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Sports injuries and illnesses in the Sochi 2014 Olympic Winter Games

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ABSTRACT

Background Systematic surveillance of injuries and illnesses is the foundation for developing preventive measures in sport.

Aim To analyse the injuries and illnesses that occurred during the XXII Olympic Winter Games, held in Sochi in 2014.

Methods We recorded the daily occurrence (or non-occurrence) of injuries and illnesses (1) through the reporting of all National Olympic Committee (NOC) medical teams and (2) in the polyclinic and medical venues by the Sochi 2014 medical staff.

Results NOC and Sochi 2014 medical staff reported 391 injuries and 249 illnesses among 2780 athletes from 88 NOCs, equalling incidences of 14 injuries and 8.9 illnesses per 100 athletes over an 18-day period of time. Altogether, 12% and 8% of the athletes incurred at least one injury or illness, respectively. The percentage of athletes injured was highest in aerial skiing, snowboard slopestyle, snowboard cross, slopestyle skiing, halfpipe skiing, moguls skiing, alpine skiing, and snowboard halfpipe. Thirty-nine per cent of the injuries were expected to prevent the athlete from participating in competition or training. Women suffered 50% more illnesses than men. The rate of illness was highest in skeleton, short track, curling, cross-country skiing, figure skating, bobsleigh and aerial skiing. A total of 159 illnesses (64%) affected the respiratory system, and the most common cause of illness was infection (n=145, 58%).

Conclusions Overall, 12% of the athletes incurred at least one injury during the games, and 8% an illness, which is similar to prior Olympic Games. The incidence of injuries and illnesses varied substantially between sports.

INTRODUCTION

It is well-established that regular exercise provides a number of significant health benefits, including a reduction in the risk of premature death, as well as non-communicable diseases, such as cardiovascular disease, hypertension, some cancers, obesity and diabetes.[1 2] Increasing the exercise loads and entering the realm of elite sports does not seem to diminish these beneficial health effects. The majority of the available data suggest that compared with age-adjusted controls from the general population, elite athletes benefit from a better life expectancy, lower rates of various diseases, as well as lower hospital admission rates.[3–7] However, at the same time, elite athletes are exposed to a higher risk of acute and chronic musculoskeletal disorders following their sports participation.[5 8–11] In addition, recent studies have documented that athletes' risk of sports-related illnesses is almost equally high.[12–15]

Systematic monitoring of injury and illness trends over long periods of time provides epidemiological data that are invaluable to protect the health of the athletes—one of the main priorities of the International Olympic Committee (IOC).[16] A scientific, evidence-based understanding of incidence rates, characteristics, risk factors and associated mechanisms of injuries and illnesses, across different sports and athlete populations, provides the opportunity not only to enhance the treatment given to the injured or ill athlete, but more importantly, to inform the development and assessment of prevention measures.

Some International Sports Federations (IFs) have instituted comprehensive injury and illness surveillance systems longitudinally or in their main events, and published their results.[14 15 17–50] For the 2008 Olympic Summer Games in Beijing, the IOC convened for the first time a group of experts to develop an injury surveillance system for multisports events,[51 52] and in the Vancouver 2010 Olympic Winter Games the surveillance was expanded to also include illnesses, to account for all health aspects of the elite athlete.[12] The extended approach became the standard and was repeated with success in the London 2012 Olympic Games.[13]

The aim of the present paper is to analyse and describe the injury and illness rates and characteristics in the Sochi 2014 Olympic Winter Games. Practical implications and suggestions for further initiatives and research to protect the athletes' health are provided.

METHODS

We employed the IOC injury and illness surveillance system for multi-sport events in this prospective cohort study.[51] We asked all National Olympic Committee (NOC) medical teams to report the daily occurrence (or non-occurrence) of injuries and illnesses on a standardised medical report form. Concurrently, we retrieved the same information on all athletes treated for injuries and illnesses in the polyclinic and all other medical venues by the Sochi Organising Committee for the 2014 Olympic Winter Games' (Sochi 2014) medical staff.

We used the athlete accreditation number to control for duplicates resulting from athletes being treated for the same condition by the NOC and the Sochi 2014 medical staff. In cases of duplicates, we retained the NOC data.

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Implementation

We informed the NOCs about the study in a letter sent 4 months in advance of the Olympic Games. The day before the opening of the Games we organised a meeting with all NOC medical staff to account for and discuss the study procedures. In this meeting we also started the distribution of the daily injury and illness report forms, as well as an instructional booklet detailing the study protocol.

Throughout the data collection, we recorded the response rate of NOCs having more than 10 participating athletes, and frequently visited these to address any questions and encourage continuous reporting during the games.

Definition of injury and illness

We defined injuries and illnesses as new (pre-existing, not fully rehabilitated conditions were not recorded) or recurring (athletes having returned to full participation after a previous condition) musculoskeletal symptoms or concussions (injuries) or illnesses incurred in competition or training during the Sochi Olympic Games (6–23 February 2014) receiving medical attention, regardless of the consequences with respect to absence from competition or training.[51] In cases where a single incident caused multiple injury types or affected multiple body parts, we recorded only the most severe diagnoses, as determined by our research team.[13] Severe injuries and illnesses were defined as injuries or illnesses entailing an estimated absence from training or competition of more than 1 week.

Injury and illness report form

Our injury and illness record form was identical to the one we used in the 2010 (Vancouver) and 2012 (London) Olympic Games.[12 13] With respect to injuries, we recorded the following information: accreditation number, sport and event, whether the injury occurred in competition or training, date and time, body part, type, cause and estimated time lost from competition or training. Likewise, we recorded the following information for illnesses: accreditation number, sport and event, date, affected system, main symptom(s), cause and estimated time loss.

We provided instructions on how to complete the form correctly in the instructional booklet. Furthermore, we distributed the injury and illness report forms to all NOCs in the following languages: English, French, Chinese, German, Japanese, Russian and Spanish.

Confidentiality and ethical approval

We utilised the athlete accreditation number to query the IOC athlete database for their age, gender and nationality. We treated all information with strict confidence, and anonymised our medical database at the end of the Games.

The study was approved by the medical research ethics committee of the South-Eastern Norway Regional Health Authority.

Data analysis

We calculated the summary measures of injury and illness incidences (i) according to the formula i=n/e, where n is the number of injuries or illnesses in competition, training or in total during the study period and *e* the respective number of exposed athletes; with incidence values presented as injuries/illnesses per 100 athletes. We calculated CIs of the risk ratio (RR) of the number of injuries or illnesses between two groups by a simple Poisson model, assuming constant hazard per group. We present injury and illness incidences as means and RRs with 95% CIs. We regarded two-tailed p values ≤ 0.05 as significant.

RESULTS

In total, 2780 athletes took part in the Sochi Olympic Games. Of these, 1121 were women (40%) and 1659 men (60%). There were eight double-starters, meaning athletes who participated in two different sports, giving a total of 2788 athletes exposed to injury or illness.

Incidence and distribution of injuries

Among these athletes, we recorded a total of 391 injuries, equalling an overall injury rate of 14 injuries (95% CI 12.6 to 15.4) per 100 participating athletes (table 1). This corresponds to 7.8 injuries and 5 illnesses per 1000 athlete-days. On average, 12% (n=330) of the athletes sustained at least one injury. In addition, there were 43 with two, 2 with three, and 1 athlete with four injuries each, respectively.

The rate of injury was highest in aerial skiing (48.8 injuries (95% CI 27.9 to 69.7) per 100 athletes), snowboard slopestyle (37.0 (19.4 to 54.5)), snowboard cross (34.4 (19.7 to 49.2)), slopestyle skiing (30.8 (15.7 to 45.8)), halfpipe skiing (25.5 (11.6 to 39.3)), moguls skiing (24.6 (11.7 to 37.4)), alpine skiing (20.7 (15.7 to 25.7)) and snowboard halfpipe (18.2 (7.9 to 28.5)). The injury rates were lowest in Nordic combined, speed skating, biathlon, ski jumping, cross-country skiing, luge and short track (incidence rates ranging from four to nine injuries per 100 athletes).

The injury rates in female (14.9 injuries (95% CI 12.7 to 17.2) per 100 athletes) and male (13.2 (11.4 to 14.9), RR=1.13 (0.93 to 1.38)) athletes were similar (table 2). However, female athletes were at significantly higher risk of injury in slopestyle skiing (RR=3.00 (1.04 to 8.63)), whereas male were at higher risk of injury in ski jumping (7 vs 0 injuries).

Severity, location and type of injuries

While two-thirds of the injuries were estimated to result in no time loss from sport (n=240, 61%), 39% of the injuries (n=151) were expected to prevent the athlete from participating in competition or training. It was estimated that 18% of the injuries (n=69) would result in an absence from sports from 1 to 3 days, 5% (n=21) in an absence from 4 to 7 days, 6% (n=22) in an absence from 8 to 28 days, and 10% (n=39) in an absence for more than 28 days. Information on severity was missing on one injury.

A total of 61 injuries (16%) were classified as severe and entailed an estimated absence from training or competition of more than 1 week (table 1). These injuries were

- 25 ligament sprains/ruptures, of which 23 affected the knee (five in moguls, four in alpine skiing, four in ice hockey, three in aerial skiing, three in ski cross, two in snowboard cross and one in snowboard slopestyle);
- 14 fractures (three fractures to the foot, hand and finger in ice hockey; three clavicle, forearm and wrist fractures in alpine skiing; two ankle and face fractures in slopestyle skiing; two fractures to the pelvis and wrist in snowboard cross; two clavicle and elbow fractures in Nordic combined; one rib fracture in ski cross; and one rib fracture in ski jumping);
- six contusions, haematomas or bruises (four in snowboard and freestyle skiing);
- two muscle strains (in ice hockey to the groin and lower back);
- two tendon ruptures (to the knee in alpine skiing and thigh in bobsleigh);

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Table 1 Rates of injuries overall, injuries leading to time loss (≥1 day or >7 days of estimated absence), competition and training injuries and illnesses overall in the Olympic sports

		Injuries					
Olympic sport	Athletes (n)	All	≥1 day	>7 days	Competition	Training	All illnesses
Ice sports							
Curling	100	12 (12.0)	1 (1.0)	1 (1.0)	8 (66.7)	4 (33.3)	14 (14.0)
Ice hockey	466	52 (11.2)	25 (5.4)	15 (3.2)	35 (67.3)	16 (30.8)	26 (5.6)
Skating							
Figure	149	20 (13.4)	2 (1.3)	1 (0.7)	2 (10.0)	17 (85.0)	18 (12.1)
Short track	106	9 (8.5)	4 (3.8)	1 (0.9)	7 (77.8)	2 (22.2)	15 (14.2)
Speed	177	8 (4.5)	3 (1.7)	–	2 (25.0)	1 (12.5)	17 (9.6)
Ice track							
Bobsleigh	171	31 (18.1)	5 (2.9)	2 (1.2)	4 (12.9)	27 (87.1)	20 (11.7)
Luge	108	9 (8.3)	1 (0.9)	–	1 (11.1)	8 (88.9)	3 (2.8)
Skeleton	47	5 (10.6)	–	–	1 (20.0)	4 (80.0)	13 (27.7)
Snow sports							
Alpine skiing	314	65 (20.7)	29 (9.2)	12 (3.8)	15 (23.1)	48 (73.8)	27 (8.6)
Freestyle skiing							
Aerials	43	21 (48.8)	6 (14.0)	4 (9.3)	5 (23.8)	16 (76.2)	5 (11.6)
Halfpipe	51	13 (25.5)	6 (11.8)	4 (7.8)	3 (23.1)	10 (76.9)	4 (7.8)
Moguls	57	14 (24.6)	10 (17.5)	5 (8.8)	6 (42.9)	7 (50.0)	1 (1.8)
Ski cross	59	8 (13.6)	6 (10.2)	6 (10.2)	5 (62.5)	2 (25.0)	4 (6.8)
Slopestyle	52	16 (30.8)	6 (11.5)	4 (7.7)	4 (25.0)	12 (75.0)	3 (5.8)
Snowboarding							
Halfpipe	66	12 (18.2)	3 (4.5)	2 (3.0)	5 (41.7)	7 (58.3)	2 (3.0)
Slopestyle	46	17 (37.0)	12 (26.1)	5 (10.9)	4 (23.5)	12 (70.6)	1 (2.2)
Snowboard cross	61	21 (34.4)	10 (16.4)	8 (13.1)	9 (42.9)	11 (52.4)	2 (3.3)
Slalom	64	9 (14.1)	2 (3.1)	2 (3.1)	2 (22.2)	7 (77.8)	1 (1.6)
Nordic skiing							
Biathlon	204	14 (6.9)	5 (2.5)	2 (1.0)	4 (28.9)	10 (71.4)	20 (9.8)
Cross-country skiing	297	23 (7.7)	7 (2.4)	3 (1.0)	9 (39.1)	13 (56.5)	41 (13.8)
Nordic combined	54	2 (3.7)	2 (3.7)	2 (3.7)	1 (50.0)	1 (50.0)	5 (9.3)
Ski jumping	96	7 (7.3)	4 (4.2)	2 (2.1)	2 (28.6)	5 (71.4)	2 (2.1)
Total	2788	391 (14.0)*	151 (5.4)	82 (2.9)	135 (34.5)†	245 (62.7)†	249 (8.9)*

Values presented are numbers (and incidences in brackets) of injured or ill athletes.
*Information on sport/event missing in three injuries and five illnesses.
†Information on training/competition is missing in 11 injuries. Data include eight double-starters.

- two elbow or shoulder dislocations (one each in aerial and slopestyle skiing);
- two lower back muscle cramps or spasms (in biathlon and cross-country skiing);
- one nerve/spinal cord injury to the thoracic spine in ski cross;
- one disc herniation in the lumbar spine in ice hockey;
- one bone bruise injury to the knee in alpine skiing;
- one Achilles tenosynovitis in biathlon; and
- one unclassified injury to the lumbar spine.

Of the 11 reported concussions, three were estimated to lead to more than 7 days of absence (two in halfpipe skiing and one in snowboard slopestyle).

Causes, mechanisms and circumstances of injury

While 81% (n=315) of the injuries were reported to occur acutely, 19% (n=76) were reported to be caused by overuse. The three most commonly reported injury causes/mechanisms were contact with a stationary object (25%), overuse with gradual onset (14%) and non-contact trauma (13%).

Contact with the ground, which includes features built as part of the course, was the most frequent mechanism of injury in ski cross (63%), snowboard slopestyle (59%), snowboard halfpipe (50%), halfpipe skiing (50%), aerial skiing (47%), snowboard slalom (44%), moguls skiing (36%), snowboard cross (33%), and slopestyle skiing (31%), and alpine skiing (26%). Similarly, in ice hockey, contact mechanisms accounted for 77% of the injuries, with contact with another athlete accounting for 40% of the injuries, contact with a moving object accounting for 23% of the injuries, and contact with a stationary object accounting for 13% of the injuries.

Overuse with gradual onset was conversely the most frequent cause of injury in curling (75%), bobsleigh (35%), cross-country skiing (26%) and figure skating (25%). Of all overuse injuries (gradual and sudden onset) occurring in the Games, 75% were recorded with no estimated absence from competition or training.

Of all the injuries, 35% were sustained in competition (8.8 (7.7 to 9.9) injuries per 100 athletes) and 63% during training (4.8 (4.0 to 5.7) injuries per 100 athletes), indicating an 82% higher rate of injury in training (RR=1.82 (1.47 to 2.24)). However, when analysing only the severe injuries, estimated to result in at least 7 days of absence, no difference was found, with competition accounting for 56% of the injuries and training for 42% (RR=0.74 (0.47 to 1.15)). Information on training/competition was missing in 11 injuries.

Injuries in training and in competition differed significantly in characteristics (location, type, mechanism and subsequent time

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Table 2 Rates of injuries overall and injuries leading to time loss (>7 days of estimated absence) in female and male athletes in the Olympic sports

	Female athletes			Male athletes		
Olympic sport	n	All injuries	Time loss >7 days	n	All injuries	Time loss >7 days
Ice sports						
Curling	50	5 (10.0)	1 (2.0)	50	7 (14.0)	–
Ice hockey	168	19 (11.3)	3 (1.8)	298	32 (10.7)	12 (4.0)
Skating						
Figure	74	10 (13.5)	–	75	10 (13.3)	1 (1.3)
Short track	50	3 (6.0)	–	56	6 (10.7)	1 (1.8)
Speed	83	3 (3.6)	–	94	5 (5.3)	–
Ice track						
Bobsleigh	40	9 (22.5)	1 (2.5)	131	22 (16.8)	1 (0.8)
Luge	31	3 (9.7)	–	77	6 (7.8)	–
Skeleton	20	2 (10.0)	–	27	3 (11.1)	–
Snow sports						
Alpine skiing	130	27 (20.8)	4 (3.1)	184	38 (20.7)	8 (4.3)
Freestyle skiing						
Aerials	22	12 (54.5)	2 (9.1)	21	9 (42.9)	2 (9.5)
Halfpipe	23	5 (21.7)	2 (8.7)	28	8 (28.6)	2 (7.1)
Moguls	28	10 (35.7)	4 (14.3)	29	4 (13.8)	1 (3.4)
Ski cross	28	5 (17.9)	4 (14.3)	31	3 (9.7)	2 (6.5)
Slopestyle	22	11 (50.0)	2 (9.1)	30	5 (16.7)	2 (6.7)
Snowboarding						
Halfpipe	27	8 (29.6)	2 (7.4)	39	4 (10.3)	–
Slopestyle	21	7 (33.3)	3 (14.3)	25	10 (40.0)	2 (8.0)
Snowboard cross	23	10 (43.5)	5 (21.7)	38	11 (28.9)	3 (7.9)
Slalom	32	6 (18.8)	2 (6.3)	32	3 (9.4)	–
Nordic skiing						
Biathlon	99	5 (5.1)	–	105	9 (8.6)	2 (1.9)
Cross-country skiing	125	8 (6.4)	2 (1.6)	172	15 (8.7)	1 (0.6)
Nordic combined	–	–	–	54	2 (3.7)	2 (3.7)
Ski jumping	30	–	–	66	7 (10.6)	2 (3.0)
Total	1126	168 (14.9)*	37 (3.3)	1662	219 (13.2)*	44 (2.6)

Values presented are numbers (and incidences in brackets) of injured or ill athletes.
*Unknown gender for four injuries. Data include eight double-starters.

loss from sport) and in terms of rates in different sports (table 1). The rate of injury was higher in training than in competition in aerial skiing (RR=3.20 (1.17 to 8.74)), alpine skiing (RR=3.20 (1.80 to 5.71)), bobsleigh (RR=6.75 (2.36 to 19.29)), figure skating (RR=8.50 (1.96 to 36.80)) and luge (RR=8.00 (1.00 to 64.00)). When including only injuries estimated to result in at least 7 days of absence, the higher injury rate in training was seen only in alpine skiing (RR=11.0 (1.42 to 85.20)).

Ice hockey was the sole sport in which the competition injury rate was higher than the training injury rate (RR=0.48 (0.25 to 0.83)), a difference which increased when isolating the injuries estimated to result in more than 7 days of absence (RR=0.15 (0.04 to 0.68)).

Incidence and distribution of illnesses

Among the 2788 exposed athletes, a total of 249 illnesses were reported, resulting in an incidence of 8.9 illnesses (95% CI 7.8 to 10.0) per 100 athletes (table 1). On average, 8% (n=229) of the athletes incurred an illness, as there were nine athletes with two illnesses each. Female athletes (10.9 illnesses (9.0 to 12.9) per 100 athletes) were at significantly higher risk of contracting an illness than male athletes (7.3 (6.0 to 8.6), RR=1.5 (1.17 to 1.93)).

Illnesses were reported in a variety of sports. Skeleton was the sport with the highest illness rate (27.7 illnesses (95% CI 12.6 to 42.7) per 100 athletes), followed by short track (14.2 (7.0 to 21.3)), curling (14.0 (6.7 to 21.3)), cross-country skiing (13.8 (9.6 to 18.0)), figure skating (12.1 (6.5 to 17.7)), bobsleigh (11.7 (6.6 to 16.8)) and aerial skiing (11.6 (1.4 to 21.8)) (table 1). The illness rates were lowest in snowboard slalom, moguls skiing, ski jumping, snowboard slopestyle, luge, snowboard halfpipe and snowboard cross (incidence rates ranging from 1 to 4 illnesses per 100 athletes).

Affected system, causes and severity of illness

A total of 159 illnesses (64%) affected the respiratory system, and these were most frequently reported in skeleton (21% of the athletes), cross-country skiing (10%), curling (8%), biathlon (8%), bobsleigh (8%), short track (7%) and Nordic combined (7%). The second, third, fourth and fifth most frequently affected systems were the digestive system (n=28, 11%), nervous system (n=13, 5%), skin and subcutaneous tissue (n=12, 5%) and genitourinary system (n=9, 4%), respectively.

Infection was the most common cause of illness (n=145, 58%), affecting athletes in mainly the same sports as mentioned above. Of the 159 respiratory illnesses, 118 (74%) were caused by an infection.

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One in four illnesses (n=63, 25%) were expected to result in absence from training or competition. Of these, two illnesses (1%) were expected to result in an estimated time loss of more than 7 days (one upper respiratory tract infection; and one illness affecting the nervous system).

Rate of response, injury and illness per NOC size

Thirty-four of the 88 NOCs had more than 10 participating athletes. Athletes from these NOCs comprised 2623 of the in total 2779 athletes competing for an NOC, corresponding to 94% (table 3). Throughout the 18 days of the Sochi Games, the 34 NOCs submitted a total of 610 of a maximum of 612 forms (99.7%).

Only 17% of the injuries and 2% of the illnesses were captured by both the NOCs and the Sochi 2014 staff. While 49% of the injuries and 68% of the illnesses were recorded solely by the NOCs, 34% and 30% of the injuries and illnesses, respectively, were recorded only by the Sochi 2014 staff.

Whereas the majority of injured and ill athletes from the larger NOCs were seen internally by the NOC medical staff, athletes from smaller NOCs were to a greater extent relying on diagnosis and treatment from the Sochi 2014 medical staff (table 3).

There was also an inverse relationship between NOC size (measured in number of participating athletes) and the risk of health problems, with athletes from smaller NOCs experiencing higher injury and illness rates (NOCs with <10 athletes: 30.1 (21.5 to 38.7) injuries and 14.1 (8.2 to 20.0) illnesses per 100 athletes versus NOCs with >99 athletes: 10.5 (9.0 to 12.0) injuries and 8.1 (6.8 to 9.4) illnesses per 100 athletes, injury RR=2.87 (2.08 to 4.00), illness RR=1.74 (1.11 to 2.73)).

DISCUSSION

The aim of the present paper was to describe and analyse the injury and illness rates and characteristics in the Sochi 2014 Olympic Games. The main findings of this 18-day long prospective cohort study were that 12% and 8% of all the 2780 athletes suffered from at least one injury or illness, with overall rates of 14 injuries and 8.9 illnesses per 100 athletes, respectively. The magnitude and characteristics of the injuries and illnesses varied substantially between sports and gender.

While the highest injury rates were found in snow sports characterised by aerial manoeuvers and high-speed, namely aerial skiing (49% of all athletes injured), snowboard slopestyle (37%), snowboard cross (34%), slopestyle skiing (31%), halfpipe skiing (26%), moguls skiing (25%), alpine skiing (21%), and snowboard halfpipe (18%), the highest rates of illness were found in ice sports such as skeleton (28%), short track (14%), curling (14%), figure skating (12%), bobsleigh (12%), as well as in cross-country skiing (14%).

Injury rates in the Olympic sports

The overall rate of injury in the Sochi Games was similar to those in Beijing 2008, Vancouver 2010 and in London 2012 (12% of all athletes injured in Sochi vs 11% in Vancouver and London, and 10% in Beijing).[12 13] Compared to their Vancouver Winter Games counterparts, higher injury rates were found in the Sochi Games athletes competing in aerial skiing (49% vs 19% of the athletes injured), alpine skiing (21% vs 15%), biathlon (7% vs 1%), cross-country skiing (8% vs 3%), curling (12% vs 4%), luge (8% vs 2%), moguls skiing (25% vs 2%), skeleton (11% vs 6%), snowboard halfpipe (18% vs 13%), and snowboard slalom (14% vs 7%). Conversely, lower injury rates were found among the Sochi Games athletes competing in ice hockey (11% vs 18%), short track (9% vs 18%) and ski cross (14% vs 19%). In general, our findings on the sports-specific injury rates in Sochi are corroborated by a large body of research from the Fédération Internationale de Ski (FIS) World Cup, where snowboard cross and halfpipe,[47] aerial and halfpipe skiing and ski cross,[42] as well as particularly downhill of the alpine skiing events[41 46] have been identified as disciplines with a higher rate of injury.

A change in injury incidence can be the result of changes in the composition of the Olympic Games programme (eg, 12 new events introduced in Sochi), environmental factors, such as weather, snow or ice conditions, venue or track design, competition rules, in equipment or other factors. Changes in injury rates can also follow an increased or reduced awareness among the athletes and their medical staff in recognising and reporting even minor incidents (broad injury and illness definition applied in IOC surveillance studies). In certain sports, changes may also be attributable to more comprehensive and accurate data reporting by team physicians who over time have been trained as

Table 3 Response rates, injuries and illnesses in NOCs of different sizes (measured by number of athletes)

	<10	10–49	50–99	>99	All
NOCs (athletes)	54 (156)	12 (258)	10 (622)	12 (1743)	88 (2779*)
Injuries (injuries per 100 athletes)	47 (30.1)	67 (26.0)	93 (15.0)	183 (10.5)	390† (14.0)
Illnesses (illnesses per 100 athletes)	22 (14.1)	44 (17.1)	42 (6.8)	141 (8.1)	249 (9.0)
Report forms submitted‡ (%)	–	216 (100.0)	178 (98.9)	216 (100)	610 (99.7)
Recorded by both NOC and OCOG					
Injuries	9 (19.1)	11 (16.4)	14 (15.1)	34 (18.6)	68 (17.4)
Illnesses	1 (4.5)	–	1 (2.4)	2 (1.4)	4 (1.6)
Recorded only by NOCs					
Injuries	6 (12.8)	27 (40.3)	50 (53.8)	107 (58.5)	191 (49.0)
Illnesses	3 (13.6)	24 (54.5)	31 (73.8)	112 (79.4)	170 (68.3)
Recorded only by OCOG					
Injuries	32 (68.1)	29 (43.3)	29 (31.2)	42 (23.0)	132 (33.8)
Illnesses	18 (81.8)	20 (45.5)	10 (23.8)	27 (19.1)	75 (30.1)

*1 Independent Olympic Athlete and eight double-starters excluded.
†NOC is missing for 1 injury.
‡Countries with less than 10 athletes were excluded from the response rate analysis.

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injury and illness recorders through the implementation of surveillance systems by their own Federation. Also, rate differences (lower or higher) may simply be the result of a natural fluctuation/variability of athlete's exposure to risk, an observation that emphasises the value of on-going surveillance to monitor trends over time, for example, the effect of venue design, rule or equipment changes in the period between major sports events.

Severity, location and type of injuries

In major sports events, like the Olympic Games, injuries or illnesses of even minor severity and time loss have the potential to be participation-limiting and performance-inhibiting, and thus prevent athletes from reaching their life-time achievement. In the Sochi Games, 61% of the injuries were reported to lead to no absence from competition or training, whereas 39% were estimated to result in time loss of at least 1 day. However, 16% of the injuries were estimated to encompass time loss greater than 7 days. This may indicate a shift from the Vancouver Games, where 23% of the injuries were expected to entail a time loss of at least 1 day, and just 4% a time loss of more than 7 days; however, this is uncertain, as there was a high percentage of missing data on injury severity in Vancouver.[12] These results warrant a more extensive recording and detailed analysis of injury risk factors and mechanisms, to improve injury prevention in the future.

The risk of concussion is a recurrent concern in certain sports, and its diagnosis, prevention, treatment and return-to-play guidelines have been addressed in recent consensus meetings.[53 54] Eleven concussions were recorded in Sochi (0.4% of the athletes) which is half of the 20 concussions (0.8%) reported in Vancouver. This is higher than the rates reported from the Summer Olympics in London (n=6, 0.06% of athletes) and Beijing (n=12, 0.11%), although these rates are not directly comparable due to the different nature of the sports and events.

Causes, mechanisms and circumstances of injury

The causes, mechanisms and circumstances of injuries in competition and training differed significantly between the different sports. With 63% of the injuries occurring during training and only 35% in competition, the findings differ from those in the Vancouver Games, where the distribution was relatively even (54% vs 46%, respectively).[12]

It can, however, be hypothesised that winter sports athletes suffer a slightly higher proportion of injuries in training, whereas their summer sports counterparts sustain more injuries in competition, but more data is needed to confirm this.[13 22 36–38 42 47 52] Ice hockey was the only sport on the Sochi Olympic programme in which the majority of injuries occurred in competition, an effect which was even greater when including only the injuries estimated to result in more than 7 days of time loss. These results correspond with earlier epidemiological findings.[55–59] Ice hockey is a team and contact sport, where the intensity, speed of play, number of body checks and fatigue are considerably higher in games—where more is at stake—than in training, where a significant amount of time is used for recovery and training drills of lower intensity.

The majority of injuries in Sochi were reported to be acute, whereas overuse injuries with either a gradual or sudden onset accounted for about one-fifth of the injuries. Similar distributions have been reported from the summer and winter Olympic Games previously[12 13 52]; however, these numbers should be interpreted with caution, due to the current limitations in the recording of overuse injuries.[60–63]

Illness risk during the Olympics

The rate of illness in the Sochi Games was similar to those reported in the Vancouver Games and London Games (8% of all athletes affected in Sochi vs 7% in Vancouver and London).[12 13] Also consistent with the Vancouver and London data is the difference in the incidence of illnesses between female and male athletes, with female athletes in Sochi contracting 50% more illnesses than male athletes. The same disproportion has previously been reported in the 2009 athletics[37] and aquatics[39] world championships, but not in the 2011 athletics world championships,[38] in the 1994–2009 US Open tennis championships,[64] or in the Summer Paralympic Games.[14]

The high incidence of respiratory infections mirrors data from other elite sport events.[14 15 22 37–39 64–69] Predominant risk factors are mechanical and dehydration stresses generated within the airways and the level of airborne pollutants, irritants and allergens inhaled by the athlete under high ventilatory exercise conditions.[70] Earlier it has been reported that airway hyperresponsiveness/asthma is one of the most common chronic medical conditions in winter and summer elite sports, especially among endurance athletes.[71] Team physicians can anticipate that athletes travelling intercontinentally are at higher risk of illness,[67] but that these illnesses can be mitigated through careful planning and diagnostic work prior to the Games.[72]

Methodological considerations

In studies on sports injury, it is usually recommended to express incidences using a measure of time exposed to risk as the denominator.[14 15 35 73 74] However, considering the inherent complexity and size of the Olympic Games, this was not feasible in the present study. Instead, we expressed the incidence of injury or illnesses by means of absolute risk: the number of new cases per 100 registered athletes. This approach erroneously assumes that the frequencies and lengths of exposure are identical in all sports and that the number of athletes at risk in each NOC is constant throughout the Games, and interpretation of differences in injury incidences or patterns should therefore be made with caution.

In the current study we defined injuries and illnesses as new or recurring injuries or illnesses receiving medical attention, regardless of the consequences with respect to absence from competition or training. By using such a definition, predominantly the moderate and severe acute injuries will be recorded. The less serious injuries may be overlooked, since such injuries do not always require medical attention,[75 76] albeit our results show that the majority of reported injuries were not estimated to involve any absence from the sport. In the Olympic Games, all athletes can get healthcare through the athletes' village polyclinic and the venue medical clinics. However, the availability, size and quality of the NOCs own medical teams vary between countries, meaning that not all athletes benefit from identical healthcare, which may bias the injury and illness recording.

Throughout the 18 days of data collection in the Olympic Games, we collected 99.7% of all the NOC injury and illness report forms. This is the highest NOC response rate to date in the Olympic Games injury and illness surveillance, a result which can be attributed to favourably disposed NOC medical staff, an informational meeting with all NOCs the day before the Games' opening, the preparation of report forms in seven languages and an instructional booklet on how to fill in the forms, and a dedicated and increasingly experienced research team which conducted frequent follow-up visits to boost NOCs' compliance. However, although the NOC response rate was

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excellent, we did not test the accuracy and internal validity of their reported data. Thus, we cannot evaluate the extent to which the NOC data match the actual circumstances of the occurred injury or illness. Furthermore, it has been documented earlier in professional alpine skiing[43] and male elite football[77] that prospective injury surveillance by team medical staff underestimates the incidence of injuries and time-loss injuries. Our results support these findings, as the NOC medical teams failed to report 34% and 30% of the total reported injuries and illnesses, respectively.

The same result demonstrates how recording data both among NOC medical staff and in the organising committee's medical stations is absolutely vital to the scientific quality of the surveillance study. A mere 17% of the injuries and 2% of the illnesses were captured by both recorder groups. Our study also shows that in particular athletes from smaller NOCs benefit from diagnosis and treatment from the local organising committee's medical staff, whereas the majority of athletes from larger NOCs are seen by their own NOC medical staff. More importantly, we identified an inverse relationship between NOC size and the risk of health problems, with athletes from the smallest NOCs experiencing an almost threefold injury rate and twofold illness rate compared with the largest NOCs. It is difficult not to see this finding in light of distinct differences in resources available to the NOC. Large delegations usually come from countries with well-developed exercise physiology and sports medicine communities, and are generally able to offer their athletes more comprehensive healthcare and closer medical follow-up in the lead up to and during the Games, potentially giving them a competitive advantage.

Practical implications

The epidemiology of injuries in the Sochi and Vancouver Olympic Games[12] and the FIS World Cup[42 44 47 49] has demonstrated a high risk of severe injuries in many of the snowboarding and freestyle skiing events. Likewise, in recreational freestyle skiing and snowboarding, it has been found that the rate of severe injuries, in the form of spine and head injuries, is double inside terrain parks compared with outside.[78] Furthermore, it has recently been demonstrated that a preponderance of the injuries occur in jumps, kickers and the halfpipe, in other words, in features that facilitate aerial manoeuvers.[45 48 79 80] In order to mitigate the risk of these injuries, we need more refined data on their sport-specific risk factors and mechanisms. Our data, although crude, show that a large proportion of the injuries are caused by contact with the ground (or other stationary objects attached to it).[12] It has been shown that the magnitude of impact risk can be characterised by the equivalent fall height, a measure of jumper impact velocity normal to the slope.[81 82] By employing jump design algorithms taking the equivalent fall height into account, the landing impact from aerial manoeuvers and thus the risk of injury can be minimised.[82–86]

The IOC is currently developing a customised electronic medical record (EMR) for the Rio 2016 Games and beyond to replace the medical encounter system used by the local organising committees since the Barcelona 1992 Games. The implementation of the EMR will not only improve the healthcare provision in the Olympic and Paralympic Games, but also provide a number of new opportunities for recording of injuries and illnesses in a confidential manner. With time, NOC physicians and physiotherapists will be able to record their daily injury and illness data, feeding into the same EMR database, possibly rendering the IOC paper record forms obsolete. Data privacy will evidently be of high importance, with data accessible strictly to authorised users. In the long term, our aim is to invite NOCs to use the same EMR in their daily medical follow-up of their athletes in between the Games. An electronic injury and illness surveillance will also facilitate advances in the quality and usefulness of the data that we capture. For example, one will be able to record risk factors and mechanisms that are specific to each sport and event, which will significantly improve our ability to subsequently ideate and tailor injury prevention initiatives.

The continuously accumulating evidence that injury and illness rates vary substantially between sports demonstrates the need for tailoring preventive measures to the specific context of each sport. Sport bodies such as the IOC, International Paralympic Committee (IPC), IFs and NOCs have the responsibility to protect the health of their athletes. The Olympic Movement Medical Code encourages all stakeholders to take measures to ensure that sport is practised with minimal risks of physical injury and illness or psychological harm.[87] For IFs, a critical component of this responsibility is the implementation of a scientifically sound injury and illness surveillance system in all major events. Some sports federations, such as FIFA (Fédération Internationale de Football Association), FINA (Fédération Internationale de Natation), FIS, FIVB (Fédération Internationale de Volleyball), IAAF (International Association of Athletics Federations), IIHF (International Ice Hockey Federation), WR (World Rugby) and UEFA (Union of European Football Associations) have put increasing effort into working systematically and scientifically to protect their athletes' health. We encourage other IFs and sports organisations to follow their example.

CONCLUSION

In summary, 12% of the athletes incurred an injury and 8% suffered from at least one illness during the Sochi Olympic Winter Games. The incidences and characteristics of injuries and illnesses in training and competition varied substantially between sports and gender. Future initiatives will include the recording of sport-specific injury and illness risk factors and mechanisms, to better inform the development of tailored prevention measures targeting the athlete at risk.

Contributors All authors contributed to the study conception and design, data collection and interpretation. TS analysed the data and drafted the paper. All authors provided revisions and contributed to the final manuscript. TS is the guarantor.

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REFERENCES

1 World Health Organization. *Global recommendations on physical activity for health*. WHO.http://www.who.int/dietphysicalactivity/publications/9789241599979/en/ (accessed 29 Sep 2014).
2 Centers for Disease Control and Prevention. Physical activity and health—the benefits of physical activity. http://www cdc gov/. http://www.cdc.gov/physicalactivity/everyone/health/index.html (accessed 28 Aug 2014).
3 Teramoto M, Bungum TJ. Mortality and longevity of elite athletes. *J Sci Med Sport* 2010;13:410–16.
4 Sarna S, Sahi T, Koskenvuo M, *et al*. Increased life expectancy of world class male athletes. *Med Sci Sports Exerc* 1993;25:237–44.
5 Kujala UM, Sarna S, Kaprio J, *et al*. Hospital care in later life among former world-class Finnish athletes. *JAMA* 1996;276:216–20.
6 Clarke PM, Walter SJ, Hayen A, *et al*. Survival of the fittest: retrospective cohort study of the longevity of Olympic medallists in the modern era. *BMJ* 2012;345:e8308.
7 Zwiers R, Zantvoord FW, Engelaer FM, *et al*. Mortality in former Olympic athletes: retrospective cohort analysis. *BMJ* 2012;345:e7456.
8 Drawer S, Fuller CW. Propensity for osteoarthritis and lower limb joint pain in retired professional soccer players. *Br J Sports Med* 2001;35:402–8.
9 Drawer S, Fuller CW. Evaluating the level of injury in English professional football using a risk based assessment process. *Br J Sports Med* 2002;36:446–51.

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10 Lohmander LS, Östenberg A, Englund M, *et al*. High prevalence of knee osteoarthritis, pain, and functional limitations in female soccer players twelve years after anterior cruciate ligament injury. *Arthritis Rheum* 2004;50:3145–52.
11 Poratvon A, Roos EM, Roos H. High prevalence of osteoarthritis 14 years after an anterior cruciate ligament tear in male soccer players: a study of radiographic and patient relevant outcomes. *Ann Rheum Dis* 2004;63:269–73.
12 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.
13 Engebretsen L, Soligard T, Steffen K, *et al*. Sports injuries and illnesses during the London Summer Olympic Games 2012. *Br J Sports Med* 2013;47:407–14.
14 Schwellnus M, Derman W, Jordaan E, *et al*. Factors associated with illness in athletes participating in the London 2012 Paralympic Games: a prospective cohort study involving 49,910 athlete-days. *Br J Sports Med* 2013;47:433–40.
15 Derman W, Schwellnus M, Jordaan E, *et al*. Illness and injury in athletes during the competition period at the London 2012 Paralympic Games: development and implementation of a web-based surveillance system (WEB-IISS) for team medical staff. *Br J Sports Med* 2013;47:420–5.
16 International Olympic Committee. *Olympic Charter—the organisation, action and operation of the Olympic Movement*. IOC. http://www.olympic.org/Documents/olympic_charter_en.pdf (accessed 7 2014).
17 Bahr R, Reeser JC. Injuries among world-class professional beach volleyball players. The Federation Internationale de Volleyball beach volleyball injury study. *Am J Sports Med* 2003;31:119–25.
18 Junge A, Dvorak J, Graf-Baumann T, *et al*. Football injuries during FIFA tournaments and the Olympic Games, 1998–2001: development and implementation of an injury-reporting system. *Am J Sports Med* 2004;32:80S–9S.
19 Junge A, Dvorak J, Graf-Baumann T. Football injuries during the World Cup 2002. *Am J Sports Med* 2004;32:23S–7S.
20 Dvorak J, Junge A, Grimm K, *et al*. Medical report from the 2006 FIFA World Cup Germany. *Br J Sports Med* 2007;41:578–81.
21 Junge A, Dvorak J. Injuries in female football players in top-level international tournaments. *Br J Sports Med* 2007;41(Suppl 1):i3–7.
22 Dvorak J, Junge A, Derman W, *et al*. Injuries and illnesses of football players during the 2010 FIFA World Cup. *Br J Sports Med* 2011;45:626–30.
23 Best JP, McIntosh AS, Savage TN. Rugby World Cup 2003 injury surveillance project. *Br J Sports Med* 2005;39:812–17.
24 Fuller CW, Laborde F, Leather RJ, *et al*. International Rugby Board Rugby World Cup 2007 injury surveillance study. *Br J Sports Med* 2008;42:452–9.
25 Taylor AE, Fuller CW, Molloy MG. Injury surveillance during the 2010 IRB Women's Rugby World Cup. *Br J Sports Med* 2011;45:1243–5.
26 Fuller CW, Sheerin K, Targett S. Rugby World Cup 2011: International Rugby Board injury surveillance study. *Br J Sports Med* 2013;47:1184–91.
27 Hägglund M, Waldén M, Bahr R, *et al*. Methods for epidemiological study of injuries to professional football players: developing the UEFA model. *Br J Sports Med* 2005;39:340–6.
28 Waldén M, Hägglund M, Ekstrand J. UEFA Champions League study: a prospective study of injuries in professional football during the 2001–2002 season. *Br J Sports Med* 2005;39:542–6.
29 Waldén M, Hägglund M, Ekstrand J. Football injuries during European Championships 2004–2005. *Knee Surg Sports Traumatol Arthrosc* 2007;15:1155–62.
30 Ekstrand J, Hägglund M, Waldén M. Injury incidence and injury patterns in professional football—the UEFA injury study. *Br J Sports Med* 2011;45:553–8.
31 Hägglund M, Waldén M, Ekstrand J. UEFA injury study—an injury audit of European Championships 2006 to 2008. *Br J Sports Med* 2009;43:483–9.
32 Hägglund M, Waldén M, Magnusson H, *et al*. Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med* 2013;47:738–42.
33 Webborn N, Willick S, Reeser JC. Injuries among disabled athletes during the 2002 Winter Paralympic Games. *Med Sci Sports Exerc* 2006;38:811–15.
34 Webborn N, Willick S, Emery CA. The injury experience at the 2010 winter paralympic games. *Clin J Sport Med* 2012;22:3–9.
35 Willick SE, Webborn N, Emery C, *et al*. The epidemiology of injuries at the London 2012 Paralympic Games. *Br J Sports Med* 2013;47:426–32.
36 Alonso JM, Junge A, Renstrom P, *et al*. Sports injuries surveillance during the 2007 IAAF World Athletics Championships. *Clin J Sport Med* 2009;19:26–32.
37 Alonso JM, Tscholl PM, Engebretsen L, *et al*. Occurrence of injuries and illnesses during the 2009 IAAF World Athletics Championships. *Br J Sports Med* 2010;44:1100–5.
38 Alonso JM, Edouard P, Fischetto G, *et al*. Determination of future prevention strategies in elite track and field: analysis of Daegu 2011 IAAF Championships injuries and illnesses surveillance. *Br J Sports Med* 2012;46:505–14.
39 Mountjoy M, Junge A, Alonso JM, *et al*. Sports injuries and illnesses in the 2009 FINA World Championships (Aquatics). *Br J Sports Med* 2010;44:522–7.
40 Feddermann-Demont N, Junge A, Edouard P, *et al*. Injuries in 13 international Athletics championships between 2007–2012. *Br J Sports Med* 2014;48:513–22.
41 Flørenes TW, Bere T, Nordsletten L, *et al*. Injuries among male and female World Cup alpine skiers. *Br J Sports Med* 2009;43:973–8.
42 Flørenes TW, Heir S, Nordsletten L, *et al*. Injuries among World Cup freestyle skiers. *Br J Sports Med* 2010;44:803–8.
43 Flørenes TW, Nordsletten L, Heir S, *et al*. Recording injuries among World Cup skiers and snowboarders: a methodological study. *Scand J Med Sci Sports* 2011;21:196–205.
44 Flørenes TW, Nordsletten L, Heir S, *et al*. Injuries among World Cup ski and snowboard athletes. *Scand J Med Sci Sports* 2012;22:58–66.
45 Bakken A, Bere T, Bahr R, *et al*. Mechanisms of injuries in World Cup Snowboard Cross: a systematic video analysis of 19 cases. *Br J Sports Med* 2011;45:1315–22.
46 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.
47 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.
48 Randjelovic S, Heir S, Nordsletten L, *et al*. Injury situations in Freestyle Ski Cross (SX): a video analysis of 33 cases. *Br J Sports Med* 2014;48:29–35.
49 Steenstrup SE, Bere T, Bahr R. Head injuries among FIS World Cup alpine and freestyle skiers and snowboarders: a 7-year cohort study. *Br J Sports Med* 2014;48:41–5.
50 Tuominen M, Stuart MJ, Aubry M, *et al*. Injuries in men's international ice hockey: a 7-year study of the International Ice Hockey Federation Adult World Championship Tournaments and Olympic Winter Games. *Br J Sports Med* 2015;49:30–6.
51 Junge A, Engebretsen L, Alonso JM, *et al*. Injury surveillance in multi-sport events: the International Olympic Committee approach. *Br J Sports Med* 2008;42:413–21.
52 Junge A, Engebretsen L, Mountjoy ML, *et al*. Sports injuries during the Summer Olympic Games 2008. *Am J Sports Med* 2009;37:2165–72.
53 McCrory P, Meeuwisse W, Johnston K, *et al*. Consensus Statement on Concussion in Sport: the 3rd International Conference on Concussion in Sport held in Zurich, November 2008. *Br J Sports Med* 2009;43(Suppl 1):i76–90.
54 McCrory P, Meeuwisse WH, Aubry M, *et al*. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Br J Sports Med* 2013;47:250–8.
55 Stuart MJ, Smith A. Injuries in Junior A ice hockey. A three-year prospective study. *Am J Sports Med* 1995;23:458–61.
56 Molsa J, Airaksinen O, Nasman O, *et al*. Ice hockey injuries in Finland. A prospective epidemiologic study. *Am J Sports Med* 1997;25:495–9.
57 Pinto M, Kuhn JE, Greenfield ML, *et al*. Prospective analysis of ice hockey injuries at the Junior A level over the course of one season. *Clin J Sport Med* 1999;9:70–4.
58 Benson BW, Meeuwisse WH, Rizos J, *et al*. A prospective study of concussions among National Hockey League players during regular season games: the NHL-NHLPA Concussion Program. *CMAJ* 2011;183:905–11.
59 McKay CD, Tufts RJ, Shaffer B, *et al*. The epidemiology of professional ice hockey injuries: a prospective report of six NHL seasons. *Br J Sports Med* 2014;48:57–62.
60 Clarsen B, Rønsen O, Myklebust G, *et al*. The Oslo Sports Trauma Research Center questionnaire on health problems: a new approach to prospective monitoring of illness and injury in elite athletes. *Br J Sports Med* 2014;48:754–60.
61 Bahr R. No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. *Br J Sports Med* 2009;43:966–72.
62 Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. *Br J Sports Med* 2013;47:495–502.
63 Clarsen B, Bahr R. Matching the choice of injury/illness definition to study setting, purpose and design: one size does not fit all! *Br J Sports Med* 2014;48:510–12.
64 Sell K, Hainline B, Yorio M, *et al*. Illness data from the US Open Tennis Championships From 1994 to 2009. *Clin J Sport Med* 2013;23:25–32.
65 Al-Shaqsi S, Al-Kashmiri A, Al-Risi A, *et al*. Sports injuries and illnesses during the second Asian Beach Games. *Br J Sports Med* 2012;46:780–7.
66 Ruedl G, Schobersberger W, Pocecco E, *et al*. Sport injuries and illnesses during the first Winter Youth Olympic Games 2012 in Innsbruck, Austria. *Br J Sports Med* 2012;46:1030–7.
67 Schwellnus MP, Derman WE, Jordaan E, *et al*. Elite athletes travelling to international destinations >5 time zone differences from their home country have a 2–3-fold increased risk of illness. *Br J Sports Med* 2012;46:816–21.
68 Schwellnus M, Derman W, Page T, *et al*. Illness during the 2010 Super 14 Rugby Union tournament—a prospective study involving 22 676 player days. *Br J Sports Med* 2012;46:499–504.
69 Theron N, Schwellnus M, Derman W, *et al*. Illness and injuries in elite football players—a prospective cohort study during the FIFA Confederations Cup 2009. *Clin J Sport Med* 2013;23:379–83.
70 Kippelen P, Fitch KD, Anderson SD, *et al*. Respiratory health of elite athletes—preventing airway injury: a critical review. *Br J Sports Med* 2012;46:471–6.
71 Carlsen KH, Anderson SD, Bjermer L, *et al*. Exercise-induced asthma, respiratory and allergic disorders in elite athletes: epidemiology, mechanisms

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and diagnosis: part I of the report from the Joint Task Force of the European Respiratory Society (ERS) and the European Academy of Allergy and Clinical Immunology (EAACI) in cooperation with GA2LEN. *Allergy* 2008;63:387–403.
72 Hanstad DV, Rønsen O, Andersen SS, *et al*. Fit for the fight? Illnesses in the Norwegian team in the Vancouver Olympic Games. *Br J Sports Med* 2011;45:571–5.
73 Fuller CW, Ekstrand J, Junge A, *et al*. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Br J Sports Med* 2006;40:193–201.
74 Bahr R, Holme I. Risk factors for sports injuries—a methodological approach. *Br J Sports Med* 2003;37:384–92.
75 Inklaar H. Soccer injuries. I: Incidence and severity. *Sports Med* 1994;18:55–73.
76 Finch CF. An overview of some definitional issues for sports injury surveillance. *Sports Med* 1997;24:157–63.
77 Bjørneboe J, Flørenes TW, Bahr R, *et al*. Injury surveillance in male professional football; is medical staff reporting complete and accurate? *Scand J Med Sci Sports* 2011;21:713–20.
78 Henrie M, Petron D, Chen Q, *et al*. *Comparison of Ski and snowboarding injuries that occur inside versus outside Terrain Parks. Presentation at ISSS Congress*. Keystone, Co, USA, May 1–7; 2011.
79 Russell K, Meeuwisse WH, Nettel-Aguirre A, *et al*. Injuries and terrain park feature use among snowboarders in Alberta. *Br J Sports Med* 2011;45:311.
80 Russell K, Meeuwisse WH, Nettel-Aguirre A, *et al*. Feature-specific terrain park-injury rates and risk factors in snowboarders: a case-control study. *Br J Sports Med* 2014;48:23–8.
81 Müller E. Biomechanics of Ski Jumping—Scientific Jumping Hill Design. In: Muller E, Schwameder H, Kornexl E, Raschner C, eds. *Science and Skiing*. London: Chapman and Hall, 1997:36–48.
82 Hubbard M. Safer Ski jump landing surface design limits normal impact velocity. In: Johnson RJ, Shealy JE, Langren M, eds. *Skiing trauma and safety*. West Conshohocken, PA: ASTM International, 2009: Volume 17.
83 Hubbard M, Swedberg AD. Design of Terrain Park jump landing surfaces for constant equivalent fall height is robust to "Uncontrollable" factors. In: Johnson R, Shealy J, Greenwald R, Scher I, eds. *Skiing trauma and safety*. Vol 19. West Conshohocken, PA: ASTM International, 2012.
84 McNeil JA, McNeil JB. Dynamical analysis of winter terrain park jumps. *Sports Eng* 2009;11:159–64.
85 McNeil JA, Hubbard M, Swedberg AD. Designing tomorrow's snow park jump. *Sports Eng* 2012;15:1–20.
86 Petrone N, Cognolato M, Hubbard M, *et al*. Comparing the Impact Performance of a Standard Tabletop and Constant Equivalent Fall Height Snow Park Jump. Personal Communication 2014.
87 International Olympic Committee. *The Olympic Movement Medical Code*. IOC. http://www.olympic.org/PageFiles/61597/Olympic_Movement_Medical_Code_eng.pdf (accessed 28 Aug 2014).

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Sports injuries and illnesses in the Sochi 2014 Olympic Winter Games

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