OPEN ACCESS

Injuries in elite women's ski jumping: surveillance through the 2017–18 FIS World Cup season

Oleane Marthea Rebne Stenseth [1,2] Sindre Fløtlien Barli [1,2] Richard Kyle Martin,[3] Lars Engebretsen[1,2,4]

► Additional material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bjsports-2019-100799).

[1]Institute of Clinical Medicine, Faculty of Medicine, University of Oslo, Oslo, Norway
[2]Oslo Sports Trauma Research Center, The Norwegian School of Sports Sciences, Oslo, Norway
[3]Department of Orthopedic Surgery and Sports Medicine, Mayo Clinic, Rochester, Minnesota, USA
[4]Orthopaedic Clinic, Oslo University Hospital and University of Oslo, Oslo, Norway

Correspondence to
Oleane Marthea Rebne Stenseth, University of Oslo Faculty of Medicine, Oslo 0806, Norway;
oleanemarthea@gmail.com

Accepted 4 September 2019
Published Online First 16 September 2019

To cite: Stenseth OMR, Barli SF, Martin RK, *et al*. *Br J Sports Med* 2020;**54**:44–49.

ABSTRACT

Objectives To describe the incidence, type, aetiology and severity of injuries sustained by the International Ski Federation World Cup level female ski jumpers during the 2017–18 season.

Design Prospective cohort study.

Methods Sixty-seven female ski jump athletes from 16 countries were followed throughout the 17-week winter season. Preseason baseline demographic data and injury history were recorded via questionnaire. Prospective biweekly reports and retrospective end-of-season interviews provided data on all injuries requiring medical attention.

Results Seventeen injuries were recorded, corresponding to an incidence of 25.4 injuries/100 athletes/season. The incidence of time-loss and severe injuries were found to be 17.9 and 4.5, respectively. The knee was the most common site of injury (4/17; 23.5%). Fourteen injuries occurred on the ski jump hill and crash-landing was the most common mechanism of injury (10/14; 71%). Eighty-five per cent of all moderate and severe injuries occurred in snow or windy conditions. Length of jumps resulting in injury averaged 83.7% (95% CI 72.9% to 94.4%) of hill size. Moderate injuries causing 8–28 days absence from training activities were most common (7/17; 41%) and there were three severe injuries necessitating >4 weeks absence.

Conclusion Injuries among elite female ski jumpers are common and the majority are acute, resulting in time loss from training and competition. The knee was the most common site of injury and poor weather conditions may be a risk factor. Future studies are needed to identify risk factors for injury and to guide injury prevention initiatives.

INTRODUCTION

Ski jumping is a winter sport in the Nordic ski disciplines. In the International Ski Federation (FIS) World Cup (WC) circuit, the jumpers compete on hills of various sizes. Hill size (HS) is defined as the distance from the edge of the take-off table to the end of the landing area (figure 1).[1]

On a normal hill (HS 85–109 m), the speed can range between 85 and 88 km/hour, and the velocity increases up to 25% from the take-off to the landing. Athletes are assessed a score based on a combination of adjustments for weather conditions, speed, jump distance and style points, where flying-style and a telemark landing with one foot in front of the other is rewarded.[2] Out of concern for athlete's safety and injury prevention, event officials aim to prevent jumps that are longer than HS. This is accomplished through indirect adjustments to athlete take-off speed by altering the starting point.[1]

Ski jumping has been practised for centuries and women first started competing in the FIS WC in 2011; women were included in the Winter Olympics for the first time in 2014. For women FIS competitors, the HS (jump distance) is capped at 95% distance of the men's distance on the same hill, due to suspicion from the FIS that women have a higher risk for injuries on the ski jump hill than men. This suspicion is not based on any scientific data and as women's ski jumping is a relatively new sport, there is a paucity of data regarding injury patterns and subsequently no published evidence to support or refute this notion. The FIS Injury Surveillance System (ISS) was introduced in 2006 to monitor injury patterns and trends in the various FIS disciplines and women's ski jumping was included for the 2014–15 winter season.[3]

We aimed to define the incidence of new injuries, both acute and overuse/chronic-overload, which occurred during a single FIS women's ski jumping WC season. Injury type, aetiology and severity, in addition to information regarding athlete injury prevention training were recorded. These data represent the first step in the sequence of injury prevention research and intervention.[4]

METHODS

Study design and definitions

This study incorporates a mixed method research design, combining baseline interviews, prospective biweekly injury registration and a retrospective end-of-season interview to collect injury data. All in-season injuries occurring during training or competition were captured, as well as the baseline questionnaire captured injuries from the 2016–17 season (table 2). Official FIS WC training was considered competition in the registration. An acute injury was defined by the need of immediate medical attention, and an overuse/chronic-overload injury was defined as having not occurred from an inciting event but precluding athlete participation in full training activities. Injury location (body part) and specific injury diagnoses were also registered.

Inclusion criteria

All athletes (≥16 years) who represented their national team in one or more competitions during the 2017–18 FIS WC were invited to participate in the study (n=83).

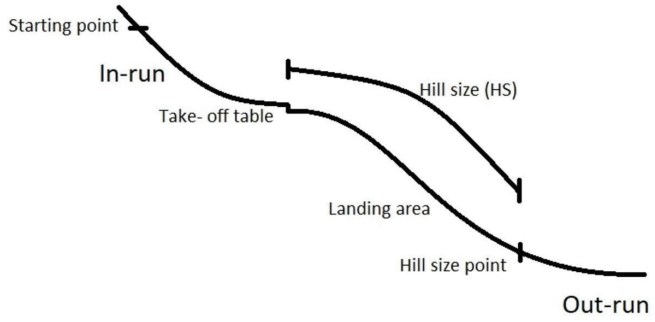

Figure 1 Athletes begin at the top of an in-run and accelerate down to the take-off table where they become airborne. The ski jumpers return to ground in the landing area and decelerate to a stop in the out-run.

Data collection

Study information was presented to head coaches at the first FIS WC competition of the season. Each team appointed a medical doctor/physiotherapist (n=8) or head coach (n=8) as the contact person responsible for reporting injuries. Informed consent was obtained from all study participants. Health information was de-identified using an individual athlete code and athletes remained anonymous throughout the study. Each team was given a series of individual athlete codes kept by the contact person. Individual athletes were not identified by the study investigators other than via their unique code.

Baseline demographic data were collected on written documents at the time of enrolment (online supplementary appendix A). Biweekly standardised injury registration forms (online supplementary appendix B) were sent by email to the contact person for each team throughout the 17-week data collection period (1 December 2017–1 April 2018). Those who failed to respond within 4 days received a reminder. Retrospective interviews were arranged at the end of the season with the athletes to verify in-season reporting and to record information regarding their injury prevention strategies (online supplementary appendix C). In cases where athletes were not present for the retrospective interview, data were collected from the contact person.

Authors OMRS and SFB were responsible for the baseline and the retrospective end-of-season interviews as well as the in-season biweekly injury registrations.

Injury severity

Injury severity was based on time loss from training and competition due to injury. Severe injuries were defined as resulting in >28 days away from full training, moderate between 8–28 days, mild 4–7 days and slight 1–3 days. No time loss (0 days) was also an option, classified as not severe.

Table 2 Injury incidence per 100 athletes per season with 95% CI

	All injuries	Time loss injuries (>1 day absence)	Severe injuries (>28 days absence)
2016–17 season	27.5 (17.0 to 38.0)	20.3 (10.8 to 29.8)	13.0 (5.1 to 20.9)
2017–18 season	25.4 (15.0 to 35.8)	17.9 (8.7 to 27.1)	4.5 (-0.5 to 9.5)

Thirteen athletes reported entering the 2017–18 International Ski Federation season with lingering injuries.

Table 1 Baseline demographic information

Number of athletes (n)	69
Age (years)*	20.7 (3.7)
Height (cm)*	165.3 (6.1)
Weight (kg)*	53.7 (4.6)
Years of ski jumping experience	11.6 (4.3)

*Values are mean (SD).

Statistical analysis

Demographic information are presented as proportions and mean values with SD. All data were registered in an exposure file created with Microsoft Excel software (Microsoft Excel 2016, Microsoft Corporation, Washington, USA). Injury incidences (i) was calculated using the formula i=n/e, where n is the number of injuries and e corresponds to the number of athletes we acquired in-season data from. Risk of injury is presented as absolute injury rates (number of injuries/100 athletes/season). Injury incidences are presented with 95% CIs and CI for one-sample means were based on t-distribution. A percentage of the CI regarding length of jumps resulting in injury was calculated using the average HS in the respective ski jump hills.

RESULTS

Response rate

In total, 83 women's ski jumpers represented their respective national teams throughout the season and were invited to participate in the study. Sixty-nine athletes consented to participate and in-season injury data were acquired for 67 athletes (81%). Twelve of the athletes did not complete the retrospective interview at the end of the season as they were not present at the final WC competitions.

Baseline data and previous-season injury reporting

Baseline demographic information is presented in table 1.

Of the 69 ski jumpers completing the preseason baseline questionnaire, 19 reported having sustained an injury during the season immediately preceding the study period, and none reported multiple injuries. Injury rates are listed in table 2.

2017–18 in-season injury incidence

Thirteen athletes sustained an injury during the 17-week FIS ski jumping season and multiple injuries were reported by three athletes for a total of 17 injury events. This corresponds with an incidence of 25.4 injuries per 100 athletes per season (95% CI 15.0 to 35.8). Most injuries were acute (n=15; 88.2%) compared with overuse/chronic-overload injuries (n=2; 11.8%). Table 3 lists the anatomic location and severity of all recorded injuries.

The 17 injuries led to 22 different diagnoses being made (figure 2). The knee was the most common site of injury (4/17; 23.5%) and three-quarters were ACL ruptures. Most injuries were moderate or severe (59%) and all severe injuries involved the knee. Injuries were reported by medical staff (n=6) athletes (n=4) and coaches (n=3) throughout the season. The athletes who reported injuries did so during the retrospective interview after consulting with their medical doctor/physioterapist.

Aetiology

Eighty-two per cent of all injuries occurred on the ski jump hill (n=14), split between competition (n=5; 36%) and training (n=9; 64%). Crash-landing was the most common mechanism

Table 3 Body location and severity of all injuries

	Not severe (0 days absence)	Slight (1–3 days absence)	Mild (4–7 days absence)	Moderate (8–28 days absence)	Severe (>28 days absence)	Total
Knee	–	–	–	1	3	4
Hip	2	–	–	–	–	2
Ankle	–	1	–	1	–	2
Shoulder/clavicle	1	–	–	1	–	2
Lower leg	–	–	–	2	–	2
Head	–	–	–	1	–	1
Face	1	–	–	–	–	1
Sternum/ribs	1	–	–	–	–	1
Thoracic spine/upper back	–	1	–	–	–	1
Thigh	–	–	–	1	–	1
Total	5	2	–	7	3	17

of injury on the hill (10/14), and adverse conditions on the in-run or out-run were cited as contributing to three injuries. Length of jumps resulting in injury averaged 87.9 m (95% CI 76.6 to 99.2) constituting 83.7% (72.9%–94.4%) of HS on the respective ski jump hills. Only one athlete sustained an injury during a jump that was longer than the HS. One injury was sustained on a large hill while the rest occurred on normal hills. Most of the crashes resulting in injury occurred when athletes were attempting a telemark landing (67%). Eighty-five per cent of all moderate and severe acute injuries occurred in snowing or windy conditions (table 4).

Injury prevention

Of the 57 athletes who completed the end-of-season interview, 52 (91%) stated that they performed specific training exercises with the goal of injury prevention. Reported injury prevention strategies included stability training (65%), lower limb strength training (60%), mobility training (24%) and core strength training (16%). Twenty per cent of the athletes reported regular physiotherapist follow-up, while 11% reported massage as a part of injury prevention. Three athletes reported no injury prevention training and two did not answer the question.

DISCUSSION

This is the first cohort study published in the English-language investigating injuries among elite women's ski jumpers. Nineteen per cent of the participants sustained at least one injury during the 2017–18 FIS WC season, and overall injury risk was 25.4/100 athletes/season. While most injuries resulted in time loss from training or competition, there were relatively few severe injuries necessitating >4 weeks absence.

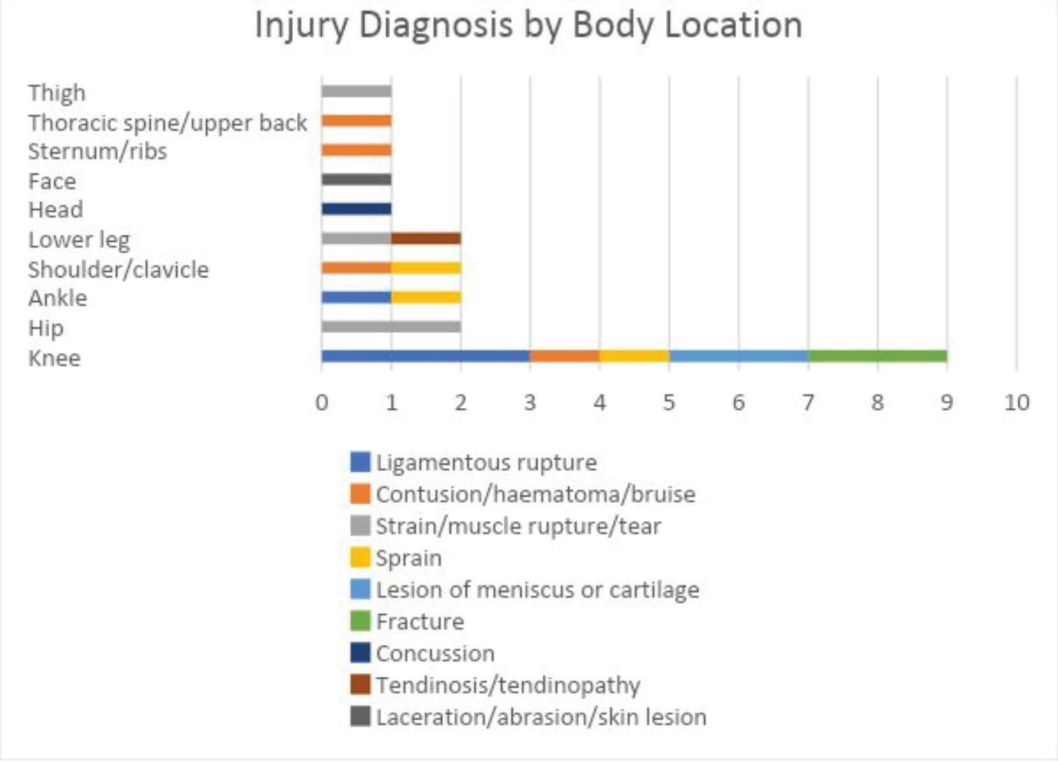

Figure 2 Injury diagnoses by body location.

Table 4 Weather conditions during acute ski jump injuries

	0–7 days (slight/mild)	>8 days (moderate/severe)
Snow/wind	3	6
Clear	3	1

Forty-six per cent (n=6) of the athletes who sustained injuries during the 2017–18 season had also reported an injury during the 2016–17 season. Two of these injuries involved the same body part.

Injury incidence

During a ski jumping career there is a high risk of being injured, but injury fatalities are rare events. The limited published literature suggests that the incidence of injuries has remained stable over the last decade.[5–8] FIS registration including both men's and women's ski jumpers from the 2006 to 2008 seasons describes an injury rate of 21.1/100 athletes/season.[9] In a 2-week survey during the 2014 Winter Olympics, women's ski jumpers reported no injuries but their male counterparts suffered 7.3 injuries/100 athletes.[10] A similar injury incidence was reported in the 2010 Olympics, with 4.5 injuries/100 athletes.[11] Since its inclusion in the FIS ISS in 2014, the incidence of injury in women's ski jumping has fluctuated between 13 and 22 injuries/100 athletes/season. This report is based exclusively on a retrospective interview and suffers from the limitation that it captures relatively few women, which means it likely underestimates true injury incidence. For example, the 2017–18 FIS ISS reports an injury incidence of 13.6 among the women's ski jumping athletes.[3]

Regarding injury severity, previous studies report a slightly lower incidence of time-loss injuries.[3 9] In the FIS survey from 2006 to 2008, the incidence rate of time-loss injuries was found to be 13.6/100 athletes/season, and the injury rate of serious injuries was found to be 5.6/100 athletes/season.[9] According to several studies, time-loss injuries constitute approximately 65% of all injuries recorded,[3 9–11] and severe injuries represent about one-quarter of all injuries.[3 9] Although this study found higher rates of total and time-loss injuries, the rate of severe injuries was found to be lower than previous studies, with 4.5 severe injuries/100 athletes/season (18%). The baseline questionnaire uncovered a much higher rate of severe injuries from the 2016–17 season, but due to the retrospective nature of the data collection and the inclusion of only athletes participating in 2017–18, these data cannot be compared with the current report.

Observed injuries

The knee was the most common site of injury and the most frequent diagnoses were ligamentous ruptures, contusions and sprains. Fractures, concussions and lower extremity injuries are the most commonly reported injuries in the existing literature.[3 9] The incidence of concussions and head injuries appears to have decreased since the 1980s.[3 12 13]

Most injuries occurred on the hill, and crash landing was the most common cause. Poor conditions on the in-run or out-run were the second most common, associated with three knee injuries. The out-run is important for landing and unfavourable conditions may have impaired the athletes' ability to keep their skis steady, leading to injury. Poor weather conditions were not specifically named as a cause of injury, however it is worth noting the majority of severe injuries and 69% of all acute ski jumping injuries occurred in windy and/or snowy conditions. These are important associations that should be explored further and may be useful targets for future injury prevention strategies. Additionally, the degree to which the telemark landing contributed to injuries or helped prevent injuries in our population cannot be determined. Future studies should incorporate video analysis of the injuries to determine if the telemark landing or the binding are contributing to injury.

Sex differences

The injury rates of male and female ski athletes have previously been reported across other ski disciplines but no comparison exists for ski jumping.[14–19] The 2014–18 FIS ISS[3] suggests the overall risk of injury in ski jumping is lower than the other disciplines. Over this time, the gender dominating the annual injury risk has been alternating, but in the 2017–18 season there was a higher incidence for men.[3] During the 2017–18 WC season, the women's HS was limited to 95% of the distance that is used in men's ski jumping. This was implemented due to concern regarding injury risk, which was proposed to be higher for women. The practice of altering rules and regulations for female athletes is not uncommon.[20 21] This study does not directly compare injury rates between the sexes, but suggests that longer jumps may not be associated with more injuries, as most injuries occurred on jumps shorter than HS. The results suggest that women may be safe to jump on the same HS as men in WC competitions, however, larger and longer-term comparative studies are needed to validate this.

Injury prevention

Considering 46% of all athletes who sustained an injury in 2017–18 had also reported an injury during the previous season, the development of a standardised injury prevention programme may be needed. A recent meta-analysis[22] discusses the importance of identifying and correcting at-risk movement patterns and the utility of injury prevention programmes integrated into warm-up routines. Injury prevention programmes have proven effective in various sports[23–25] and can reduce the risk of injury by up to 30%[24] and ACL ruptures by 50%.[26] The programme should be sport specific and modified according to the individual biomechanics and physical demands of the sport.[27] High compliance is essential for maximum benefit.[28]

Most athletes reported specific injury prevention strategies but there was substantial variation in approaches to this aspect of their training. All data regarding injury prevention were individual, and no information regarding team-wide strategies was obtained. Implementing a standardised injury prevention programme for all athletes could improve this variation. A programme designed with specific exercises for ski jumping athletes based on components considered vital in injury prevention training[22 27] should be developed and distributed to all national teams.

Strengths and limitations

This study has several strengths. The high rate of observed injuries indicates this is a topic that warrants attention. This is the most extensive study on injuries among female ski jumpers, and the participants are likely representative of the greater elite women's ski jumping population. Biweekly registrations revealed the majority of the injuries, whereas the retrospective interview minimised the risk of missing injuries. The circumstances surrounding the injuries such as weather and aetiology were recorded, as were injury prevention strategies used by the athletes.

We acknowledge limitations to this study. First, prospective injury surveillance data were obtained for 67 athletes—a response rate of 81%. Language differences combined with

variability in the organisation and structure of the national teams may have limited compliance. The majority of the non-enrolled athletes participated in the WC competitions without direct affiliation to a national team. With no consistent and identifiable contact person, early and ongoing communication regarding the study was therefore limited with those athletes. Second, injury reporting was performed by the coach or injured athlete in many cases. Medical knowledge among these individuals is unknown, and the diagnosis was not independently verified with medical personnel, introducing potential bias. Finally, this observational study was limited to a small number of elite athletes followed over a short time period with no comparison group. This limits the strength of conclusions that may be drawn from the data, and future studies should focus on comparing the reported injury rates with that seen in cohorts of non-elite and male ski jumpers.

CONCLUSION

Injuries among elite female ski jumpers are common and a substantial proportion of these injuries result in time loss from training and competition. The majority of the injuries were sustained on the ski jumping hill and poor weather conditions may be a risk factor. Regarding the injury risk relative to jump distance, most injuries occurred during jumps that were shorter than HS. This is the first study to describe the epidemiology of women's ski jumping injuries and it will be important to continue high-quality injury surveillance for several seasons.

Future studies should focus on mechanism of injury, with injury risk factor identification by video analysis of injuries occurring in competitions. Analysis of differences between male and female ski jumpers in relation to injury rates and mechanisms will contribute to the development of the sport. It will also be important to focus on the implementation and efficacy of evolving injury prevention strategies. Widespread adoption of these programmes may be limited by the fact that several nations do not have a specific medical team due to economic barriers.

What are the findings?

- Elite female ski jumpers sustain acute injuries at a high rate and a significant proportion of the injuries result in time loss from training and competition.
- The knee is the most common site of injury and ACL rupture is the most common diagnosis.
- It is important to continue high-quality injury surveillance for several seasons and future studies should focus on injury mechanism and gender differences in relation to injury rates and mechanism.

How might it impact on clinical practice in the future?

- Women's ski jumping is a relatively new sport and this study represents the first fundamental step in the injury prevention sequence for this population.
- Jumping distances are reduced for women compared with men due to concern for increased injury risk, but the present study suggests longer jumps and larger hill size may not be associated with more injuries.

Acknowledgements The authors would like to thank the International Ski Federation including their ski jump committee, medical committee and Chika Yoshida, Race Director Ladies Ski Jumping, for all practical support. The authors would like to thank the World Cup athletes, coaches and medical team personnel who participated. The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through generous grants from the Royal Norwegian Ministry of Culture, the South-Eastern Norway Regional Health Authority, the IOC and the Norwegian Olympic Committee and Confederation of Sport. The Injury Registration Form was based on the form 'Daily Report on Injuries and Illnesses' created by the IOC.

Contributors OMRS, SFB and LE contributed to project planning. SFB and OMRS contributed to data collection. OMRS, SFB, RKM and LE contributed to manuscript preparations and data analysis. LE is responsible for the overall content as the guarantor.

Funding This study was funded internally by the Oslo Sport Trauma Research Center.

Competing interests None declared.

Patient and public involvement statement Patients were not involved in designing the study.

Patient consent for publication Not required.

Ethics approval The study was approved by the FIS medical committee and reviewed by the South-Eastern Norway Regional Committee for Research Ethics and Norwegian Center for Research Data.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information.

ORCID iDs
Oleane Marthea Rebne Stenseth http://orcid.org/0000-0002-2080-3674
Sindre Fløtlien Barli http://orcid.org/0000-0002-5175-8087

REFERENCES

1. Gasser HH. Standards of the construction of Jumping Hills - 2012 International Ski Federation; 2012. Report No: 1.
2. The International Ski Competition Rules (ICR). Ski jumping, 2018. 2nd Section, 430. Available: www.fis-ski.com
3. Hisdal E, Bahr R. Fis injury surveillance system 2006-2018, 2018. FIS, Fédération Internationale de Ski; Report No: 12. Available: www.fis-ski.com
4. 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.
5. Wester K. Serious Ski jumping injuries in Norway. *Am J Sports Med* 1985;13:124–7.
6. Stillhard A, Buschor C, Krastl G, *et al*. Frequency of injuries, in particular dental injuries, in Ski jumping and Nordic combined. *Swiss Dent J* 2015;125:815–9.
7. Wright RJ. Nordic Ski jumping fatalities in the United States: a 50-year summary. *J Trauma* 1988;28:848–51.
8. Wester K. Improved safety in Ski jumping. *Am J Sports Med* 1988;16:499–500.
9. Florenes TW, Nordsletten L, Heir S, *et al*. Injuries among world cup Ski and snowboard athletes. *Scand J Med Sci Sports* 2012;22:58–66.
10. Soligard T, Steffen K, Palmer-Green D, *et al*. Sports injuries and illnesses in the Sochi 2014 Olympic winter games. *Br J Sports Med* 2015;49:441–7.
11. Engebretsen L, Steffen K, Alonso JM, *et al*. Sports injuries and illnesses during the winter Olympic Games 2010. *Br J Sports Med* 2010;44:772–80.
12. Wright 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;14:393–7.
13. Wright RJ, McIntyre L, Rand JJ, *et al*. Nordic Ski jumping injuries: a survey of active American jumpers. *Am J Sports Med* 1991;19.
14. Florenes TW, Bere T, Nordsletten L, *et al*. Injuries among male and female world cup alpine skiers. *Br J Sports Med* 2009;43:973–8.
15. Johansen MW, Steenstrup SE, Bere T, *et al*. Injuries in world cup Telemark skiing: a 5-year cohort study. *Br J Sports Med* 2015;49:453–7.
16. Major DH, Steenstrup SE, Bere T, *et al*. Injury rate and injury pattern among elite world cup snowboarders: a 6-year cohort study. *Br J Sports Med* 2014;48:18–22.
17. Florenes TW, Heir S, Nordsletten L, *et al*. Injuries among world cup freestyle skiers. *Br J Sports Med* 2010;44:803–8.

18. Bere T, Flørenes TW, Nordsletten L, *et al*. Sex differences in the risk of injury in world cup alpine skiers: a 6-year cohort study. *Br J Sports Med* 2014;48:36–40.
19. Weber CD, Horst K, Lefering R, *et al*. Major trauma in winter sports: an international trauma database analysis. *Eur J Trauma Emerg Surg* 2016;42:741–7.
20. Ice Hockey Australia. *International ice hockey Federation official rule book 2018-2022*, 2018.
21. FoI L. FIL rules 2018. Available: https://filacrosse.com/rules/ [Accessed 14 Feb 2019].
22. Mehl J, Diermeier T, Herbst E, *et al*. Evidence-Based concepts for prevention of knee and ACL injuries. 2017 guidelines of the ligament Committee of the German knee Society (DKG). *Arch Orthop Trauma Surg* 2018;138:51–61.
23. Thorborg K, Krommes KK, Esteve E, *et al*. Effect of specific exercise-based football injury prevention programmes on the overall injury rate in football: a systematic review and meta-analysis of the FIFA 11 and 11+ programmes. *Br J Sports Med* 2017;51:562–71.
24. Sadigursky D, Braid JA, De Lira DNL, *et al*. The FIFA 11+ injury prevention program for soccer players: a systematic review. *BMC Sports Sci Med Rehabil* 2017;9:18.
25. Myklebust G, Engebretsen L, Bråkken IH, *et al*. Prevention of anterior cruciate ligament injuries in female team handball players: a prospective intervention study over three seasons. *Clin J Sport Med* 2003;13:71–8.
26. Donnell-Fink LA, Klara K, Collins JE, *et al*. Effectiveness of knee injury and anterior cruciate ligament tear prevention programs: a meta-analysis. *PLoS One* 2015;10:1–17.
27. Michaelidis M, Koumantakis GA. Effects of knee injury primary prevention programs on anterior cruciate ligament injury rates in female athletes in different sports: a systematic review. *Phys Ther Sport* 2014;15:200–10.
28. Soligard T, Nilstad A, Steffen K, *et al*. Compliance with a comprehensive warm-up programme to prevent injuries in youth football. *Br J Sports Med* 2010;44:787–93.