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Injury rate and injury patterns among alpine European Cup athletes: *Are injury rates and injury patterns different between European Cup and World Cup athletes?*

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Abbreviations

FIS	International Ski Federation
FIS ISS	FIS Injury Surveillance Study
EC	European Cup
WC	World Cup
OWG	Olympic Winter Games
WSC	World Ski Championship
ACL	Anterior Cruciate Ligament
RR	Risk Ratio
CI	Confidence Interval

1. Introduction

1.1 Background

Alpine skiing is a popular winter sport with more than 200 million skiers worldwide (1). In 1936, at Garmich-Partenkinchen, male and female alpine skiing became a part of the official Olympic programme (2). The International Ski Federation (FIS) was established in 1924, and today 123 National Ski Associations comprise the membership of FIS (3). The FIS Alpine World Cup (WC) is today one of the most popular winter sports with the highest broadcasting time (4). Winning the total WC requires extremely high levels of skiing throughout the whole season. It is considered by experts to be even more athletically valuable than winning a gold medal in the Olympic Winter Games (OWG) or the World Ski Championships (WSC) (5).

Research has shown that participation in sports and physical activity can lead to several health benefits (6). However, sport participation may also present a danger of health in the form of accidents and injuries. Sport injuries may cause discomfort and disability, and the injured athlete may be forced to give up or cut down his or her sporting activities. These injuries are often associated with considerable medical expenses (6, 7).

Previous studies have reported a high risk of injuries among alpine WC athletes (8, 9). A qualitative study examined the psychological processes associated with injury and illness among elite Canadian skiers. Sustaining an injury led to several psychological impacts, such as concerns about the future and the ski career and thoughts about quitting (10). No previous studies have, to our knowledge, investigated injury risk and patterns among athletes competing in sublevels of the WC, such as the Alpine European Cup (EC). The EC serves as qualification for the FIS WC and provides excellent opportunities for up and coming young athletes to gain experience (11). Steffen et al. (2010) stated in their review that injury surveillance among young highly competitive athletes are needed to monitor injuries, identify high risk sports, and ensure new knowledge on injury trends. This can form the basis for further research on injury risk factors and mechanisms, and in the end lead to injury prevention (12).

1.2 The context and aims of the thesis

The FIS Injury Surveillance System (FIS ISS) was developed prior to the 2006/07 winter season by FIS in collaboration with the Oslo Sports Trauma Research Center. The main purpose of the FIS ISS is to monitor injury patterns and trends in the different FIS disciplines (alpine skiing, freestyle skiing, snowboarding and telemark skiing and ski jumping). Secondly, the FIS ISS is meant to provide background data for in-depth studies of the causes of injury. The ultimate purpose of the injury registration is to reduce the risk of injuries among the athletes by suggesting preventive measures for the future (13).

Studies from the FIS ISS have previously investigated injury risk and patterns among alpine WC athletes, however there is limited knowledge about injuries among alpine EC athletes (8, 9). The aim of this study was therefore to investigate and describe the injury risk and pattern of injuries among EC athletes, and to compare these data to injuries among top-level athletes from the alpine WC.

Figure 1: *Injury registration in the European Cup finals in Soldeu, Andorra, in 2014. Photo: Author*

2. History

Skiing has an ancient history. The earliest traces of skis came from wood fragments and Stone Age rock carvings discovered around the Artic Rim from as early as 6000 years BC. The skis provided an important means of transportation, and were used for hunting, fishing and in warfare (14-16).

Modern alpine skiing has its origin from Norway's Telemark County in the last half of the 1800's, where new inventions and techniques for skiing were developed. The Norwegian Telemark farmer, Sondre Norheim, invented a ski strap that ran around the heel and was connected to the toe strap. This strap was holding the ski firmly enough to the foot so the skier could manoeuver the ski better or jump without danger of losing the ski. The Telemark skiers had an improved and more dynamic technique with quick and precise steering and braking. The Austrian Mathias Zdarsky, evolved the alpine ski technique by introducing the V position. He founded the first alpine ski school and he is known by many today as the father of alpine skiing (15, 16). Alpine skiing has become a popular activity with more than 200 million skiers worldwide (1).

Alpine skiing was introduced in the Olympic program in 1936 at Garmisch-Partenkirchen, as a combined competition of downhill and slalom. In 1948 these were held as separate competitions. Four years later giant slalom was added to the program and super giant slalom (super-G) became a fourth separate event in 1988 (17).

3. The FIS Alpine World Cup and European Cup

On the 18th of February in 1910, 22 delegates from 10 different nations joined together in Christiania, Norway, to form an international skiing commission. This group became formally known as The International Ski Federation (FIS) on the 2nd of February 1924 during the first Olympic Winter Games in Chamonix, France, with 14 member nations. Today, 123 National Ski Associations comprise the membership of FIS (3). In the 2013/2014 season, alpine skiing had the highest broadcasting time among FIS WC winter sports, with 3551 hours, and was estimated to have a total audience of 2721 million (4).

The FIS WC is the top international circuit of alpine skiing competitions staged annually, and winning the WC is considered by some experts to be athletically more valuable than winning a gold medal at the Olympic Winter Games or the World Ski Championships. To win the total WC, the competitor is required to ski at an extremely high level in several events throughout the season, and not just in one race (5).

The FIS Alpine EC is one of the five FIS Alpine Continental Cups. The other four Continental Cups are: the Nor-Am Cup, the Far East Cup, the South American Cup and the Australia New Zealand Cup (18). The FIS Continental Cup series serves as qualification for the FIS WC, and provides excellent opportunities for up and coming young athletes to gain experience (11). The winners of the different events, overall winners or best-placed competitors in the EC are qualified to compete in WC races for the following season (18).

3.1 Alpine Skiing Disciplines

Alpine skiing consists of five different disciplines; downhill, super-G, giant slalom, slalom and combined events. Downhill and super-G are speed events, while slalom and giant slalom are technical events. The last event is a combined event consisting of one downhill or super-G run and a single slalom run (5, 19).

3.1.1 Downhill

Downhill has the longest courses and the highest speeds (20). It has a minimum of control gates and speeds often exceed 113 km/h (21). Downhill is characterized by the six components: technique, courage, speed, risk, physical condition and judgement (19). The vertical drop has to be between 800-1100 m in males' courses in the WC and 500-1100 m in the EC. In the females' courses the vertical drop has to be between 450-800 m. Downhill competitions are carried out in one run and the competitor with the fastest time wins (19).

3.1.2 Slalom

Slalom has the shortest course and quickest turns (20). Slalom rewards quickness, balance and aggressiveness and the ideal slalom course must include a series of turns designed to allow the competitors to combine speed with neat execution and precision of turns. In the WC, the vertical drop for males' courses has to be between 180-220 m and 140-220 m for females. In the EC, the vertical drops for males and females' courses have to be between 140-220 meters and 120-200 meters respectively. Slalom competitions consist of two runs on two different courses, where the competitor with the fastest total time wins (19).

3.1.3 Giant Slalom

Giant slalom is considered as the alpine discipline that requires the most technical skills (21). It consists of a variety of long, medium and short turns, and requires precision, control and balance from the competitor. The competitor is free to choose his own line between the gates. The vertical drop has to be 250-450 meters for males' courses and

250-400 meters for females' courses. In the WC 300 meters is the minimum for vertical drop. Competitions consist of two runs and the competitor with the fastest total time wins. Both runs are usually held on the same day (19).

3.1.4 Super Giant Slalom (Super-G)

Super-G combines elements of speed as in downhill while integrating technical turns as in giant slalom (21). It is set like downhill courses whit shorter distances and a variety of long and medium turns. The vertical drop has to be between 400-650 m for males in WC and EC events. For females' courses the vertical drop has to be 400-600 meters in WC events and 350-600 meters in EC events. Super-G competitions consist of one run as in downhill, where the competitor with the fastest time wins (19).

3.2 Rules for participation in FIS EC and WC competitions

In order to compete in FIS international competitions, the competitor must be no younger than the age group U18 (minimum 16 years) (19). The FIS maintains a scoring system that includes racers registered internationally and competing in FIS events. The FIS points list assigns the top WC skiers to the first places on the list, adjusting other competitors accordingly. For a FIS competitor, lower points reflect better results. The number one ranked WC competitor in one of the alpine disciplines is given 0.0 FIS points in the discipline concerned (22).

In the EC, each nation is entitled to a basic quota of two participants in slalom, giant slalom and super-G events, and three in downhill events, on the conditions that these competitors have a maximum of 120 FIS points, as follows:

1. Slalom and giant slalom: in any of the five events
2. Downhill and super-combined (with downhill): in downhill or super-G
3. Super-G and super-combined (with super-G): in downhill, super-G or giant slalom

Each nation's additional quota for entry is determined by the number of competitors ranked in the top 100 in the event concerned, according to the FIS points list; for example 8 competitors among the top 100 = 10 participants (18).

Each national association may enter one competitor in FIS WC races, taking into consideration following conditions:

1. Slalom and giant slalom: a maximum of 120 FIS points in any of the five events
2. Downhill and super-G: a maximum of 80 FIS points in the respective event
3. Combined events with downhill: a maximum of 80 FIS points in downhill
4. Combined events in super-G: ranked top 60 in the WC starting list or a maximum of 80 FIS points in super-G

Additional quota is established on the basis of the number of competitors per nation classified within rank 1-60 in the WC starting list. A national ski association may enter a maximum of 8 additional competitors (23).

3.3 Ski regulations

Ski regulations for EC and WC competitions are described by FIS in "Specifications for Competition Equipment and Commercial Markings" (24). Prior to the 2012/2013 season, FIS decided that the ski equipment would be subject to new regulations in the EC and WC, in order to increase athletes' safety. The goal was to reduce the speed and forces on skiers in the turns and the aggressiveness in the ski-snow interaction (25, 26). Regulations for ski length and radius for EC and WC competitions are presented in table 1.

Table 1: Regulations for the ski length and radius in alpine EC and WC competitions (24)

		As from 2013/2014
Ski length (minimum)	Downhill Females	210
	Downhill Males	218
	Super-G Females	205
	Super-G Males	210
	Giant slalom Females	188
	Giant slalom Males	195
	Slalom Females	155
	Slalom Males	165
Radius (minimum)	Downhill Ladies	50
	Downhill Males	50
	Super-G Females	40
	Super-G Males	45
	Giant slalom Females	30
	Giant slalom Males	35
	Slalom Females	
	Slalom Males	

4. Technical and physical characteristics of alpine skiing

Good skiing technique is about managing forces. We divide the forces of skiing into two categories: internal and external. Internal forces are those that skiers generate with their muscles, and are used to align the segments of the body, manipulate the skis and poles, and push against the snow to get a desired reaction from it. External forces act on the skier from outside the body. Gravity, friction between the skis and snow, and wind resistance are some examples of external forces in skiing (27).

A study done by Neumayr et al. (2010), describing physical and physiological variables in Austrian WC alpine ski racers, found that ski racing performance depends on several variables and cannot be predicted by just one physiological factor. Alpine skiing demands a variety of qualities in the skier: Sport-specific qualities, such as ski-technique, and sport-unspecific qualities, such as the athletes' physical, physiological and psychological profile. In alpine elite skiers all motor features, like endurance, strength, velocity, flexibility and coordination, as well as psychological factors, like motivation, concentration and the ability to sustain stress, contribute to competition performance. In the study, high aerobic power and muscle strength appeared to be crucial for success in alpine ski racing (28).

Gorski et al. (2014) measured anthropometric and physical profiles of young Swiss alpine skiers and comparisons between different performance-level and age groups were made. Between 2004-2011, the Swiss-Ski Power test was used to evaluate alpine skiers of different skill levels aging between 11 and 20 years. It consisted of anthropometric measurements (height and body mass) and physical tests for speed, coordination, explosive strength of upper- and lower limb, abdominal strength, anaerobic capacity and aerobic endurance. They found a progressive increase in anthropometric measures and improvements in tests results with increasing age. Males had better results than females in all tests. Differences between higher-level and lower-level athletes were more pronounced in tests for lower-limb strength and anaerob capacity (29).

5. Concepts in epidemiological sports literature

Epidemiology is the scientific study of the distribution, risk factors and causes of different diseases and injuries in a population (30). Research has shown that participation in sports and physical activity can lead to several health benefits, such as reduced risk of certain chronic diseases and enhanced or perceived function with age (6). However, sport participation may also present a danger of health in the form of accidents and injuries. Sport injuries may cause discomfort and disability, and the injured athlete may be forced to give up or cut down his or her sporting activities. These injuries are often associated with considerable medical expenses (6, 7).

Sports injury research is important to provide information about the magnitude of the injury problems and assist in the identification of priority areas for injury prevention strategies and research (31). The outcome of sport injury research is highly dependent on the selection of research design and methods for collecting and analysing data. Standardised data collection methodologies and definitions, are necessary to improve the comparability and interpretation of published data (7, 31, 32).

5.1 Injury Prevention

Van Mechelen et al. (1992) have proposed a four-step injury prevention model (figure 2). The first step is to establish the extent of the injury problem. Secondly, the aetiology of the sport injuries needs to be identified. The third step is to introduce measures that are likely to prevent these injuries. Finally, the effect of the preventive measures is evaluated by repeating the first step (7).

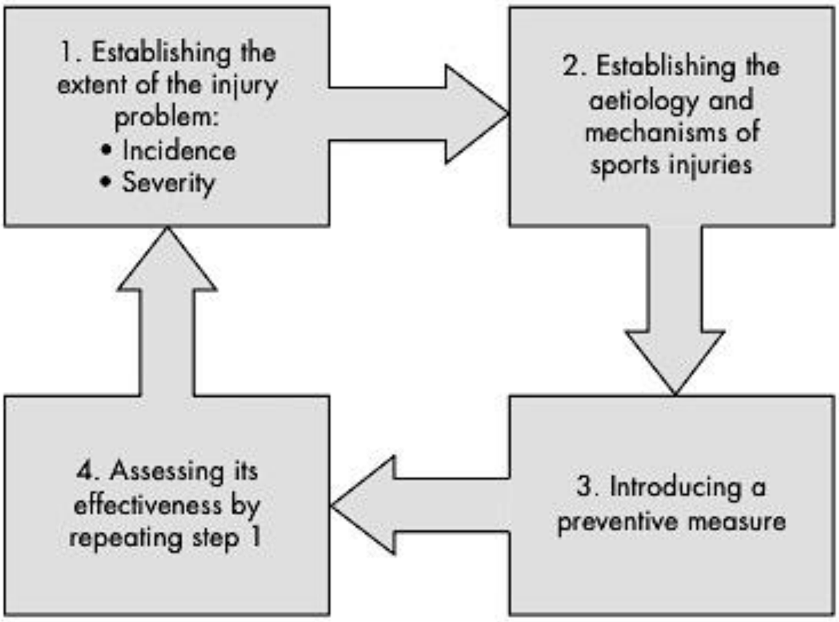

Figure 2: *Four-step injury prevention model described by van Mechelen (1992) (7). The model is retrieved from Bahr&Krosshaug (2005)(33)*

Finch (2006) developed van Mechelen's model further and presented a new framework for injury prevention research, called the "Translating Research into Injury Prevention Practice" (TRIPP) framework. According to Finch (2006), the four-step model of van Mechelen had a number of limitations. The most serious limitation was that it did not consider implementation issues. Once prevention measures have been proven effective, these measures need to be accepted, adopted and complied with by the athletes and the sport bodies they are targeted at (34).

5.2 FIS Injury Surveillance System (FIS ISS)

Prior to the 2006/2007 winter season a injury surveillance system was developed by FIS in collaboration with Oslo Sports Trauma Research Center, with a purpose to monitor injury patterns and trends in the different FIS disciplines (13). A methodological study by Flørenes et al. (2009) found that retrospective athlete interviews with athletes/coaches was the best method to detect injuries sustained during one alpine WC season. This method was compared with prospective registration by team medical staff and prospective reporting by the technical delegate (35). Previous studies have provided information about injury risk and injury patterns among WC competitors in snowboarding and alpine, freestyle and telemark skiing (8, 9, 36-39). No injury recordings have yet been done among sublevel competitors from FIS competitions, such as the FIS alpine EC.

The FIS ISS is also meant to provide background data for in-depth studies of the causes of injury. The ultimate purpose of the injury registration is to reduce the risk of injuries among the athletes by suggesting preventive measures for the future (13).

5.3 Injury definition

Variations in definitions and methodologies create significant differences in results and conclusions obtained from studies of sports injuries. An Injury Consensus Group was therefore established to propose standards for injury definitions and injury collection procedures in studies of injuries football, and provide a basis for injury studies in other sports. The definition of an injury was suggested as: “Any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time loss from football activities”. An injury requiring the player to seek medical assessment or treatment was referred to as medical attention injury, and an injury leading to absence from training or matches as a time-loss injury (40).

In epidemiological studies investigating injuries among competitive alpine skiers, different definitions of injuries have been used. In the FIS ISS, injuries are defined as follows: “all injuries that occurred during training or competition and required attention by medical personnel” (8, 9). Westin et al. (2012) used a similar definition; “an injury that occurred during training or competition, which made it impossible for the skier to participate fully in skiing or physical training not on snow for at least one training session or competition” (41). Hildebrandt et al. (2013) aimed to investigate acute and overuse injuries among young competitive skiers, and their definition of injuries was therefore “all musculoskeletal problems requiring interruption or restriction of normal training and for medical attention” (42). In contrast, Stenroos et al. (2014) reported only acute injuries among Finnish skiers, taking place in alpine skiing competitions or snow training sessions, resulting in a pause from training longer than one week (43).

5.4 Injury incidence

The three most common ways of reporting injuries in epidemiological sports studies are: 1) absolute number of injuries; 2) proportion of injuries; and; 3) incidence of injuries (31). Count data alone in epidemiological studies has very limited utility. Results presented as numbers or proportion of injuries does not take account of different levels of exposures to risk factors. To allow direct comparisons of disease (or injury) frequencies in two or more groups it is necessary to also know the size of the source population from which affected individuals were derived, as well as the time period of which the data were collected (31, 44). Calculation of incidence is frequently used as a measure of disease or injury in epidemiological studies. It is defined as the number of new sports injuries or accidents during a particular period divided by the total number of sports participants at the start of the period. In order to get a precise indication of the true extent of the sport injuries, the incidence needs to be calculated in relation to exposure in days, hours or sport events (7, 44).

Appropriate calculation of measures of disease (or injury) frequency is, as mentioned, the basis for the comparison of diseases or injuries in populations (44). Relative risk, also known as risk ratio (RR), is the most commonly reported result in studies of risk (45). The RR estimates the magnitude of an association of injury incidence between different groups, and indicates the likelihood of sustaining an injury in one group relative to another group. It is defined as the incidence of injuries in one group divided by the corresponding incidence in another group (44). A RR of 1.0 indicates that the risk of injury in the two groups is identical. A value greater than 1.0, indicates a higher risk. If the RR is 3.0, the incidence is estimated to be three times higher in this group, and if the RR is 0.33, the incidence is estimated to be about one third of that in the compared group (44, 46).

5.5 Risk factors and mechanisms of injury

Understanding the causes of injuries is central to advance knowledge, particularly regarding prediction and prevention of sports injuries (47). To establish causes of specific sport injuries, information on why a particular athlete may be at risk in a given situation (risk factors) and how the injuries happen (injury mechanisms) is needed (33). A complete understanding of injury causation needs to address the multifactorial nature of sport injuries. Meeuwisse (1994) proposed a multifactorial model, describing the interaction between different causative factors (Figure 3)(47). Risk factors are often referred to as internal or external. Internal risk factors, such as sex, age, body composition, may influence the risk of sustaining injuries and predispose the athlete to injury. Once the athlete is predisposed, external risk factor (e.g. weather conditions, equipment), may act on the athlete to cause injury. It is the sum of these factors and the interaction between them that make the athlete susceptible for injury. However, the presence of both internal and external risk factors is not always sufficient for injuries to occur. According to Meeuwisse (1994), the final link in the chain of causation is the inciting event related to the injury (47). A precise description of the inciting event is a key component to understand the causes of injuries. The inciting events are often called "injury mechanisms" in epidemiological literature, and these include information about the specific sport situation, athlete behaviour or detailed biomechanical descriptions of joint motion and loads (33).

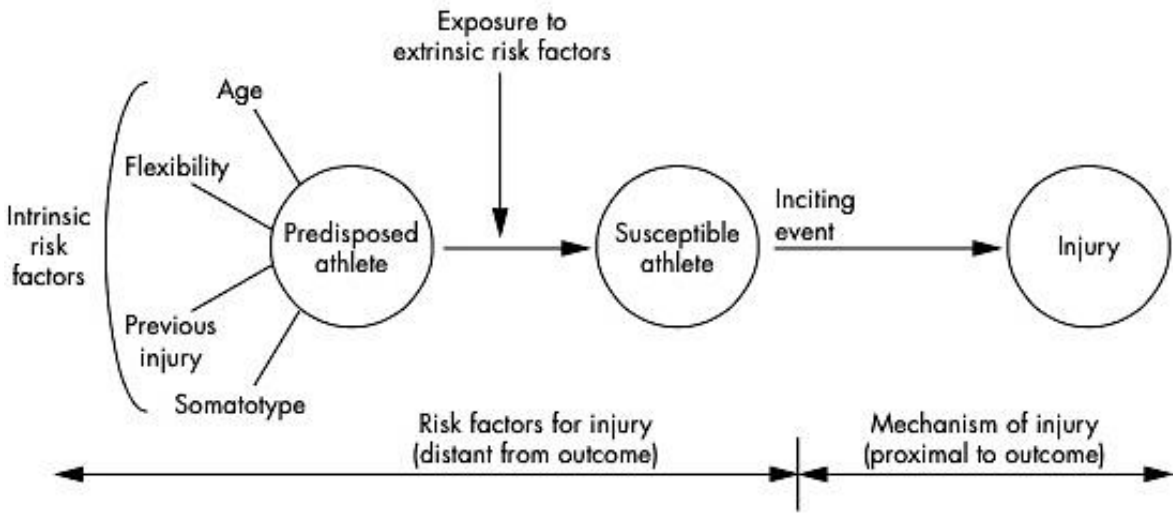

Figure 3: *Model describing the interaction between internal and external risk factors leading to an inciting event and resulting in injury, first described by Meeuwisse (1994)(47). The model is retrieved from Bahr&Krosshaug (2005)(33)*

6. Injuries in Alpine Skiing

6.1 Injury incidence in competitive alpine skiing

In studies of injuries in competitive alpine skiing, different measures of incidence have been used, which makes comparison of the risk of injuries in the different studies challenging (Table 2). Injury incidence among WC alpine skiers has been well established through studies from the FIS ISS (8, 9). The most recent study found an overall injury incidence of 36.2 (95% CI: 33.3-39.2) injuries per 100 athletes per season and 9.3 (8.2-10.5) injuries per 1000 runs. To our knowledge, no studies have previously compared the risk of injuries among alpine WC athletes and EC athletes. A study by Ekeland et al. (1996) reported an incidence of 4.0 injuries per 1000 runs among young competitive skiers participating in the Junior World Championship in Kvitfjell, Norway in 1994 (48). However this was a small, single event study.

A five-year cohort study reported the incidence of injuries among adolescent competitive skiers attending Swedish ski high schools to be 1.7 injuries per 1000 ski-hours and 3.35 injuries per 100 month of studies at the school. They found that 71% of the students reported an on-going injury when entering the study and 48% of the students sustained at least one further injury during the study. In a similar study by Hildebrandt et al. (2013) the total risk of injuries (both traumatic and overuse injuries) was 0.69 (95% CI: 0.41-1.15) among male and 0.63 (95% CI: 0.41-1.03) among female competitive skiers attending an Austrian ski boarding school. The injury risk was expressed as the number of injured athletes divided by the total number of athletes within a two-year study period (42). Stenroos et al. (2014) reported a total of 61 injuries among 661 Finnish competitive ski racers. In this study athletes of all ages were included, but a majority of the athletes (82%) were aged between 9 and 15 years (43).

In a study by Pujol et al. (2007) both alpine WC and EC competitors were included, but were not separated into two distinct groups. The study investigated ACL injuries among competitive skiers from the French national team during a 25-year study period. They found an overall ACL-injury rate of 8.5 per 100 skier-seasons. The injury rates remained constant over time and 19% of the athletes had a reinjury in the same knee. The rate of a primary ACL injury was reported to be highest among the skiers ranked top 30 in the World Cup (49).

In these studies high rates of injuries among competitive alpine skiers have been reported. Because of different definitions in incidence and exposure being used, comparison of injury rates in the different epidemiological studies is difficult. From the studies mentioned, it remains unclear if the injury risk is different among top-level WC skiers and younger sublevel skiers.

Table 2: Epidemiological studies on injury rates in competitive alpine skiing

Reference	Study Design	Population	Injury Definition	Injury Recording	Exposure	Outcome (Injury Rate)
Ekeland et al. (1997)(50)	Retrospective survey	Alpine ski racers competing in the Olympic Winter Games 1994 (n=256)	Previous injuries preventing skiing for at least 20 days	Athlete questionnaire	Not calculated	72% of the 54 respondents (reply percentage only 21%) reported > 1 injury
Stevenson et al. (1998)(51)	Retrospective survey	Members of the Vermont Alpine Racing Association and New England NCAA Division 1 (n=1010)	Injuries to knee(s) occurring on snow while skiing	Athlete questionnaire	Not calculated	27% of the respondents (40% response rate) reported a knee injury.
Bergstrøm et al. (2001)(52)	Prospective survey	Junior alpine racers competing in the Junior World Championship, 1995: 453 girls and 546 boys	Injuries occurring during training or competitions requiring skiers to be transported or treated by the medical team with ISS from 1-75	Questionnaire/Injury reports	Number of started runs	4.0 injuries per 1000 runs
Pujol et al. (2007)(49)	Retrospective survey	379 athletes from the elite French national team, 1980-2005	ACL ruptures	Review of the national database and medical reports from team surgeon	Number of skier seasons	8.5 ACL ruptures per 100 skier-season
Flørenes et al. (2009)(8)	Prospective cohort study	521 athletes from the FIS Alpine World Cup	Injuries occurring during training or competition requiring medical attention	Interviews with athletes and team coaches at the end of the 2006-07 and 2007-08 seasons	Number of athletes and started runs per season	36.7 injuries per 100 athletes per season, 9.8 injuries per 1000 runs
Westin et al. (2012)(41)	Prospective cohort study	431 athletes from Swedish ski high schools	Injuries with absence from at least one training or competition	Monthly reports from athletes by e-mail	Number of skier hours and skier ski months	1.7 injuries per 1000 ski-hours, 3.11 injuries per 100 month studying at the ski high school
Hildebrandt et al. (2013)(42)	Prospective cohort study	104 alpine skiers from a Austrian ski boarding school	Musculoskeletal problems requiring medical attention and interruption/restriction of normal training	Interviews at the end of the winter and summer season from 2009-2011	Not calculated	89 of the 104 skiers reported 235 injuries. 69 skiers reported >1 traumatic injury
Stenroos et al. (2014)(43)	Retrorospective cohort study	661 Finnish competitive ski racers	Acute injuries resulting in a training pause > 1 week	Athlete questionnaire/interviews	Not calculated	61 injuries recorded among 661 ski racers
Bere et al. (2014)(9)	Prospective cohort study	1593 athlete interviews from the FIS Alpine World Cup	Injuries occurring during training or competition requiring medical attention	Interviews with athletes and team coaches at the end of six winter seasons (2006-2012)	Number of athletes and started runs per season	36.2 injuries per 100 athletes per season, 9.3 injuries per 1000 runs

6.2 Injury patterns

Several studies have reported severe injuries of the lower extremity as common among competitive alpine skiers (8, 9, 41-43). Among alpine WC skiers the most commonly injured body part was the knee, which accounted for more than one third of all injuries reported (36-38%) (8, 9). More than half of these injuries were severe, with absence from training or competitions for more than 28 days. The most common injury type was joint- and ligament injuries (44%), followed by fractures and bone stress (19%). A majority of the joint- and ligament injuries were located in the knee (68%), and the most frequent specific diagnose was ACL rupture (8, 9). Similar patterns were found among adolescent (aged 16-19 years) competitive Swedish skiers (41).

Hildebrandt et al. (2013) included both traumatic and overuse injuries in their study. They found that a majority of the injuries were traumatic (58%), and these were more common than overuse injuries (42%). Injuries occurred more frequently during the winter season (71%) than during the summer season (29%). A majority of the traumatic injuries (83%) led to time-loss. Of all traumatic injuries, bone injuries (39%) were more common than ligament injuries (32%). However, in this study, joint- and ligament injuries were separated into two different categories of injury types, and these two together accounted for 40% of the traumatic injuries. A high percentage (96%) of the overuse injuries were muscle- and tendon injuries (42). Stenroos et al. (2014) also reported fractures (n=16) and ligament injuries (n=17) as equally common among young competitive alpine skiers (43).

Results from these studies shows that injury patterns among alpine WC athletes and adolescent competitive skiers are similar. Although, it might seem that bone injuries and fractures are more common among younger athletes.

6.3 Sex differences

There is a controversy regarding sex differences in risk of injury in competitive alpine skiing. Bere et al. (2014) found significant differences in injury rates when comparing injuries among male and female alpine WC athletes. The absolute injury rate was significantly higher among males with 39.7 injuries per 100 athletes per season, compared to females with 31.9 injuries, RR=1.24. Males also had significant higher risk of time-loss injuries than females, RR= 1.23, and a higher risk of injuries per 1000 runs, RR=1.58. There were no differences in incidence of knee injuries in general or ACL-injuries (9). These results are supported by Pujol et al (2007), who found no differences in incidence of ACL injuries between male and female skiers from the elite French national team during a 25-year study period (49). In contrast, Stevenson et al. (1998) found a significant difference in risk of ACL-injuries between competitive female and male skiers from ski clubs in the US. Female skiers were 3.1 times more likely to have sustained an ACL disruption compared to male skiers (51). In these two studies only ACL-injuries were investigated, and not other types of injuries.

Hildebrandt et al. (2013) reported a higher risk of moderate injuries (absence: 7-28 days) among male skiers compared to female skiers (42). Raschner et al. (2012) found a higher risk of ACL injuries among female skiers compared to male skiers, RR=2.3, 95% (53). No other sex differences in injury risk or patterns were detected in studies of injuries among competitive adolescent skier (41, 43).

6.4 Injury incidence in alpine skiing compared with other sports

Two injury surveillance studies reported alpine skiing as one of the winter sports with the highest incidence of injuries during the OWG in Vancouver, 2010 and Sochi, 2014 (54, 55). The incidence of injuries among alpine skiers was 20.7 per 100 athletes during the OWG in Sochi, 2014. Higher incidences of injuries were reported in different disciplines of freestyle and snowboard (24.6-48.8 injuries per 100 athletes), except for snowboard half pipe (18.2 injuries per 100 athletes). Athletes from 22 different winter sports were included in the study (55). Among athletes participating in the Youth Olympic Winter Games in Innsbruck, Austria (2012), alpine skiing was also one of the winter sports with highest incidence of injuries among 17 different winter sports. Similar to the studies from the OWG, the highest incidences were reported in different disciplines of freestyle and snowboard (56).

Flørenes et al. (2012) compared the injury risk between different WC disciplines (alpine skiing, snowboard, freestyle, ski jumping, Nordic combined and cross country skiing) from two winter seasons (2006-2008). They reported significant higher risks of severe injuries (absence >28 days) in alpine skiing, freestyle skiing and snowboard, compared to Nordic combined, ski jumping and cross-country skiing (36).

6.5 Injury risk factors

The knowledge of injury risk factors in competitive alpine skiing is limited. Spörri et al. (2012) conducted interviews with 61 expert stakeholders from the WC ski racing community. The top five categories of injury risk identified from these interviews were: 1) system of ski, binding, plate and boot, 2) changes in snow conditions, 3) physical aspects of the athlete, 4) speed and 5) course setting. According to the experts, the system of ski, binding, plate and boot is too direct in force transmission, too aggressive in ski-snow interaction, and too difficult to get off the edge once the ski is carving. As a result, it is hard for the athlete to control the equipment if he or she gets out of balance. Changing snow conditions requires great effort from the athletes to adapt immediately and is difficult to set up and prepare the equipment for the different conditions. A superior fitness level was suggested by the experts as one of the most important perceived factors for injury prevention. Two problems regarding physical aspects of the skiers were reported: 1) the fitness level of todays athletes reaches physical limitations and cannot be further improved in order to resist the external forces and 2) younger athletes, especially females, are not always sufficiently prepared to enter the WC (57).

Raschner et al. (2012) investigated the relationship between ACL injuries and physical fitness among young competitive alpine skiers during a 10-year study period. They found that core strength was a critical factor for ACL injuries among these athletes (53).

6.6 Injury mechanisms

In a study by Bere et al. (2013) injury mechanisms related to the skier situation, skier behaviour and piste-related factors of 69 injuries occurring in WC races were analysed. In most cases the skier was turning when the injury situation occurred (n=55). The remaining injuries occurred in relation to landing from jumps (n=13) and one from gliding after crossing the finishing line. They found that most of the injuries to the head and upper body (96%) resulted from crashing, while in most of the knee injury situations (83%) the skiers were still skiing. Gate contact contributed to injuries in 21 cases (30%), while six injuries (9%) occurred at contact with the safety nets. The injury risk was increased in the final section of the course. Suggested explanations for this were tiredness and lack of concentration, leading to miscalculations and ski errors (58).

A study by Gilgien et al. (2014) quantified the mechanical characteristics of WC alpine skiing in different disciplines by using differential global navigation satellite technology. These mechanisms were compared with the respective number of injuries per hour skiing. They found that the skiers' mechanical characteristics were significantly different for the specific discipline. In super-G and downhill, injuries might be mainly related to higher speed and jumps, while injuries in the technical disciplines might be caused by the combination of turn speed and turn radius resulting in high loads (59).

In a study by Bere et al (2011), based on video analysis of 20 ACL injury situations among WC skiers, injury mechanisms were classified into 3 main categories: 1) the slip-catch, 2) the dynamic snowplough and 3) the landing back-weighted. The main mechanism appeared to be a "slip-catch situation" where the skier is out of balance backward and inward, loosing pressure on the outer ski. When the outer ski catches the inside edge, the knee is forced into a flexion, internal rotation and valgus position. A similar loading pattern was observed for "the dynamic snowplough", where the skier is out of balance backward with more weight on one ski than the other. This is forcing the skier into a split position where the loaded ski roles from the outside edge of the ski to the inside, leading to internal rotation and valgus position in the knee. In the third category the skier is out of balance backwards in a jump and landing with almost extended knees on the ski tails. In these cases the suggested loading mechanisms was a combination of tibiofemoral compression, boot-induced anterior drawer, and quadriceps anterior drawer (60).

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Article: Injury rate and injury patterns among alpine European Cup athletes: ***Are injury rates and injury patterns different between European Cup and World Cup athletes?***

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Abstract

Background: High risks of injuries have previously been reported among the International Ski Federation (FIS) World Cup (WC) alpine athletes, however limited knowledge exist of injuries among FIS European Cup (EC) athletes.

Objective: To describe the risk of injuries and injury patterns among EC athletes, and compare these data with injury risks and patterns among WC athletes

Methods: Injuries were recorded through the FIS Injury Surveillance System for two consecutive seasons (2013-2015), based on retrospective interviews at the end of each season with athletes from EC and WC teams. All acute training or competition injuries, which required medical attention, were recorded. Race exposure was based on the exact number of started runs in the EC and WC for each of the athletes. Injury incidence was expressed as the absolute injury rate (injuries/100 athletes/season) and as the relative injury rate (injuries/1000 runs).

Results: There were no significant differences in the absolute injury rate, Risk Ratio (RR)=1.01 (95% CI: 0.77-1.31) or the relative injury rate, RR=0.83 (95% CI: 0.55-1.26) between EC and WC athletes. Injury patterns among EC and WC athletes were similar. Time-loss injuries were most common (83%) and the knee was the most commonly injured body part (EC 41%, WC 46%).

Conclusion: This is to our knowledge the first study to provide information of injury incidence among EC alpine athletes. There were no differences in injury risk between EC and WC athletes, and the injury patterns among EC and WC athletes were similar. Prevention efforts should therefor be directed as much towards EC as WC alpine athletes.

Introduction

The FIS WC is the top international circuit of alpine skiing competitions staged annually. Winning the total WC is considered by some experts to be athletically more valuable than winning a gold medal at the Olympic Winter Games (OWG) or the World Ski Championships (WSC) (1). Today, the alpine WC is one of the most popular winter sports with the highest broadcasting time (2).

The FIS Alpine EC is one of the five FIS Alpine Continental Cups. The FIS Continental Cup series serves as qualification for the WC and provides excellent opportunities for up and coming young athletes to gain experience (3). The winners of the different EC events, overall EC winners or best-placed competitors are qualified to compete in the WC races for the following season (4).

Alpine skiing consist of five different disciplines; downhill, super giant slalom (super-G), giant slalom, slalom and super-combined. The super-combined generally consists of a shorter downhill race and a one-run slalom race. Sometimes the downhill is replaced by a super-G race (5).

Previous epidemiological studies have reported a high risk of injuries among alpine competitive athletes (6-10). Three of these studies investigated injuries among adolescent competitive skiers (8-10). Westin et al. (9) found that close to 50% of Swedish adolescent skiers had sustained at least one injury during their study period at a ski high school. Injuries among WC athletes have been recorded through the FIS Injury Surveillance System (FIS ISS) since 2006. The main purpose of the FIS ISS is to monitor injury patterns and trends in the different FIS disciplines, and to provide background data for in-depth studies of the causes of injury. The ultimate purpose of the injury registration is to reduce the risk of injuries among the athletes by suggesting preventive measures for the future (11). High injury risk among alpine WC skiers from six WC seasons (2006-2012) has been reported, with an incidence of 36.2 injuries per 100 athletes per season and 9.3 injuries per 1000 runs. Joint- and ligament injuries of the knee, such as ACL ruptures, were common among both adolescent skiers and alpine WC athletes (6-10).

No previous studies have investigated injuries among alpine EC athletes, thus little is known about injury rates and patterns among these athletes. Systematic injury surveillance among highly competitive young athletes is needed to ensure new knowledge of injury trends and to build the basis for injury prevention (12). The aim of this study was therefore to investigate and describe the injury risk and pattern of injuries among EC athletes, and to compare these data to injuries among top-level athletes from the alpine WC.

Methods

Study design and population

Injuries were recorded through retrospective interviews in the FIS ISS (13) with EC and WC alpine skiers from 19 different nations (Austria, Canada, Croatia, Czech Republic, Finland, France, Great Britain, Germany, Italy, Liechtenstein, Monaco, Norway, Poland, Russia, Slovenia, Switzerland, Slovakia, Sweden, USA) at the end of the 2013/14 and 2014/15 seasons. All included nations had a response rate of >80%. The EC and WC seasons were defined as starting on 1st of November (or from the first EC or WC events of the season if later) and lasting until the interviews took place. The interviews were conducted at the last events of the EC finals in Soldeu, Andorra, at the WC events in Kvitfjell, Norway, and at the WC finals in Lenzerheide, Switzerland and Meribel, France.

Athletes were identified from the FIS website and were included if they had started in at least one EC or WC race in either slalom, giant slalom, super-G, downhill or super-combined in the two seasons. The athlete also had to be confirmed as an official member of the EC or WC team by the team coach. The team coaches reviewed our list of athletes to control and complete the list from their nation. Athletes not defined as being on the EC or WC team by the coaches were excluded from the cohort. Some athletes were defined as being both EC and WC competitors by coaches from their respective nations. The WC cohort has been a stable cohort for 9 years in the FIS ISS compared to the EC cohort with only two years; therefore the athletes were in these cases defined as WC athletes.

Information was sent to the team coaches and athletes by e-mail prior to the events. The purpose and procedures of the interviews was also explained at the team captain's meetings, where head coaches from all nations with athletes competing in the events are required to be present. The head coaches were encouraged to inform the athletes about the interviews. All interviews were conducted in person by physicians or physiotherapists from the Oslo Sports Trauma Research Center (OSTRC). The athlete interviews were recorded in the finishing area during official training or competition, and in some cases during organized meetings at the team's hotels. If an athlete did not understand English or was not present at the event, the team coach, physician or physiotherapist was interviewed. The interviewers filled in a standardized interview form (Appendix 1) for each athlete, where the athlete was asked if they had had any injuries during the 2013/14 and 2014/15 EC or WC season. To facilitate athlete recall of injuries, time-loss due to injury and injury circumstances, a week-by-week calendar of the alpine EC or WC season was included in the interview form. In this form the athlete gave written consent to participate in the FIS ISS. If the athlete did not wish to participate, he or she was omitted from the cohort.

Injury definition

The definition of injury, as well as the classification of the type of injury and body part injured, was based on the consensus statement/document on injury surveillance in football. An injury was defined as: "all injuries that occurred during training or competition and required attention by medical personnel"(14). Training was defined as either activity/training on snow, or other basic training, not on snow. For each injury reported, a separate injury form was filled in. This form included information on body part and side of the body injured, injury type, severity, injury circumstances and specific diagnosis (Appendix 2). The classification of severity of the injuries was defined by the duration of absence from training and competition as follows: slight (no absence), minimal (1 - 3 days), mild (4 - 7 days), moderate (8 - 28 days) and severe (>28 days) (14).

Statistics

To present the extent of injuries among EC and WC athletes, the incidence was expressed as the absolute injury rate (number of injuries per 100 athlete) and relative injury rate (number of injuries per 1000 runs, with their corresponding 95% confidence interval (95% CI). In calculation of the absolute injury rate all injuries recorded throughout the seasons, including injuries from all competitions and training, were included. To calculate exposure information from the FIS website was used to estimate the number of started runs by each athlete. The relative injury rate included injuries from official FIS EC or WC competitions only, since these were the only competitions where it was possible to extract information of runs started in the 2013/14 and 2014/15 season. The calculations were based on the Poisson model, and Z-tests were used to compare injury patterns and incidence between EC and WC athletes. The risk ratio (RR) with 95% CI was computed. An independent t-test was used to analyse differences in mean age between injured EC and WC athletes. A two-tailed p-level of <0.05 was considered significant.

Results

In total 823 interviews of EC and WC alpine athletes were conducted during the 2013/14 and 2014/15 seasons (Table 1). During the two seasons, 299 athletes were interviewed both seasons. Thirty athletes from the EC 2013/14 season were defined as WC athletes the next season (2014/15), and 13 athletes from the WC 2013/14 season were defined as EC athletes in the 2014/15 season.

Table 1: Number of athletes where information was obtained from the athletes in person or from coaches/medical staff and distribution of interviews related to sex

	EC (%)	WC (%)	Total (%)
Interview source			
Athlete	112 (37.2)	182 (34.9)	294 (35.7)
Coach/medical staff	189 (62.8)	340 (65,1)	529 (64.3)
Total	301 (100)	522 (100)	823 (100)
Sex			
Male	169 (56.1)	296 (56.7)	465 (56.5)
Female	132 (43.9)	226 (43.3)	358 (43.5)
Total	301 (100)	522 (100)	823 (100)

Absolute injury rate

A total of 229 injuries (EC: n=84, WC: n=145) were reported. The injured EC athletes were younger (mean age: 21.2, SD: 2.7, range: 17-31) than the injured WC athletes (mean age: 26.3, SD: 4.1, range: 18-37, $p < 0.05$). Time-loss injuries accounted for 85% (n=195) of all injuries registered. The majority of these injuries were moderate (absence 8-28 days) or severe injuries (absence >28 days). There were no significant differences in the absolute injury rate per 100 athletes (Table 2).

Table 2: Absolute injury rates with 95% CI for recorded injuries among EC and WC athletes related to time-loss (severity)

	Incidence (injuries/100 athletes)			Risk Ratio
Absence	**EC**	**WC**	**Total**	**EC vs. WC**
No absence	3.0 (1.0-4.9)	4.6 (2.8-6.4)	4.0 (2.6-5.4)	0.65 (0.30-1.40)
1-3 days	1.3 (0.0-2.6)	2.9 (1.4-4.3)	2.3 (1.3-3.3)	0.46 (0.15-1.40)
4-7 days	2.3 (0.6-4.0)	2.9 (1.4-4.3)	2.7 (1.6-3.8)	0.81 (0.33-1.99)
8-28 days	5.0 (2.5-7.5)	5.0 (3.1-6.9)	5.0 (3.5-6.5)	1.00 (0.53-1.89)
>28 days	15.9 (11.4-20.5)	12.5 (9.4-15.5)	13.7 (11.2-16.3)	1.28 (0.88-1.86)
Total	27.9 (21.9-33.9)	27.8 (23.3-32.3)	27.8 (24.2-31.4)	1.01 (0.77-1.31)

Sex differences

There were no significant sex differences in the EC and WC (Table 3).

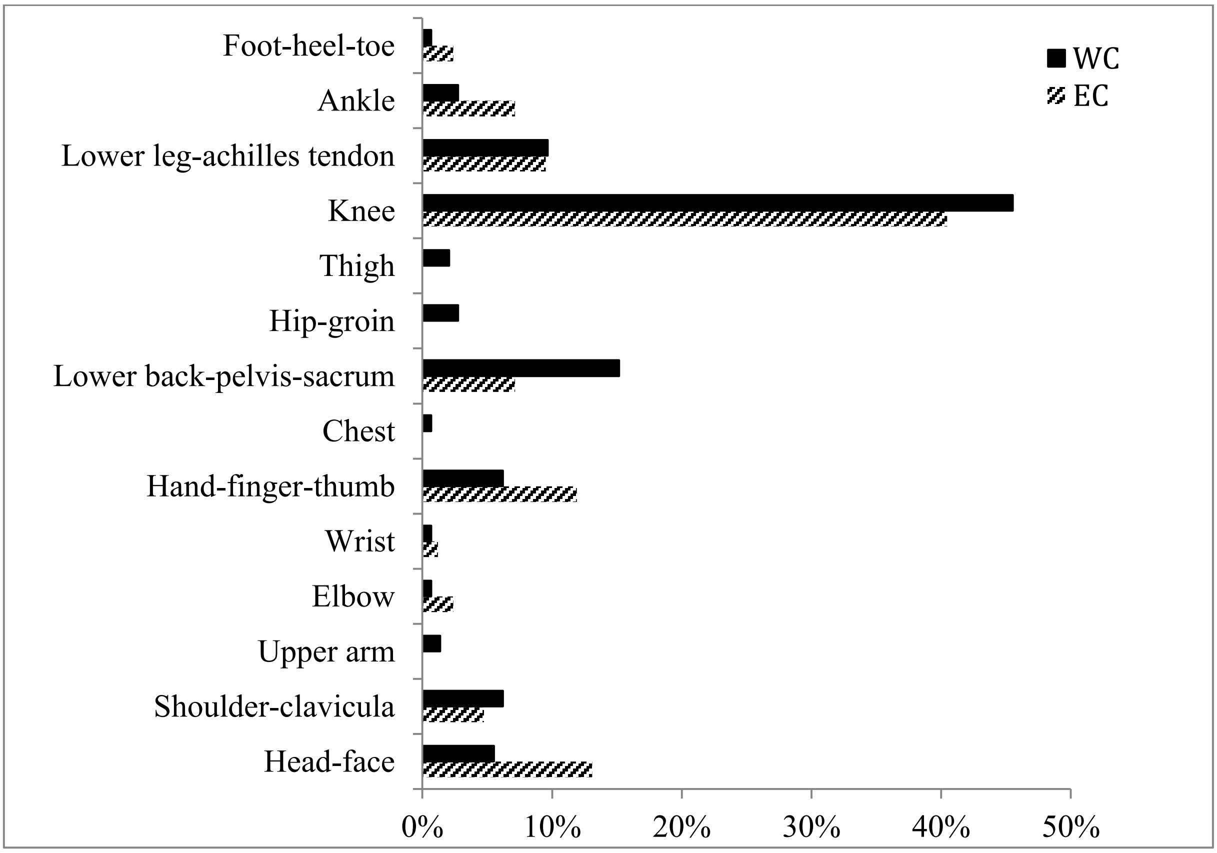
Table 3: Incidence per 100 athletes (with 95% CI) among males and females in the EC and WC with calculations of risk ratio

	EC	**WC**	**Risk Ratio EC vs. WC**
Female	33.3 (23.5-43.2)	27.0 (20.2-33.8)	1.24 (0.84-1.82)
Male	23.7 (16.3-31.0)	28.4 (22.3-34.4)	0.83 (0.57-1.22)
RR female vs. male	1.41 (0.92-2.16)	0.95 (0.68-1.32)	

Body part injured

More than half of all injuries recorded (n= 142, 62%) were located in the lower extremity. The most commonly injured body part among EC and WC athletes was the knee, which accounted for 41% (n=34) of the injuries among EC athletes and 46% (n=66) among WC athletes. Most of these knee injuries (EC n=26, WC n=40) led to time loss >28 days. The second most commonly injured body part among EC athletes was the head/face, which accounted for 13% (n=11) of the injuries in the EC, followed by injuries of the hand/finger/thumb (n=10, 12%). In the WC, the second most common body part injured was the lower back/pelvis/sacrum (n=22, 15%) followed by injuries of the lower leg/achilles tendon (n=14, 10%) (Figure 1). There were no significant differences in absolute injury rate related to body part injured between EC and WC athletes.

Figure 1: Distribution of injuries related to body part among EC and WC athletes expressed as percentage of injuries reported for the EC (n=84) and the WC (n=145)



Injury type

The most common injury type in both the EC and WC were joint/ligament injuries, followed by fractures/bone stress and muscle/tendon injuries (Table 4). There were no significant differences when comparing incidence per 100 athletes between EC and WC athletes related to injury type.

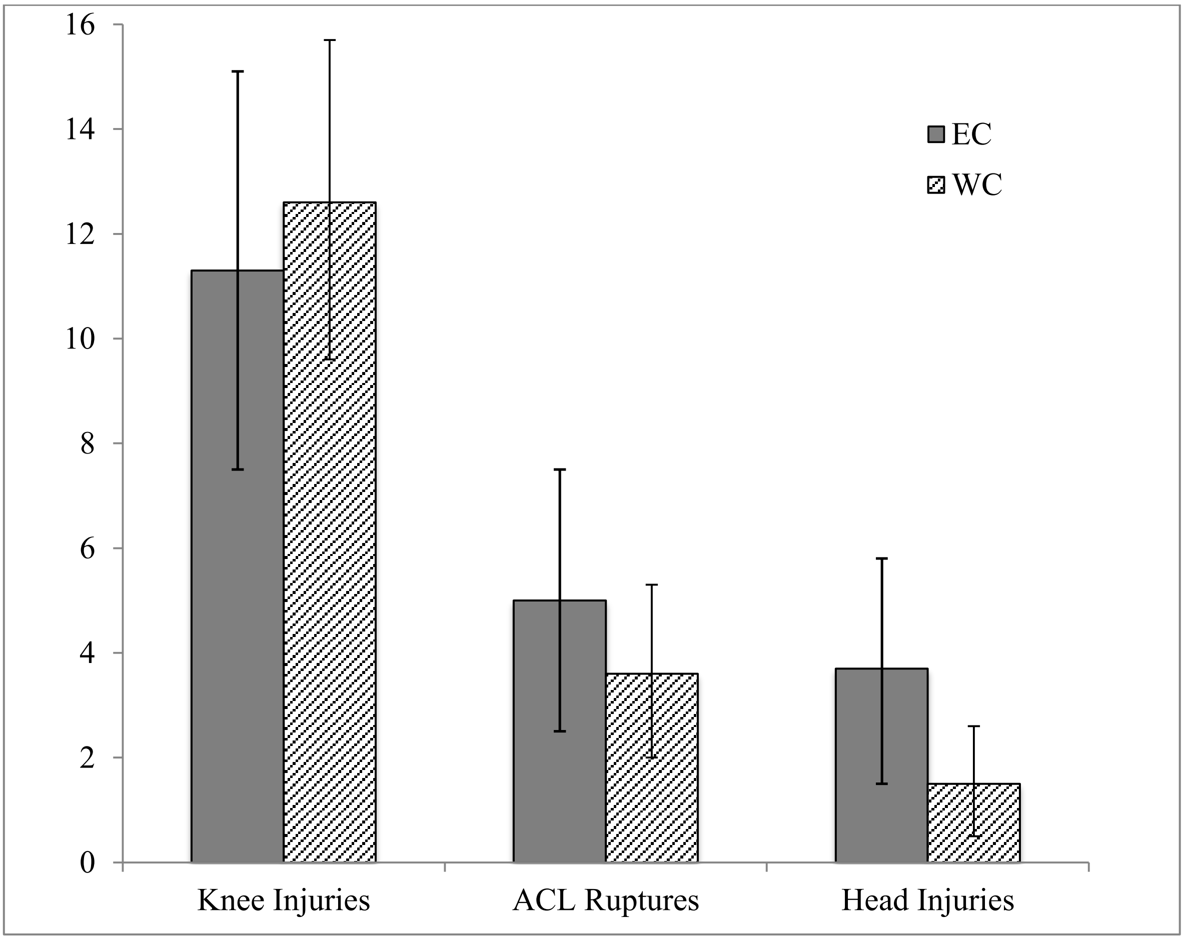
Table 4: All injuries (n=107) recorded among EC and WC athletes related to type of injury

Injury type	EC (%)	WC (%)	Total (%)
Contusions	4 (4.8)	8 (5.5)	12 (5.2)
Fractures and bone stress	20 (23.8)	30 (20.7)	50 (21.8)
Joint (non-bone) and ligament	43 (51.2)	73 (50.3)	116 (50.7)
Laceration and skin lesion	2 (2.4)	3 (2.1)	5 (2.2)
Muscle and tendon	6 (7.1)	23 (15.9)	29 (12.7)
Nervous system including concussion	9 (10.7)	6 (4.1)	15 (6.6)
Other injury type	0 (0.0)	1 (0.7)	1 (0.4)
Total	84 (100)	145* (100)	229* (100)

* No information available on injury type for 1 injury

Most of the joint/ligament injuries (n=73, 63%) were located in the knee (EC n=28, WC n=45). The most common specific diagnosis was ACL rupture (n= 34) followed by concussion (n= 15). Of all knee injuries, 44% (n=15) among EC athletes and 29% (n=19) among WC athletes were ACL ruptures. There were no differences in incidence of knee injuries, RR=0.89 (CI: 0.59-1.35), ACL ruptures, RR=1.37 (CI: 0.70-2.69) or head injuries, RR=2.39 (CI: 0.96-5.93) per 100 athletes between EC and WC athletes (Figure 2).

Figure 2: Knee injuries, total ACL ruptures and head injuries, expressed as injuries per 100 athletes in the EC (knee n=34, ACL n=15, head n=11) vs. WC (knee n=66, ACL n=19, head n=8), with 95% confidence intervals



Among EC athletes, 33 (39%) of the injuries reported occurred during official EC competitions, and 32 (38%) during training activities on snow. One injury was sustained during basic training (not on snow). Seventeen (20%) injuries occurred in other FIS competitions, including WC races. Of the 145 injuries reported among WC athletes, 66 (46%) injuries were sustained during official WC races, OWG or in the WSC, and 67 (46%) during training (4 of these happened in basic training activities not on snow). The remaining injuries (n=12, 8%) occurred during other FIS competitions, such as EC competitions or other FIS races.

Relative injury rate

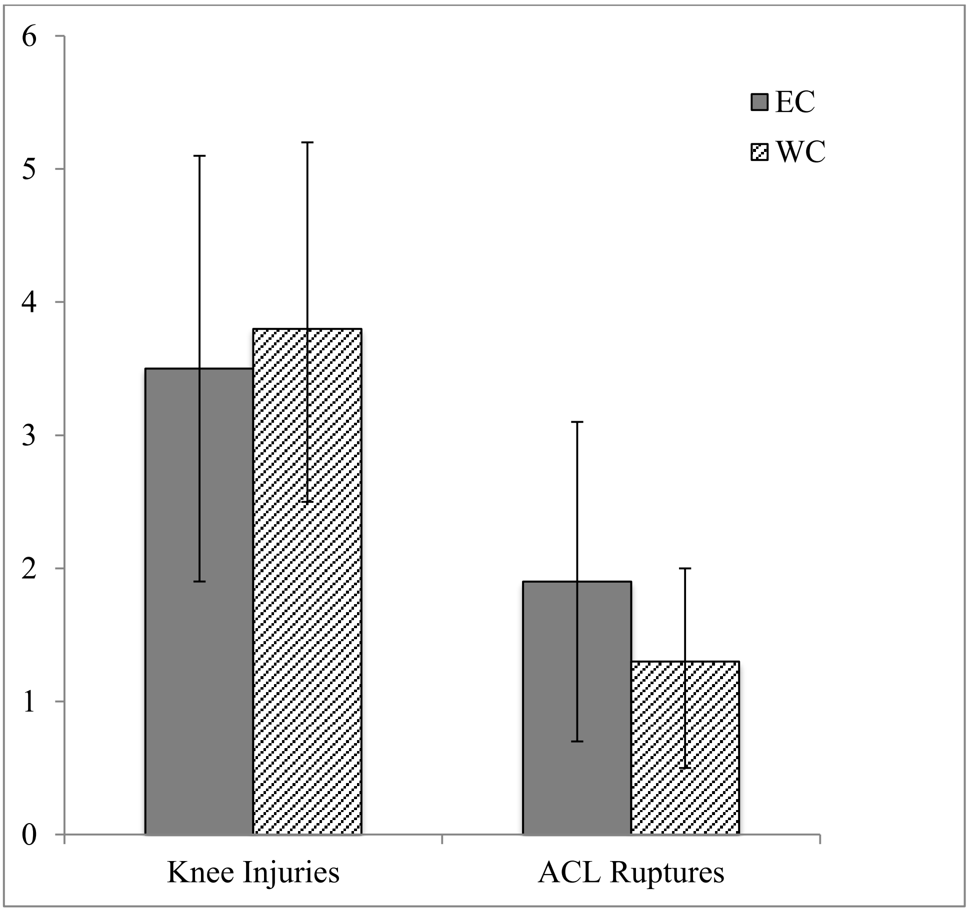
Based on the FIS database, total exposure during EC and WC/OWG/WSC competitions during the 2013/14 and 2014/15 seasons was estimated to be 13751 runs. A total of 99 injuries (43% of all injuries reported) occurred during official EC and WC races. This accounted for 39% of the injuries (n=33) among EC athletes and 46% (n=66) among WC athletes. When comparing disciplines in the EC with the WC, no significant differences were found (Table 5). There was a significantly higher risk of injuries in EC downhill compared to super-G, RR=4.36 (CI: 1.24-15.31), giant slalom, RR=3.10 (CI: 1.42-6.80) and slalom, RR=6.30 (CI: 2.25-17.67). In the WC, a significantly higher risk of injuries was found between downhill and slalom, RR=6.27 (CI=2.72-14.46), super-G and slalom, RR=4.66 (CI: 1.88-11.55) and giant slalom and slalom, RR=4.18 (CI: 1.76-9.95). There were no sex differences in the relative injury rate between EC and WC athletes.

More than half (52%, n=51) of the injuries sustained during EC and WC competitions were knee injuries. ACL ruptures accounted for 56% (n=10) of the knee injuries occurring during competitions among EC athletes and for 33% (n=11) among WC athletes. There were no significant differences in the relative injury rate between EC and WC athletes related to knee injuries or ACL ruptures (Figure 3).

Table 5: Number of injuries (n=99) and exposure (the total number of runs, n=13751) in the different disciplines during EC and WC competitions with calculation of relative injury rate (injuries per 1000 runs)

Discipline	Injuries (n)		Exposure (runs)		Incidence (injuries per 1000 runs)			Risk Ratio
	EC	WC	EC	WC	EC	WC	Total	EC vs. WC
Downhill	13	26	708	1850	18.4 (8.4-28.3)	14.1 (8.7.19.5)	15.2 (10.5-20.0)	1.31 (0.67-2.54)
Super-G	3	14	713	1341	4.2 (-0.6-9.0)	10.4 (5.0-15.9)	8.3 (4.3-12.2)	0.40 (0.12-1.40)
Giant Slalom	12	19	2028	2271	5.9 (2.6-9.3)	8.4 (4.6-12.1)	7.2 (4.7-9.7)	0.71 (0.34-1.46)
Slalom	5	7	1715	3125	2.9 (0.4-5.5)	2.2 (0.6-3.9)	2.5 (1.1-3.9)	1.30 (0.41-4.10)
Total	33	66	5164	8587	6.4 (4.2-8.6)	7.7 (5.8-9.5)	7.2 (5.8-8.6)	0.83 (0.55-1.26)

Figure 3: Knee Injuries and ACL ruptures, expressed as injuries per 1000 runs, among EC athletes (knee n=18, ACL n=10) and WC athletes (knee n=33, ACL n=11), with 95% confidence intervals



Discussion

This is to our knowledge the first study to examine the overall injury pattern and injury incidence among EC alpine athletes. We also compared the injury risk between EC and WC athletes. The main findings were that there were no differences in injury risk and pattern of injuries among EC and WC athletes. The knee was the most commonly injured body part, and a majority of the injuries were moderate or severe injuries (with absence 8-28 days or >28 days).

Incidence

We found that almost one third of EC and WC athletes sustained an injury per season. This is in accordance with previous studies reporting high risk of injuries among WC athletes (6, 7). This is to our knowledge the first study to report high injury incidence among alpine EC athletes. However, previous studies have reported high injury rates among adolescent competitive skiers (8-10). Hildebrandt et al. (2013) found that as much as 66% of all male skiers and 67% of all female skiers attending an Austrian Ski boarding school had sustained at least one traumatic injury during a two-year period (8). Westin et al. (2012) reported similar results among young athletes attending a ski high school in Sweden, where close to 50% of the athletes had sustained at least one injury during their study period (3-4 years) (9). Comparison of injury risk between the different studies is challenging because of the different definitions of injury incidence used. Despite this, the high incidence of injuries among EC athletes reported in the present study, and among young competitive skiers reported in previous studies, emphasizes the importance of injury prevention at an early stage of the ski careers (8-10).

There were no sex differences in injury risk in the current study. Studies have reported similar findings among adolescent male and female competitive skiers (8, 9). In contrast, a significantly higher risk of injuries was reported among male WC athletes compared to female WC athletes (6, 7). We, however, detected no sex differences between male and female WC athletes. Bere et al. (2014) had data from six WC seasons, and therefor might have had more statistical power than the current study (7).

These results may indicate that the injury risk among males increase relative to females with increased level of competition (WC).

Risk factors

Understanding the cause of injuries is central to advance knowledge, particularly regarding prediction and prevention of sports injuries (15). A study comparing injury risk between subelite and elite gymnasts, found a higher injury risk among subelite gymnasts, when considering injuries in relation to training hours (16). The authors suggested lower levels of physical conditioning and technical skills among subelite gymnasts could cause these results. Although comparison of alpine athletes with gymnasts should be carried out with caution, it has been suggested that factors like fitness level and technical/tactical skills of the skier are related to injuries among competitive alpine athletes (17, 18). However, the best WC athletes possess extremely high levels of physical fitness. It has been suggested that the fitness level of today's WC athletes may have reached physical limitations and possibly cannot be further improved in order to resist the outer forces in alpine skiing (18). Physical factors, such as aerobic power and muscle strength, are important in relation to success in alpine skiing (19). It is reasonable to suggest that WC athletes are more physically conditioned and possess better technical skills than EC athletes. Therefore, risk factors related to physical and technical skills, might be more relevant among younger and less experienced athletes. This is supported by a study by Raschner et al. (2012), where poor core strength was reported as a predominant critical factor for ACL injuries among young competitive skiers (20).

Course difficulty, such as challenging course/piste, jumps and course setting were reported as contributing risk factors of ACL injuries among WC alpine skiers (17). WC athletes usually compete in more difficult courses than EC athletes, which means that the courses are normally longer with higher vertical drops and higher speed (5, 21). Thus, WC athletes may have less time to react and adjust to sudden changes in snow- and course conditions. Winning the WC is considered prestigious, which might lead the WC athletes to take high risks in these challenging races (1). However, EC athletes had the same incidence of injuries as WC athletes, despite less challenging and demanding courses in the EC. In our study, the injured EC athletes were younger than the injured WC athletes. Some of the youngest athletes are probably more inexperienced, and may not be fully prepared, technically and physically, for EC competitions. In these competitions, the athletes have to deal with heavier equipment and more challenging courses, than what they may be used to from other FIS races, junior and national competitions (5, 22, 23).

We found that EC and WC athletes had the same risk of injuries. However, it is reasonable to suggest that injury risk among EC and WC might be related to different causes and risk factors. High speed, challenging courses and high risk-taking, might be possible risk factors among WC skiers, while factors, such as experience-level, physical and technical skills, may be more relevant among EC skiers. Other factors, such as, snow- and weather conditions and equipment, concerning both EC and WC athletes, were also suggested as risk factors related to injuries in competitive alpine skiing (17, 18). A complete understanding of injury causation needs to address the multifactorial nature of sport injuries (15). Therefore, all risk factors related to injuries in competitive alpine skiing, such as equipment, physical aspects of the athletes, snow- and weather conditions and course setting, should be considered in prevention of injuries in alpine skiing.

Injury Patterns

We found that more than half of the injuries (62%) were located in the lower extremity. Time-loss injuries accounted for 85% of all injuries, with a majority of moderate or severe injuries. Joint- and ligament injuries were the most common injury type, and 63% of these were located in the knee. These results are in accordance with other epidemiological studies (6, 7, 9, 10) reporting similar injury patterns among competitive alpine skiers.

A high percentage of all knee injuries in our study were ACL ruptures (EC=44%, WC=29%). These results are supported by previous findings, reporting ACL injuries as common among competitive alpine skiers (6, 7, 9, 10, 24). Pujol et al. (2007) reported that about 1/3 of the skiers from the French elite team had sustained at least one ACL injury during a 25 year study period (24). These findings demonstrate that prevention of severe injuries of the lower extremity, like ACL injuries, is essential among competitive alpine skiers.

From systematic video analyses of injuries in WC alpine skiing several mechanisms have been described to cause ACL ruptures, like the slip-catch, landing back-weighted and the dynamic snowplough. Most knee/ACL injuries occurred while the athletes were still skiing, before or without falling (25). Inappropriate technique and strategy were reported as key factors leading to injury situations, where the skier came out of balance backward and/or inwards. Other contributing factors for ACL injuries were related to aggressiveness of skis and/or booths and race conditions, such as small bumps on the course (17). Even though these observations were based on analyses of injuries among WC athletes, it is likely that the same mechanisms for ACL injuries may apply to EC athletes.

Disciplines

In the current study the risk of injuries was significantly higher in downhill compared with the other alpine disciplines among EC athletes. This might be explained by the level of experience of the athletes in the EC, since high-speed training and competitions in maximum speed disciplines are done to a much lesser extent among young athletes (10, 22) These results are supported by findings from Bergstrøm et al. (2001), where a significantly higher rate of injuries was found in downhill compared to the other disciplines among junior alpine skiers during the Alpine Junior Championship in Norway (26).

We found that the risk of injuries among WC athletes was significantly higher in downhill only when compared to slalom. These findings are slightly different from results from a previous study, where the risk of injuries in downhill were reported as significantly higher compared with all of the other disciplines (7). These differences may be caused by low power in the present study, with only few injuries in each discipline. When comparing the injury risk between disciplines, it should be kept in mind that the length of a run varies between disciplines. Although, there is a higher rate of injuries in downhill in both EC and WC, Gilgien et al. (2014) reported that disciplines in WC alpine skiing were equally dangerous per time unit (27).

Methodological Considerations

When using retrospective interviews, recall bias is a challenge, and there might have been a loss of registration of minor injuries. However, retrospective interviews were found to be the best method available to record injuries among skiers and snowboarders. This method was compared with prospective registration by team medical staff and prospective reporting by the technical delegate (13). To facilitate athlete recall of injuries, a week-by-week calendar of the alpine EC or WC season was included in the interview form.

In some cases, athletes were defined as being on both the EC and WC teams by the coaches, and some of the athletes included in this cohort were defined as EC athletes the first season and WC athletes the next season, and opposite for some of the WC athletes. Thus, it was not always possible to separate EC and WC athletes into two distinct groups, and this may cause methodological challenges when comparing injury incidence between these groups. For instance, some EC athletes reported injuries occurring in WC races, and these injuries were not included when calculating injuries per 1000 runs for EC. This could therefore lead to underestimation of the true injury incidence for these athletes.

Another limitation is that exact calculation of exposure was available for WC/OWG/WSC and EC competitions only, and not for training or other competitions. Although, when calculating absolute injury rate (injuries per 100 athletes per season) all injuries occurring during competitions and training are included. Therefore, these two calculations of incidence represent reasonable estimates in injury incidence among EC and WC athletes. The results from this study were based on data from only two EC and WC seasons, and the relatively low number of some injury types makes some of the statistical comparisons challenging.

Conclusion

We found no differences in injury risk between EC and WC alpine athletes, and injury patterns among EC athletes were similar to those among WC athletes. These results emphasize the importance of injury prevention among young elite athletes (EC), and not only among athletes competing at the top level (WC).

What this study adds to existing knowledge

- This is the first study to examine the injury incidence and injury patterns among alpine EC athletes
- There were no differences in risk of injuries between EC and WC athletes
- Injury patterns among EC and WC athletes were similar, with a majority of time-loss injuries. The knee was the most commonly injured body part in both the EC and WC

How might it impact clinical practise in the near future

- Injury prevention strategies should focus on reducing injury incidence among alpine EC athletes as well as WC athletes
- Continued research on injury risk factors and mechanisms among EC athletes is needed. This can be achieved by analysing videos of injury situations among EC athletes.
- Prevention should focus on reducing severe injuries in the lower extremity

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Ethics Approval

The project has been reported to the Regional Committee for Medical Research Ethics, South Eastern Norway Regional Health Authority, Norway and approved by the Social Science Data Services.

Competing Interests

None

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Appendix 1:

Injury Surveillance System - Interview
FIS World Cup Alpine 2014/15
Males

Athlete Name: Athlete : Male: □ Female: □
Nation: Discipline: Trainer:
Contact (e-mail/cell): MD/PT:

Comments	Date	Place	Nation	Discipline	Sex	Category	Injury
						Training	
	26.10.2014	**Soelden**	AUT	Giant Slalom	M	WC	
						Training	
	16.11.2014	**Levi**	FIN	Slalom	M	WC	
						Training	
	26.11.2014	**Lake Louise**	CAN	Downhill training	M	TRA	
Cancelled	27.11.2014	**Lake Louise**	CAN	Downhill training	M	TRA	
Cancelled	28.11.2014	**Lake Louise**	CAN	Downhill training	M	TRA	
	29.11.2014	**Lake Louise**	CAN	Downhill	M	WC	
	30.11.2014	**Lake Louise**	CAN	Super G	M	WC	
						Training	
	02.12.2014	**Beaver Creek**	USA	Downhill training	M	TRA	
	03.12.2014	**Beaver Creek**	USA	Downhill training	M	TRA	
Cancelled	04.12.2014	**Beaver Creek**	USA	Downhill training	M	TRA	
	05.12.2014	**Beaver Creek**	USA	Downhill	M	WC	
	06.12.2014	**Beaver Creek**	USA	Super G	M	WC	
	07.12.2014	**Beaver Creek**	USA	Giant Slalom	M	WC	
						Training	
Repl.: Val d Isere	12.12.2014	**Are**	SWE	Giant Slalom	M	WC	
Repl:: Val d Isere	14.12.2014	**Are**	SWE	Slalom	M	WC	
						Training	
	17.12.2014	**Val Gardena / Groeden**	ITA	Downhill training	M	TRA	
Cancelled	18.12.2014	**Val Gardena / Groeden**	ITA	Downhill training	M	TRA	
Replaces: 20.12.2014	19.12.2014	**Val Gardena / Groeden**	ITA	Downhill	M	WC	
Replaces: 19.12.2014	20.12.2014	**Val Gardena / Groeden**	ITA	Super G	M	WC	
						Training	
	21.12.2014	**Alta Badia**	ITA	GS	M	WC	
	21.12.2014	**Alta Badia**	ITA	Giant Slalom	M	WC	
						Training	
	22.12.2014	**Madonna di Campiglio**	ITA	Slalom	M	WC	
						Training	
	26.12.2014	**Santa Caterina**	ITA	Downhill training	M	TRA	
Cancelled	27.12.2014	**Santa Caterina**	ITA	Downhill training	M	TRA	
	28.12.2014	**Santa Caterina**	ITA	Downhill	M	WC	
						Training	
Cancelled	01.01.2015	**Muenchen**	GER	City Event	M	WC	
						Training	
	06.01.2015	**Zagreb**	CRO	Slalom	M	WC	
						Training	
	10.01.2015	**Adelboden**	SUI	Giant Slalom	M	WC	
	11.01.2015	**Adelboden**	SUI	Slalom	M	WC	

					Training		
	13.01.2015	**Wengen**	SUI	Downhill training	M	TRA	
Cancelled	14.01.2015	**Wengen**	SUI	Downhill training	M	TRA	
	15.01.2015	**Wengen**	SUI	Downhill training	M	TRA	
	16.01.2015	**Wengen**	SUI	Alpine combined	M	WC	
	16.01.2015	**Wengen**	SUI	Downhill	M	COM	
Rescheduled	17.01.2015	**Wengen**	SUI	Slalom	M	WC	
Rescheduled	18.01.2015	**Wengen**	SUI	Downhill	M	WC	
					Training		
	20.01.2015	**Kitzbuehel**	AUT	Downhill training	M	TRA	
Cancelled	21.01.2015	**Kitzbuehel**	AUT	Downhill training	M	TRA	
	22.01.2015	**Kitzbuehel**	AUT	Downhill training	M	TRA	
	23.01.2015	**Kitzbuehel**	AUT	Super G	M	WC	
	23.01.2015	**Kitzbuehel**	AUT	Alpine combined	M	WC	
	24.01.2015	**Kitzbuehel**	AUT	Downhill	M	WC	
	25.01.2015	**Kitzbuehel**	AUT	Slalom	M	WC	
					Training		
Night event	27.01.2015	**Schladming**	AUT	Slalom	M	WC	
					Training		
	03.02.2015	**Vail / Beaver Creek**	USA	Downhill training	M	TRA	
Replaces: 04.02.2015	05.02.2015	**Vail / Beaver Creek**	USA	Super G	M	WSC	
Cancelled	05.02.2015	**Vail / Beaver Creek**	USA	Downhill training	M	TRA	
	06.02.2015	**Vail / Beaver Creek**	USA	Downhill training	M	TRA	
	07.02.2015	**Vail / Beaver Creek**	USA	Downhill	M	WSC	
	08.02.2015	**Vail / Beaver Creek**	USA	Alpine combined	M	WSC	
	08.02.2015	**Vail / Beaver Creek**	USA	Downhill	M	COM	
	10.02.2015	**Vail / Beaver Creek**	USA	Team	A	WSC	
	12.02.2015	**Vail / Beaver Creek**	USA	Giant Slalom	M	FIS	
	13.02.2015	**Vail / Beaver Creek**	USA	Giant Slalom	M	WSC	
	14.02.2015	**Vail / Beaver Creek**	USA	Slalom	M	FIS	
	15.02.2015	**Vail / Beaver Creek**	USA	Slalom	M	WSC	
					Training		
	19.02.2015	**Saalbach**	AUT	Downhill training	M	TRA	
	20.02.2015	**Saalbach**	AUT	Downhill training	M	TRA	
	21.02.2015	**Saalbach**	AUT	Downhill	M	WC	
	22.02.2015	**Saalbach**	AUT	Super G	M	WC	
					Training		
	26.02.2015	**Garmisch Partenkirchen**	GER	Downhill training	M	TRA	
	27.02.2015	**Garmisch Partenkirchen**	GER	Downhill training	M	TRA	
	28.02.2015	**Garmisch Partenkirchen**	GER	Downhill	M	WC	
	01.03.2015	**Garmisch Partenkirchen**	GER	Giant Slalom	M	WC	
					Training		
	05.03.2015	**Kvitfjell**	NOR	Downhill training	M	TRA	
	06.03.2015	**Kvitfjell**	NOR	Downhill training	M	TRA	
	07.03.2015	**Kvitfjell**	NOR	Downhill	M	WC	
	08.03.2015	**Kvitfjell**	NOR	Super G	M	WC	
					Training		
	14.03.2015	**Kranjska Gora**	SLO	Giant Slalom	M	WC	
	15.03.2015	**Kranjska Gora**	SLO	Slalom	M	WC	
					Training		
	17.03.2015	**Meribel**	FRA	Downhill training	M	TRA	
	18.03.2015	**Meribel**	FRA	Downhill	M	WC	
	19.03.2015	**Meribel**	FRA	Super G	M	WC	
	20.03.2015	**Meribel**	FRA	Team	A	NGP	
	21.03.2015	**Meribel**	FRA	Giant Slalom	M	WC	
	22.03.2015	**Meribel**	FRA	Slalom	M	WC	
					Training		

Number of injuries: Number of injury forms:

☐ The athlete has read and understood the Athlete Information form and consents to participate in the FIS Injury Surveillance System

Athlete signature

Appendix 2:

Injury Surveillance Study - World Cup Teams Interview

FIS PARTNER
FIS INJURY SURVEILLANCE SYSTEM

Oslo Sports Trauma

Injury report / *Verletzungsmeldung / Rapport de blessure*

Athlete information/
Informationen zum Athleten/Donnèes sur l'athleète

Name/ *Name/Nom:* ☐

Country/ *Land/Pays:* ☐☐☐

Gender/ *Geschlecht/ Sexe:*
- ☐ Male/ *Mann/Homme*
- ☐ Female/ *Frau/Femme*

Injury information/
Information zur Verletzung/Information sur la blessure

Discipline: ☐

Injury 1 Date of injury: ☐

Body part injured/ *Verletzter Köperteil/Partie du corps blessée:*
- ☐ Head-face/ *Kopf-Gesicht/Tête-Face*
- ☐ Neck-cervical spine/ *Nacken-Halswirbel/Nuque-Vertèbre cervicale*
- ☐ Shoulder-clavicula/ *Schulter-Schlüsselbein/Epaule-Clavicule*
- ☐ Upper arm/ *Oberarm/Bras*
- ☐ Elbow/ *Ellbogen/Coudes*
- ☐ Forearm/ *Unterarm/Avant-bras*
- ☐ Wrist/ *Handgelenk/Poignet*
- ☐ Hand-finger-thumb/ *Hand-Finger-Daumen/Main-Doigt-Pouce*
- ☐ Chest (sternum-ribs-upper back)/ *Brustkasten (Brustbein-Rippen-Brustwirbelsäule)/Thorax (Sternum-Côtes-Haut du dos)*
- ☐ Abdomen/ *Bauch/Abdomen*
- ☐ Lower back-pelvis-sacrum/ *Lendenwirbelsäule-Becken-Kreuzbein/Bas du dos-Pelvis-Sacrum*
- ☐ Hip-groin/ *Hüfte-Leiste/Hanche-Aine*
- ☐ Thigh/ *Oberschenkel/Cuisse*
- ☐ Knee/ *Knie/Genoux*
- ☐ Lower leg-Achilles tendon/ *Unterschenkel-Achillessehne/Jambe-Tendon d'Achille*
- ☐ Ankle/ *Fussgelenk/Cheville*
- ☐ Foot-heel-toe/ *Fuss-Ferse-Zehen/Pied-Talon-Orteils*
- ☐ Information not available/ *Information nicht verfügbar/Information non disponible*

Did you use any protection?
- ☐ Helmet
- ☐ Back/ *Wirbelsäule/Dos*
- ☐ Shoulder/ *Schylter/Epaule*
- ☐ Elbow/ *Ellbogen/Coudes*
- ☐ Wrist/ *Handgelen/Poignet*
- ☐ Hip-pants
- ☐ Knee/ *Knie/Genoux*
- ☐ Leg-shin
- ☐ Teeth
- ☐ Pole-protection
- ☐ Jacket with different protection
- ☐ Other

Circumstances:
- ☐ FIS World Cup/World Championship(WCS)
- ☐ Other FIS competition
- ☐ Other competition
- ☐ Official FIS WC/WCS training
- ☐ Official FIS training
- ☐ Other training activity on snow
- ☐ Basic training, not on snow (weight lifting, running etc.)

Injury type/ *Art der Verletzung/Genre de la blessure:*
- ☐ Fractures and bone stress/ *Frakturen und Ermüdungsbrüche/Fracture et fracture de fatigue*
- ☐ Joint (non-bone) and ligament/ *Gelenke (nicht Knochen) und Bänder/Joint (articulation) et ligament*
- ☐ Muscle and tendon/ *Muskel und Sehnen/Muscle et tendon*
- ☐ Contusions/ *Quetschungen/Contusions*
- ☐ Laceration and skin lesion/ *Fleischwunden und Hautverletzung/Plaie et lésion de la peau*
- ☐ Nervous system including concussion/ *Nervensystem inkl. Gehirnerschütterung/Système nerveux y compris commotion cérébrale*
- ☐ Other/ *Andere/Autres*
- ☐ Information not available/ *Information nicht verfügbar/Information non disponible*

Absence from training and competition/ *Abwesenheit von Training und Wettkämpfen/Absence à l'entrainement et en compétitions:*
- ☐ No absence/ *Keine Absenz/Pas d'absence*
- ☐ 1 to 3 days/ *1 bis 3 Tage/1 à 3 jours*
- ☐ 4 to 7 days/ *4 bis 7 Tage/4 à 7 jours*
- ☐ 8 to 28 days/ *8 bis 28 Tage/8 à 28 jours*
- ☐ >28 days/ *>28 Tage/>28 jours*
- ☐ Information not available/ *Information nicht verfügbar/Information non disponible*

Side/ Seite/Part:
- ☐ Right/ *Rechts/Droite*
- ☐ Left/ *Links/Gauche*
- ☐ Not applicable/ *Nicht anwendbar/Non applicable*

Specific diagnosis/ *Genaue Diagnose/Diagnostic spécifique:* ☐

Please complete page 2/ *Bitte vervollständigen Sie Seite 2/Svp remplir page 2*