >28 days | Un-known | |
| 0 | 8 | | | | | | 8 |
| 1–3 days | | 4 | 1 | 1 | | | 6 |
| 4–7 days | | 2 | 1 | 3 | | | 6 |
| 8–28 days | | | 2 | 7 | 1 | | 10 |
| >28 days | | | | | 16 | | 16 |
| Unknown | | | | | 1 | | 1 |
| Not recorded | 28 | 8 | 1 | 7 | 8 | 1 | 53 |
| Total | 36 | 14 | 5 | 18 | 26 | 1 | 100 |

Results are shown as the number of cases in each severity category, classified according to the number of days of absence from training and competition (0: no time loss, 1–3 days, 4–7 days, 8–28 days and >28 days).

competitions, while 14 injuries (19%) were moderate injuries with an absence of 8–28 days and 11 (15%)

severe injuries (>28 days). In one case, we did not have any information about the duration of time loss.

When comparing the medical team reports to the athlete interviews as the reference, 36 (68%) of the 53 injuries they did not record were minor with no or 1–3 days of absence from training and competition, while 7 (13%) were moderate (8–28 days) and 8 (15%) severe (>28 days) (Table 2).

In the athlete interviews, 9 injuries reported by the TDs or medical staff were missed, and, of these, 5 did not lead to any absence, 2 to 1–3 days of missed training and competition, while 2 were moderate (8–28 days).

When comparing the information on injury type reported by the TDs with the reference, the information was accurate in all but 3 cases (two fractures and one joint/ligament injury) (Table 3). More than half of the fractures were reported by the TDs, while muscle, tendon and contusion injuries were only reported in 13–14% of the cases.

When the information provided by the medical team was compared with the athlete interviews, the same injury type was reported in 40 of the 47 cases reported by both registration methods, while there was a discrepancy in seven cases (15%) (Table 4). Through the medical team reporting six of eight (75%) fractures were reported and six of 11 (55%) nervous system/concussion injuries were reported. On the other hand most of the muscle and tendon (10 of 14 cases, 71%), as well as contusion injuries (17 of 24 cases, 71%) were not reported by the medical team.

The TDs reported the correct body part injured for 23 of 27 (85%) injuries, while the team medical registration information on body part was correct in 43 of 47 (91%) reported cases.

κ correlation coefficients are shown in Table 5. There was good to very good agreement for the body part injured and injury type, while agreement for severity varied from poor to good.

Discussion

The main finding of this study was that retrospective athlete interviews with athletes/coaches was the best method to detect injuries sustained during one World Cup season, better than prospective registration by team medical staff and better than prospective TD reporting. This was unexpected, as previous studies from football (Junge & Dvorak, 2000), physical education students (Twellaar et al., 1996) and preschool children (Fonseca et al., 2002) have shown that prospective registration recorded more injuries than retrospective registration. Junge & Dvorak (2000) found in a study of 264 football players that

Recording injuries in skiing and snowboarding

Table 3. Comparison of reported injury type between technical delegates (TD) reports and all recorded injuries ($n = 100$)

| TD reports | All recorded injuries | | | | | | | Total |
|-------------------------------|-----------------------|--------------------|-------------------|-----------|---------------------|----------------------------------|-------|-------|
| | Fracture | Joint/ ligament | Muscle/ tendon | Contusion | Skin/ laceration | Nervous system/ concussion | Other | |
| Fracture | 5 | | | | | | | 5 |
| Joint/ligament | 1 | 10 | | | | | | 11 |
| Muscle/tendon | | | 2 | | | | | 2 |
| Contusion | | 1 | | 3 | | | | 4 |
| Skin/laceration | | | | | | | | |
| Nervous system/ concussion | 1 | | | | | 4 | | 5 |
| Other | | | | | | | | |
| Not recorded | 1 | 30 | 12 | 21 | 1 | 7 | 1 | 73 |
| Total | 8 | 41 | 14 | 24 | 1 | 11 | 1 | 100 |

Table 4. Comparison of reported injury type between medical team registration and all recorded injuries ($n = 100$)

| Medical team registration | All recorded injuries | | | | | | | | Total |
|---------------------------|-----------------------|--------------------|-------------------|-----------|---------------------|-------------------------------|-------|---------|-------|
| | Fracture | Joint/ ligament | Muscle/ tendon | Contusion | Skin/ laceration | Nervous system/ concussion | Other | Unknown | |
| Fracture | 6 | | | | | 1 | | | 7 |
| Joint/ligament | | 19 | | 1 | | | | | 20 |
| Muscle/tendon | | 1 | 3 | | | 1 | | | 5 |
| Contusion | | | 1 | 5 | | | | | 6 |
| Skin/laceration | | | | | | | | | |
| Nervous system/concussion | | | | 1 | | 6 | | | 7 |
| Other | | | | | | | 1 | | 1 |
| Unknown | | 1 | | | | | | | 1 |
| Not recorded | 2 | 20 | 10 | 17 | 1 | 3 | | | 53 |
| Total | 8 | 41 | 14 | 24 | 1 | 11 | 1 | | 100 |

Table 5. Kappa (κ) values with 95% CI for agreement between the different registration methods

| Variable | Registration method | | |
|-------------|-------------------------|---------------------------|----------------------------|
| | TD reports vs interview | Medical team vs interview | TD reports vs medical team |
| Severity | 0.14 (−0.19 to 0.47) | 0.65 (0.46–0.84) | 0.39 (−0.01 to 0.78) |
| Injury type | 0.83 (0.65–1.00) | 0.79 (0.63–0.94) | 0.71 (0.46–0.96) |
| Body part | 0.81 (0.63–0.98) | 0.88 (0.77–0.99) | 0.82 (0.63–1.00) |

TD, technical delegates.

retrospective interviews with the players for the previous 2 months reported only 1/3 of injuries compared with a prospective follow-up every week. Fonseca et al. (2002) compared the incidence of injuries in preschool children obtained from diaries filled in by the children's caretakers with injuries reported by interviews of the same caretakers covering the last 30 days. They found that diaries captured a higher number of injuries during these 30 days than did retrospective interviews. Twellaar et al. (1996) prospectively recorded information on sports injuries every 3 weeks for 4 years in a group of 136 physical education students and retrospectively asked 59

students to recall all injuries. They concluded that even in a well-supervised population, prospective injury registration is not complete and the reliability of retrospective injury registration is even poorer.

The current results demonstrate that the suitability of injury recording methods depends on the setting where they are applied. The main limitation of retrospective injury reporting is recall bias, as described by Twellaar et al. (1996). To help athletes and coaches remember participation and injuries sustained throughout the season, we used interview forms outlined as week-by-week schedules of the World Cup program in each respective discipline in

the same way as in a previous study on injuries among beach volleyball players (Bahr & Reeser, 2003). The athlete interviews recorded 91% of all the injuries identified by any of the three methods and 94% of all time-loss injuries. Thus, it seems that recall bias was minimal when recording injuries to elite ski and snowboard athletes during a limited period of one World Cup season. The explanation for this may be the setting; highly committed professional athletes may be expected to remember injuries that have affected their performance during the competitive season. The fact that 40% of the interviews were carried out with coaches (for athletes not present at the event where interviews were performed) did not seem to affect the capture rate significantly. Our impression was that the coaches had a very good recall of injuries to their racers, which is perhaps not surprising considering that each coach is responsible for a limited number of athletes and that the World Cup teams travel and live together during the entire competitive season. Performing the interviews the way we did, based on forms outlining the competition schedule, therefore seems to have facilitated recall of injuries by athletes and coaches. Still, we can not rule out the possibility that there were injuries that were not captured by any of the recording systems used. The interviews were mainly performed after an official training session or race and athletes may still have been focused on the race or simply did not want to share their injury history with the researchers.

The two prospective registration methods in this study captured 61% (Medical team registration) and 36% (TD) of time-loss injuries. Only a few studies have compared prospective injury registration previously. One study (Olsen et al., 2006) compared two prospective registration methods of injury reporting in youth team handball; match reporting by scorekeepers at each match and coach reporting. They found that coach reports were the best method. Another study (Emery et al., 2005) found for 21 adolescent soccer teams (age 12–18) in Canada (317 participating players) a high rate of completion of injury report forms (96.2%) by a team designate (a volunteer coach or parent) and therapist assessment forms (85.9%) but a low rate for physician diagnosis forms (36.4%).

We were somewhat surprised to see the low capture rate of the medical team registration in this setting. The six nations participating in our study were picked because they had the necessary medical staff and organization to carry out the registration. Also, we were in close contact with the selected contact persons for each discipline in each nation throughout the season. Despite this, there are a number of factors that can explain the low capture rate. First, in some cases the doctor or physiotherapist did not always

travel with the team. Second, some teams had a number of doctors and physiotherapists sharing responsibility and taking turns travelling with the team, which may have hindered communication about the registration system and injuries sustained within the team. Third, the teams travel almost continuously during the winter season and it may have been a challenge to send in the injury form, e.g. because of poor internet access and a busy schedule. Finally, it is possible that athletes did not even seek help for injuries, especially minor injuries with no or 1–3 days of absence time loss, as also described by Olsen et al. (2006). We do not know which of these factors were the most important, but the findings suggest that an injury registration system based on medical staff reports is unreliable in this setting.

The low capture rate of the TD registration was not unexpected. We included TD registration as a third injury recoding system because – if successful – this would be an attractive option whereby injuries could be recorded at low costs using an available resource. The TD is the official FIS representative, who is always present at FIS events, and not just at the World Cup level. A number of steps were taken to inform the TDs of their responsibility to record injuries and the procedures to be followed, including training sessions with FIS representatives and those responsible for educating TDs, TD training seminars and distribution of a presentation and brochure with information about the registration and the roles and responsibilities of the TD. However, the results show that the TD registration captured only 1/3 of the time-loss injuries. There are several possible explanations for the low capture rate. First, even if TDs have a supervisory role, they were probably not aware of all injuries occurring during the race. We recommended that TDs involved the race doctor at each event to help complete forms for injuries seen by the event medical staff. This probably did not happen in all cases, and some athletes sustaining an injury may have elected to seek medical care from their own medical team without involving the event medical staff. TDs also have a number of official tasks and forms to complete, and we do not know how they prioritized the injury recording.

The disciplines differ with regards to race settings, environment and task requirements, as well as characteristics of the injuries and their mechanisms. These are factors that could complicate the use of one system for all the different disciplines. We found, however, that the retrospective interviews captured most injuries across all disciplines (75–100%). The capture rate by the medical team registration varied from 21% to 75%, but was higher than the capture rate from the TD registration in all disciplines except in freestyle skiing (TDs 44% vs 40% for the medical team registration). The caveat is that there are few

injuries for a valid comparison for some disciplines, but our results strongly indicate that retrospective interviews best reflect the injury rate across all disciplines.

We found that there was good to very good agreement between the three registration methods for body part injured and injury type, while agreement was from poor to good for severity. If the information from two methods differs, we cannot know for sure which is correct. However, the results for body part and injury type are encouraging, suggesting that the information provided is quite accurate, regardless of the recording method. In contrast, while agreement for severity was good between the athlete interviews and the medical team registration, the severity estimates provided by the TD registration differed widely with those reported by the other methods. The simple explanation for this is that severity was reported as the duration of absence from training and competition, and while the TDs were asked to *estimate* this at the time of injury, the athletes and medical staff generally reported injuries after the athlete had returned to compete and the duration of time loss was *known*. We also noted that in 36% of the cases reported by the TDs they were unable to include information on the estimated duration of absence from sports, i.e. injury severity. This may not be surprising, considering that they may not have had access to a qualified medical opinion when completing the forms. Consequently, our results demonstrate that inaccurate or missing severity estimates represent an additional limitation of the TD reporting method. This is interesting, as the surveillance systems established in football (Junge et al., 2004), athletics (Alonso et al., 2009) and the Olympic Games (Junge et al., 2006, 2008) are also based on severity estimates provided at the time of injury, albeit by a team physician.

As outlined above, there are a number of factors that may explain the difference in performance between the three different recording systems. However, it should be noted that the study was carried out of a subgroup of athletes and teams, and we do not know if the results are representative for the entire population of World Cup skiers. We included a clearly defined population of six nations and obtained information on 98% of their World Cup athletes. They represented large teams in the different disciplines, chosen because they were thought to have adequate resources and well-organized medical teams to complete the registration. Consequently, it seems likely that a registration system based on medical staff reports would function even worse if smaller nations with fewer resources were involved. On the other hand, smaller teams are more reliant on the event medical staff if they suffer injuries, which could increase the capture rate of the TD

registration. We would expect interviews to function equally well among all World Cup teams, regardless of level.

Perspectives

According to the consensus statement from football (Fuller et al., 2006), one should aim at prospective study designs when establishing injury registration systems in sports. However, our study indicates that it is important to consider the characteristics of the setting in each sport before constituting an injury registration system and that retrospective interview with athletes/coaches may represent a better alternative. Our experience with this and a previous study (Bahr & Reeser, 2003) also indicates that when performing retrospective interviews, using a structured form based on the week-by-week schedule of the competition calendar (as shown in Fig. 2) may be an important tool to secure a high compliance and reduce recall bias.

Establishing a continuous recording system for elite skiing and snowboarding is an important priority to be able to monitor injury risk and pattern over time. One purpose of such a system is to document the consequences of changes in equipment (e.g. carving skis) or competition rules (e.g. new disciplines, course designs). Motivation among everyone involved; organizers, officials, members of the different teams and especially those required to provide information is essential to obtain complete data in injury recording. The current findings show that the best reporting system is retrospective interviews with a sample of athletes/coaches. Medical team registration did not function as expected, probably because medical coverage is less consistent than in professional team sports such as FIFA competitions or professional hockey or basketball. As mentioned above, TD registration is an attractive option, as injuries could be recorded from all regions around the world at low costs using an available resource and at all FIS events, not just at the World Cup level. However, it is not known whether it is possible – with improved TD training and more active involvement of event medical staff – to improve the capture rate to acceptable levels. Also, another limitation of the TD recording system is the inaccurate severity estimates provided.

In conclusion, retrospective interviews with athletes/coaches regarding injuries sustained during one World Cup season (5–6 months) gave the most complete picture of injuries to elite ski and snowboard athletes.

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

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References

Alonso JM, Junge A, Renstrom P, Engebretsen L, Mountjoy M, Dvorak J. Sports injuries surveillance during the 2007 IAAF world athletics championships. *Clin J Sport Med* 2009; 19: 26–32.

Altman DG. Some common problems in medical research. In: Altman DG, ed. *Practical statistics for medical research*. London: Chapman & Hall, 1991: 403–409.

Bahr R, Reeser JC. Injuries among world-class professional beach volleyball players. The Federation Internationale de Volleyball beach volleyball injury study. *Am J Sports Med* 2003; 31: 119–125.

Bergstrom KA, Bergstrom A, Ekeland A. Organisation of safety measures in an Alpine world junior championship. *Br J Sports Med* 2001; 35: 321–324.

Dick R, Agel J, Marshall SW. National collegiate athletic association injury surveillance system commentaries: introduction and methods. *J Athl Train* 2007; 42: 173–182.

Dohjima T, Sumi Y, Ohno T, Sumi H, Shimizu K. The dangers of snowboarding: a 9-year prospective comparison of snowboarding and skiing injuries. *Acta Orthop Scand* 2001; 72: 657–660.

Dowling PA. Prospective study of injuries in United States Ski Association freestyle skiing–1976–77 to 1979–80. *Am J Sports Med* 1982; 10: 268–275.

Ekeland A, Dimmen S, Lystad H, Aune AK. Completion rates and injuries in alpine races during the 1994 Olympic winter games. *Scand J Med Sci Sports* 1996; 6: 287–290.

Ekeland A, Holm A. Injury and race completion rates in Alpine competitions. In: Johnson RJ, Mote CD Jr., eds. *Skiing trauma and safety: Fifth international symposium*, ASTM STP 860. Philadelphia: American Society for Testing and Materials, 1985: 293–301.

Ekeland A, Rødven A. Injuries in Norwegian Ski resorts 2002–2004. In: Johnson RJ, Shealy JE, Yamagishi T, eds. *Skiing trauma and safety: Sixteenth volume*, ASTM STP 1474. West Conshohocken, PA: American Society for Testing and Materials, 2006: 1–7.

Emery CA, Meeuwisse WH, Hartmann SE. Evaluation of risk factors for injury in adolescent soccer: implementation and validation of an injury surveillance system. *Am J Sports Med* 2005; 33: 1882–1891.

Fonseca SS, Victora CG, Halpern R, Lima R, Barros FC. Comparison of two methods for assessing injuries among preschool children. *Inj Prev* 2002; 8: 79–82.

Fuller CW, Ekstrand J, Junge A, Andersen TE, Bahr R, Dvorak J, Hagglund M, McCrory P, Meeuwisse WH. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Br J Sports Med* 2006; 40: 193–201.

Hunter RE. Skiing injuries. *Am J Sports Med* 1999; 27: 381–389.

Johnson RJ, Ettlinger CF, Shealy JE. Update on injury trends in alpine skiing. In: Johnson RJ, Zucco P, Shealy JE, eds. *Skiing trauma and safety: Thirteenth volume*, ASTM STP 1397. West Conshohocken, PA: American Society for Testing and Materials, 2000: 108–118.

Junge A, Dvorak J. Influence of definition and data collection on the incidence of injuries in football. *Am J Sports Med* 2000; 28: S40–S46.

Junge A, Dvorak J, Graf-Baumann T. Football injuries during the World Cup 2002. *Am J Sports Med* 2004; 32: S23–S27.

Junge A, Engebretsen L, Alonso JM, Renstrom P, Mountjoy M, Aubry M, Dvorak J. Injury surveillance in multi-sport events: the International Olympic Committee approach. *Br J Sports Med* 2008; 42: 413–421.

Junge A, Langevoort G, Pipe A, Peytavin A, Wong F, Mountjoy M, Beltrami G, Terrell R, Holzgraefe M, Charles R, Dvorak J. Injuries in team sport tournaments during the 2004 Olympic games. *Am J Sports Med* 2006; 34: 565–576.

Langran M, Selvaraj S. Snow sports injuries in Scotland: a case-control study. *Br J Sports Med* 2002; 36: 135–140.

Laporte J-D, Binet M-H, Constans D. Evolution of ACL Ruptures in French Ski Resorts 1992–1999. In: Johnson RJ, Zucco P, Shealy JE, eds. *Skiing trauma and safety: Thirteenth volume*, ASTM STP 1397. West Conshohocken, PA: American Society for Testing and Materials, 2000: 95–107.

Made C, Elmqvist LG. A 10-year study of snowboard injuries in Lapland Sweden. *Scand J Med Sci Sports* 2004; 14: 128–133.

Olsen OE, Myklebust G, Engebretsen L, Bahr R. Injury pattern in youth team handball: a comparison of two prospective registration methods. *Scand J Med Sci Sports* 2006; 16: 426–432.

Stephenson S, Gissane C, Jennings D. Injury in rugby league: a four year prospective survey. *Br J Sports Med* 1996; 30: 331–334.

The International Ski Federation (FIS). 2005. Memorandum for the technical delegate. Available at <http://www.fis-ski.com> (accessed March 2009).

The International Ski Federation (FIS). 2008. International ski competition rules (ICR), Joint regulation for alpine skiing. Available at <http://www.fis-ski.com> (accessed March 2009).

Torjussen J, Bahr R. Injuries among competitive snowboarders at the national elite level. *Am J Sports Med* 2005; 33: 370–377.

Torjussen J, Bahr R. Injuries among elite snowboarders (FIS Snowboard World Cup). *Br J Sports Med* 2006; 40: 230–234.

Twellaar M, Verstappen FT, Huson A. Is prevention of sports injuries a realistic goal? A four-year prospective investigation of sports injuries among physical education students. *Am J Sports Med* 1996; 24: 528–534.

van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med* 1992; 14: 82–99.

Wright JR Jr., Hixson EG, Rand JJ. Injury patterns in nordic ski jumpers. A retrospective analysis of injuries occurring at the Intervale Ski Jump Complex from 1980 to 1985. *Am J Sports Med* 1986; 14: 393–397.

Yamamura T, Sugawara M, Ishii S. Ski jumping injuries. In: Johnson RJ, Mote CD Jr., Zelcer J, eds. *Skiing trauma and safety: Ninth international symposium*, ASTM STP 1182. Philadelphia: American Society for Testing and Materials, 1993: 262–266.