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ABSTRACT

Background Identification of high-risk sports, including their most common and severe injuries and illnesses, will facilitate the identification of sports and athletes at risk at an early stage.

Aim To analyse the frequencies and characteristics of injuries and illnesses during the XXI Winter Olympic Games in Vancouver 2010.

Methods All National Olympic Committees' (NOC) head physicians were asked to report daily the occurrence (or non-occurrence) of newly sustained injuries and illnesses on a standardised reporting form. In addition, the medical centres at the Vancouver and Whistler Olympic clinics reported daily on all athletes treated for injuries and illnesses.

Results Physicians covering 2567 athletes (1045 females, 1522 males) from 82 NOCs participated in the study. The reported 287 injuries and 185 illnesses resulted in an incidence of 111.8 injuries and 72.1 illnesses per 1000 registered athletes. In relation to the number of registered athletes, the risk of sustaining an injury was highest for bobsleigh, ice hockey, short track, alpine freestyle and snowboard cross (15–35% of registered athletes were affected in each sport). The injury risk was lowest for the Nordic skiing events (biathlon, cross country skiing, ski jumping, Nordic combined), luge, curling, speed skating and freestyle moguls (less than 5% of registered athletes). Head/cervical spine and knee were the most common injury locations. Injuries were evenly distributed between training (54.0%) and competition (46.0%; p=0.18), and 22.6% of the injuries resulted in an absence from training or competition. In skeleton, figure and speed skating, curling, snowboard cross and biathlon, every 10th athlete suffered from at least one illness. In 113 illnesses (62.8%), the respiratory system was affected.

Conclusion At least 11% of the athletes incurred an injury during the games, and 7% of the athletes an illness. The incidence of injuries and illnesses varied substantially between sports. Analyses of injury mechanisms in high-risk Olympic winter sports are essential to better direct injury-prevention strategies.

INTRODUCTION

The protection of an athlete's health is an important task for the International Olympic Committee (IOC). Systematic injury and illness surveillance monitors trends over long periods of time, and the identification of high-risk sports, including their most common and severe injuries and illnesses, provide valuable knowledge to reduce the risk of occurrence. Thus, to maximise the health benefits of elite athletes, and to minimise the direct and indirect costs associated with injury, identifying athletes at high injury risk early and providing them with tools to prevent sports injuries is a significant goal. Following the four-stage model of van Mechelen *et al*,[1] injury epidemiology is the first step in the development of effective injury-prevention strategies.

Major sport events constitute an ideal environment for performing projects, such as the systematic registration of injuries and illnesses. The study population is a relatively homogenous group in terms of skill level, and the study period is defined by the event itself, which is usually characterised by a high standard of environmental factors (eg, safety of venues, optimal preparation of courses/slopes).[2 3] As early as 1998, the Fédération Internationale de Football Association (FIFA) started to survey all injuries incurring during their competitions,[4–7] and other major sports federations followed the role model of FIFA's Medical Assessment and Research Centre (F-MARC).[3 8–12] Also, the International Ice Hockey Federation (IIHF) continuously monitors injuries in their Championships. In 2004, an injury-surveillance system was applied for all team sports during the Summer Olympic Games in Athens.[2] Based on these experiences, a group of experts, gathered by the IOC, developed an injury surveillance for multisport events,[13] and the IOC performed, for the first time, an injury surveillance during the 2008 Beijing Olympic Games, showing a 10% injury risk.[14]

For Olympic winter sports, much less knowledge on injury risk exists. Furthermore, sports such as snowboard and freestyle skiing are relatively recent additions to the traditional Olympic winter sports. For World Cup athletes, the International Skiing Federation (FIS) introduced in 2006 an injury surveillance system in an attempt to record injuries in all FIS sports disciplines throughout a whole World Cup season and thereby monitor injury trends over time.[15] Similarly, there are only a limited number of papers available aimed at investigating illnesses during single[9] or multisport events.[16–18]

Recently, the International Aquatic Federation (Fédération Internationale de Natation (FINA))[9] and the International Association of Athletics Federations (Alonso 2010, personal communication) have implemented an injury and illness surveillance study during their 2009 World Championships to establish its feasibility as pilot projects for the 2010 Vancouver Olympics.

As a follow-up of the injury surveillance on Summer Olympic sports,[2 14] the aim of the present

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study was to describe the risk of injury and illnesses occurring during the XXI Winter Olympic Games in Vancouver 2010. The results will identify injury patterns to build a foundation for injury prevention and protection of the athlete's health.

METHODS

The IOC injury surveillance system for multisport events was used in the present study.[13] The injury definition and data-collection procedures were successfully implemented during the Olympic Games 2008 in Beijing.[14] Based on the experiences from aquatic sports[9] and athletics (Alonso 2010, personal communication), they were expanded to also include the registration of illnesses occurring during the Olympic Winter Games 2010.

All NOC head physicians were asked to participate in the Vancouver injury and illness surveillance study, and to report daily the occurrence (or non-occurrence) of newly sustained injuries and illnesses on a standardised reporting form. In addition, information on all athletes treated for injuries and illnesses by the Local Organizing Committee medical services was retrieved from the two medical centres at the Vancouver and Whistler venues.

Implementation of data collection

Six months before the 2010 Vancouver Olympic Games, the NOCs were informed about the study by the IOC. The medical representatives of all participating countries received a booklet with detailed information about the study, including the injury and illness forms to be filled out. Two days before the opening of the Games, NOCs physicians, physiotherapists and the medical representatives of the Winter Olympic International Sports Federations were invited to a meeting covering the details of the study. All NOC head team physicians were asked to submit a daily injury and illness form. In addition, athletes seen for an injury or illness in the venue medical stations or the central clinics (medical centres in Vancouver and Whistler) were reported through the central clinic database. To prevent double registrations, the athlete's accreditation number was manually checked in both data sources. To encourage compliance with the reporting procedures during the games, members of the study group were frequently in personal contact with NOCs, having more than 10 athletes participating.

During the 2009–2010 competitive seasons, the FIS and the IIHF carried out injury surveillance on their World cup skiers and during the World Championship respectively. These surveillance data were available to allow comparisons to the Vancouver injury surveillance.

Definition of injury and illness

An athlete was defined as injured or ill if they received medical attention regardless of the consequences with respect to absence from competition or training.[13]

Following the IOC injury surveillance system,[13] an injury should be reported if it fulfilled the following criteria: (1) musculoskeletal complaint or concussion, (2) newly incurred (pre-existing, not fully rehabilitated should not be reported) or reinjuries (if the athlete has returned to full participation after the previous injury), (3) incurred in competition or training and (4) incurred during the XXI Winter Olympic Games 2010 (12–28 February 2010).

The definition of an illness was developed based on the injury definition to ensure compatibility with the existing injury protocol and ease of understanding for the participating physicians.

An illness was defined as any physical complaint (not related to injury) newly incurred during the games that received medical attention regardless of the consequences with respect to absence from competition or training. Chronic pre-existing illnesses were not included unless there was an exacerbation requiring medical attention during the games.[9]

If multiple body parts were injured during the same incident, multiple types of injuries occurred in the same body part, or if different body parts were affected by illnesses, only the most severe injury/illness was registered, however, with several diagnoses.[13,19]

Injury and illness report form

The injury part of the report form was identical to that used during the 2008 Beijing Olympic Games[13,14] and required documentation of the following information: athlete's accreditation number, sport discipline/event, date, time, competition/training, injured body part, injury type, cause and estimated time loss. The illness part of the report form was located directly below the injury part on the same page and followed a similar design.[9] The illness documentation included the athlete's accreditation number, sport discipline/event, date of occurrence, diagnosis, affected system, main symptom(s) and cause of illness, as well as an estimate of time loss. Detailed instructions on how to fill out the form correctly were given in the booklet with examples for injuries and illnesses. Injury and illness report forms were distributed to all NOCs in the following languages of choice: Chinese, English, French, German, Russian and Spanish (see supplement). All injury and illness forms delivered to the project group were checked manually for duplicates. In cases of duplicate reporting, information from the NOC physician was preferred over the venue physician's report.

Confidentiality and ethical approval

The athletes' accreditation number was only used to avoid duplicate reporting from NOC physicians and the clinics and to provide information on age, gender, sport and national federation of the athlete from the IOC database of registered athletes. All information was treated strictly confidentially, and the injury reports were made anonymous after the Olympic games.

Data analysis

All data were statistically analysed using SPSS (SPSS for Windows, versions 15.0, SPSS, Chicago, Illinois).

The compliance of the NOCs physicians with the reporting procedures (response rate) was determined by dividing the number of received injury and illness report forms by the number of expected forms (number of IOC with more than 10 athletes multiplied by 17 days). If multiple forms from several physicians belonging to one NOC were received, only one form daily was used for the response rate analysis.

Descriptive data were generally presented for variables as frequencies and proportions, as well as mean values with SD. These data included the athletes' age, frequency and proportions of injuries and illnesses, such as injury type, location, cause, circumstance and severity, and affected illness systems with following symptoms, causes and estimated severity. The incidence of injuries and illnesses was calculated as the number of injuries/illnesses per 1000 registered athletes.

Comparisons of continuous variables were analysed using the Student t test for independent groups. Categorical variables were compared by using a χ^2 test or Fisher exact test for small numbers. A z test based on the Poisson model was used to compare the number of injuries between female and male athletes by expressing a rate ratio (RR) with the corresponding 95% CI. The level of two-tailed significance was chosen to be α=0.05.

RESULTS

Response rate and coverage of the athletes

All 33 NOCs with more than 10 registered athletes were included in the analysis of response rate, and these countries represented 2417 of the total of 2567 athletes (94.2%) (table 1). Throughout the 17 days of the Vancouver Olympics, these 33 NOCs returned a total of 461 out of a maximum of 561 forms to the project group (mean 82.2%, range 76.5–89.0%). The response rate decreased with the size of the NOCs.

A total of 42 injuries and illnesses were missed by the NOCs and only reported from the clinic database; the highest proportion for the smallest countries (11 out of 25 cases, 44.0%).

Incidence of injuries

Among the 2567 registered athletes (1045 females, 1522 males), a total of 287 injuries were reported, resulting in an injury rate of 111.8 injuries per 1000 registered athletes. On average, 11% of the registered athletes sustained at least one injury (n=270). There were nine and four athletes with two and three injuries each, respectively.

The incidence of injuries was higher in female (131.1 injuries per 1000 athletes (95% CI 109.1 to 153.1)) than in male athletes (93.3 (78.0 to 108.6), RR=1.4 (1.1 to 1.8), p=0.003). In eight cases, information on gender was missing. Injured male and female athletes did not differ in age from their non-injured counterparts. Information on age was missing for 100 injured athletes.

Injury risk in different sports

The incidence of injuries varied substantially among the different sports (table 2). In relation to the number of registered athletes, the risk of sustaining an injury was highest for bobsleigh, ice hockey, short track, alpine and for freestyle and snowboard cross (15–35% of registered athletes were affected in each sport). Every fifth female athlete was injured in bobsleigh, ice hockey, snowboard cross and in freestyle cross and aerials, while the highest-risk sports for male athletes were short track (27.8% of registered male athletes), bobsleigh (17.1%) and ice hockey (15.9%).

The injury risk was lowest for the Nordic skiing events (biathlon, cross country skiing, ski jumping, Nordic combined), luge, curling, speed skating and freestyle moguls (less than 5% of registered athletes) (table 2).

Injury location and type

For both genders, the face, head and cervical spine (female 19.7%, male 21.4%) and knee (female 16.1%, male 10.7%) were the most prominent injury locations, followed for females by wrist (8.0%) and for male athletes by thigh (10.0%). Contusions (female 31.6%, male 25.5%), ligament sprains (female 19.8%, male 10.6%) and muscular strains (female 8.1%, male 16.3%) were the most common injury types. In alpine, freestyle and snowboarding, 22 out of 102 injuries (21.6%) affected the head/cervical spine and 24 (23.5%) injuries the knee (table 3).

Twenty concussions were reported, affecting 7% of the registered athletes. These athletes participated in the snowboard (boarder cross and half pipe) and freestyle disciplines (ski cross and aerials), in bobsleigh, short track, alpine skiing and ice hockey. Shoulder, knee and ankle ligament injuries were common injury types in freestyle skiing, alpine, ski jumping and speed skating. Hand, wrist, lower leg and ankle fractures and other bone injuries mostly occurred in ice hockey, the snowboard, freestyle and alpine disciplines, as well as cross country. One supraspinatus tendon rupture was reported in cross country skiing. A catastrophic injury with death as outcome occurred in luge.

Injury mechanism and circumstance

The three most common reported injury mechanisms were a non-contact trauma (n=57, 23.0%), contact with a stagnant

Table 1 Response rates, numbers (proportions), and rates of injuries and illnesses in relation to the size of the participating National Olympic Committee (NOC)

Size of NOC (athletes)	>100	51–100	11–50	<11	Total
NOCs (n)	8	9	16	49	82
Athletes (n)	1198	717	502	150	2567
NOCs with participating physician(s) (n)	8	9	16	Not known	Not known
Response rate, forms returned by NOC physicians (n, %)	121 (89.0)	132 (86.3)	208 (76.5)	–*	461 (82.2)
Injuries/illnesses reported by NOC physicians	103	72	63	7	245
Injuries/illnesses reported only by the venue	15	6	10	11	42
Total injuries (n)	118	78	69	18	285†
Injuries per 1000 athletes	98.5	108.8	137.5	120.0	111.8
Total illnesses (n)	85	54	39	7	185
Illnesses per 1000 athletes	71.1	75.3	77.7	46.7	72.1

*Countries with fewer than 11 athletes were excluded from the response rate analysis.
†Information is missing for two injuries (could not be related to NOCs).
NOCs with more than 100 athletes (8): Canada, France, Germany, Italy, Russia, Sweden, Switzerland, USA.
NOCs with 51–100 athletes (9): Austria, China, Czech Republic, Finland, Great Britain, Japan, Latvia, Norway, Slovakia.
NOCs with 11–50 athletes (16): Australia, Belarus, Bulgaria, Croatia, Denmark, Estonia, Hungary, Kazakhstan, Korea (Republic), Netherlands, New Zealand, Poland, Romania, Slovenia, Spain, Ukraine.
NOCs with fewer than 11 athletes (49): Albania, Algeria, Andorra, Argentina, Armenia, Azerbaijan, Belgium, Bermuda, Bosnia & Herzegovina, Brazil, Cayman Island, Chile, Colombia, Cyprus, Ethiopia, Georgia, Ghana, Greece, Hong Kong, Iceland, India, Iran, Ireland, Israel, Jamaica, Korea (North), Kyrgyzstan, Lebanon, Lichtenstein, Lithuania, Macedonia, Mexico, Moldavia, Monaco, Mongolia, Montenegro, Morocco, Nepal, Pakistan, Peru, Portugal, San Marino, Senegal, Serbia, South Africa, Tajikistan, Chinese Taipei, Turkey, Uzbekistan.

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Table 2 Number (n), proportions (%) and rates of injuries (per 1000 athletes) in different sports

	Registered athletes			Injuries			Illnesses		
	Female (n)	Male (n)	Total (n)	Femalen (%)	Male n (%)	Total n (%)	Female n (%)	Male n (%)	Total n (%)
Bob									
Bob	42	117	159	10 (24)	20 (17)	32 (20)	2 (5)	5 (4)	7 (4)
Skeleton	19	28	47	1 (5)	1 (4)	3 (6)	–	1 (4)	5 (11)
Luge	29	79	108	1 (3)	1 (1)	2 (2)	4 (14)	2 (3)	7 (6)
Curling	50	50	100	–	4 (4)	4 (4)	7 (14)	3 (6)	10 (10)
Ice hockey	168	276	444	38 (23)	44 (16)	82 (18)	17 (10)	8 (3)	25 (6)
Skating									
Figure	73	73	146	12 (16)	9 (12)	21 (14)	10 (14)	6 (8)	18 (12)
Short track	55	54	109	5 (9)	15 (28)	20 (18)	4 (7)	3 (6)	10 (9)
Speed	83	93	176	5 (6)	–	5 (3)	15 (18)	6 (6)	22 (13)
Alpine and snowboarding									
Alpine	133	175	308	20 (15)	21 (12)	46 (15)	5 (4)	7 (4)	13 (4)
Freestyle									
Cross	35	33	68	8 (23)	5 (15)	13 (19)	2 (6)	–	2 (3)
Aerials	23	24	47	6 (26)	3 (13)	9 (19)	–	1 (4)	1 (2)
Moguls	27	30	57	–	1 (3)	1 (2)	–	–	–
Snowboard									
Cross	22	35	57	16 (73)	4 (11)	20 (35)	4 (18)	1 (3)	6 (11)
Half pipe	30	39	69	4 (13)	5 (13)	9 (13)	2 (7)	2 (5)	4 (6)
Slalom	29	30	59	2 (7)	2 (7)	4 (7)	2 (7)	1 (3)	4 (7)
Nordic skiing									
Biathlon	98	104	202	1 (1)	2 (2)	3 (1)	8 (8)	15 (14)	23 (11)
Cross country	129	163	292	8 (6)	1 (1)	9 (3)	5 (4)	12 (7)	20 (7)
Ski jumping	–	67	67	–	3 (4)	3 (4)	–	1 (1)	1 (1)
Nordic combined	–	52	52	–	1 (2)	1 (2)	–	4 (7)	4 (7)
Total	1045	1522	2567	137 (13)*	142 (9)*	287 (11)	91 (9)†	78 (5)†	182 (7)‡

*Information is missing for eight injuries.
†Information is missing for 16 illnesses.
‡Information is missing for three illnesses.

object (n=54, 21.8%) and contact with another athlete (n=36, 14.5%) (table 3). Information on injury cause was missing for 39 cases (13.6%). Related to sports, 60% (n=34) of the non-contact injuries were suffered by alpine, snowboarding and freestyle athletes, 57% (n=31) of the contact injuries with a stagnant object incurred in the bobsleigh run and skiing/snowboarding slopes, and 81% (n=29) of the contact injuries with another player occurred in ice hockey.

Information on injury circumstances was available for 272 injuries (94.8%) (table 4). Injuries were evenly distributed between official training (54.0%) and competition (46.0%) (p=0.18). However, a specifically high proportion of training injuries was found for the three snowboard disciplines, freestyle cross skiing, short track, figure skating, skeleton and biathlon. In these sports, three out of four injuries occurred outside the competition.

Injury severity

Of the 287 injuries, 65 (22.6%) were expected to result in a time-loss situation for the athlete (table 4). Of those with expected time loss, 11 injuries (16.9%) had an estimated absence from training or competition of more than 1 week. These injuries were one death, three fractures (lower leg, ribs), two sprains (knee, ankle), two strains (abdomen, groin) two concussions and one contusion (knee). However, information on estimated time loss was missing for 100 (34.8%) injuries. Of those, several injuries would most likely result in time loss for a longer period; eight concussions, eight fractures or other bone injuries (clavicular, face, tibia plateau, knee), five knee total or partial ligament ruptures (two MCL injuries, three ACL injuries), five shoulder and knee dis- or subluxations and one tendon rupture (supraspinatus).

Incidence and distribution of illnesses

Among 173 out of 2567 athletes (6.7%), a total of 185 illnesses were reported, resulting in an incidence of 72.1 illnesses per 1000 athletes.

There was a significantly higher proportion of illness in female compared with male athletes (8.7% vs 5.2%, p<0.001). In 15 cases, information on gender was missing. Female athletes treated for an illness were significantly older than their healthy counterparts (24.9 years, SD 5.0, p=0.04), while no age discrepancy was observed between ill and healthy male athletes (26.9 years, SD 5.2, p=0.20). Information on age was missing for 72 athletes with a reported illness.

Illnesses were reported from a variety of sports. In skeleton, figure and speed skating, curling, snowboard cross and biathlon, every 10th athlete suffered from at least one illness (table 2).

Affected system, symptom, cause and severity of illness

A total of 113 illnesses (62.8%) affected the respiratory system, mostly observed in the ice skating and Nordic skiing disciplines (table 3). As a consequence, the illness cause was most often classified as an infection (n=111, 63.8%) affecting athletes in mainly the same sports as mentioned above.

The most commonly reported symptoms were pain (n=50, 27.9%) and dyspnoea/cough (n=38, 21.2%). The most frequent diagnosis was upper-respiratory-tract infection (pharyngitis,

Table 3 Number (n) and proportions (%) of injury and illness types, locations, affected systems, symptoms and causes separated for bob (bob, skeleton, luge), curling, ice hockey, alpine and snowboarding (alpine skiing, ski and snowboard cross, freestyle aerials and moguls, snowboard half pipe and slalom) and Nordic Skiing (biathlon, cross-country, ski jumping, Nordic combined)

	Bob n=314 (%)	Curling n=100 (%)	Ice hockey n=444 (%)	Skating n=432 (%)	Alpine and snowboarding n=665 (%)	Nordic skiing n=615 (%)	All n=2567 (%)
Injuries	36 (11.5)	4 (4.0)	82 (18.5)	47 (10.9)	102 (15.3)	16 (2.6)	287 (11.2)
Injury location*							
Face (including eye, ear, nose)	–	–	11	1	1	–	13 (4.6)
Head	6	–	5	2	17	–	30 (10.5)
Neck/cervical spine	6	–	2	3	4	1	16 (5.6)
Thoracic spine/upper back	5	–	2	–	2	1	10 (3.5)
Sternum/ribs	–	–	1	1	2	1	5 (1.8)
Lumbar spine/lower back	2	1	3	3	5	2	16 (5.6)
Abdomen	1	–	3	–	–	1	5 (1.8)
Pelvis/sacrum/buttock	–	–	6	–	5	–	11 (3.9)
Shoulder/clavicular	1	–	2	2	7	3	15 (5.3)
Upper arm	1	–	2	–	–	–	3 (1.1)
Elbow	–	–	1	2	5	1	9 (3.2)
Forearm	–	–	–	–	3	–	3 (1.1)
Wrist	–	1	8	2	3	–	14 (4.9)
Hand	–	–	1	4	4	–	9 (3.2)
Finger	–	1	5	–	2	–	8 (2.8)
Hip	3	–	1	3	3	1	11 (3.9)
Groin	–	–	3	–	–	–	3 (1.1)
Thigh	4	1	8	6	1	–	20 (7.0)
Knee	1	–	7	5	24	2	39 (13.7)
Lower leg	6	–	–	5	6	1	18 (6.3)
Achilles tendon	–	–	–	2	–	1	3 (1.1)
Ankle	1	–	7	3	4	1	16 (5.6)
Foot/toe	–	–	4	1	3	–	8 (2.8)
Injury type*							
Concussion	5	–	3	1	11	–	20 (7.0)
Fracture (trauma, stress, other bone injuries)	–	–	5	2	11	1	19 (6.6)
Sprain (dislocation, subluxation, ligamentous rupture)	3	–	13	4	28	3	51 (17.7)
Strain (muscle rupture, tear, tendon rupture)	10	1	11	6	4	4	36 (12.6)
Meniscus, cartilage	–	–	1	1	1	1	4 (1.4)
Contusion, haematoma, bruise	11	–	29	9	28	3	80 (27.8)
Tendinosis, tendinopathy	1	1	1	5	6	2	16 (5.6)
Arthritis, synovitis, bursitis	1	–	–	1	1	–	3 (1.1)
Impingement	1	–	–	1	1	–	3 (1.1)
Laceration, abrasion, skin lesion	2	–	12	9	2	–	25 (8.8)
Dental injury, broken tooth	–	–	2	–	1	–	3 (1.1)
Muscle cramps, spasm	2	1	1	2	1	1	8 (2.8)
Other (incl. nerve, spinal cord, fasciitis)	1	1	3	4	4	1	14 (4.9)
Injury cause†							
Overuse (gradual onset)	2	2	2	8	4	1	19 (7.7)
Overuse (sudden onset)	1	1	1	2	4	3	12 (4.8)
Non-contact trauma	5	–	6	9	34	3	57 (23.0)
Recurrence of previous injury	3	–	–	3	4	–	10 (4.0)
Contact with another athlete	1	–	29	5	1	–	36 (14.5)
Contact with moving object	3	–	22	–	–	–	25 (10.1)
Contact with stagnant object	17	–	11	8	14	4	54 (21.8)
Violation of rules	–	–	2	–	–	–	2 (0.8)
Field or play conditions	–	–	–	–	9	1	10 (4.0)
Weather conditions	–	–	–	–	3	–	3 (1.2)
Equipment failure	–	–	1	1	1	–	3 (1.2)
Other	4	–	1	–	10	2	17 (6.9)
Illnesses‡	19 (6.1)	10 (10.0)	25 (5.6)	50 (11.6)	30 (4.5)	45 (7.6)	181 (7.1)
Illness affected system§							
Gastrointestinal	3	–	12	6	5	10	36 (20.0)
Respiratory	13	8	12	32	15	33	113 (62.8)

Continued

Table 3 Continued

	Bob n=314 (%)	Curling n=100 (%)	Ice hockey n=444 (%)	Skating n=432 (%)	Alpine and snowboarding n=665 (%)	Nordic skiing n=615 (%)	All n=2567 (%)
Allergic, immunological	–	–	–	3	1	–	4 (2.2)
Metabolic, endocrinological	–	–	1	3	–	2	6 (3.3)
Dermatologic	2	1	1	–	4	–	8 (4.4)
Other (including urogenital, gynaecological, cardiovascular, neurological, psychiatric, musculoskeletal, dental)	1	1	–	5	3	2	12 (6.7)
Illness symptom§							
Fever	1	–	4	2	1	8	16 (8.9)
Pain	7	1	1	15	13	13	50 (27.9)
Diarrhoea, vomiting	1	1	9	1	2	3	17 (9.5)
Dyspnoea, cough	4	2	4	9	5	13	38 (21.2)
Other (including dehydration, anaphylaxis, lethargy, dizziness)	6	6	7	22	9	7	58 (32.4)
Illness cause¶							
Infection	13	7	16	27	18	29	111 (63.8)
Environmental	1	1	2	7	1	5	17 (9.8)
Exercise-induced	–	–	1	2	–	4	7 (4.0)
Other (including pre-existing, drug)	4	2	6	12	8	7	39 (22.4)

Information is missing for *2 injuries, †39 injuries, ‡4 illnesses, §6 illnesses and ¶11 illnesses.

sinusitis, tonsillitis) (n=61, 54.0%). A total of 24 (13.8%) illnesses were caused by exercise-induced or environmental factors.

About a third of the illnesses (65 of 185; 35.1%) were expected to result in absence from further training or competition. Of those, three illnesses were expected to result in an estimated time loss of 8–10 days (one endocrinological problem, two respiratory/dyspnoea–acute sinusitis, tonsillitis). Information on time loss was missing for 27 cases (14.6%).

DISCUSSION

The present study is the first surveillance of injury and illness of athletes in Winter Olympic Games, and all sports of the 2010 Olympic Games were included. The principal findings were that at least 11% of the athletes incurred an injury during the games, and 7% of the athletes an illness. The incidence of injuries and illnesses varied substantially between sports.

Incidence and distribution, type and cause of injuries

In Vancouver, the injury incidence was with 111.8 injuries per 1000 athletes slightly higher than that reported from the Summer Olympics in Beijing 2008 (96.1 injuries per 1000 athletes).[14] This observed difference is most likely due to the differences in the sports themselves, since the study on the Beijing Olympic Games was conducted by the same research group using the same methodology to obtain data.

As illustrated for Winter sports by Torjussen and Bahr[20] and for Summer sports by Junge *et al*,[2] choosing the appropriate method to report the risk of injury in sports is a challenge if the aim is to compare the risk between different sports or disciplines where exposure may differ considerably. In Winter sports, there are for example two jumps in a ski jumping competition, one run in a 50 km cross country race, five runs in snowboard cross, several matches in ice hockey or curling during the Olympic Games and only one run in downhill skiing.

As an alternative to relative injury risk where the risk is expressed as rate corrected for exposure, for example, injuries per run/matches, the use of absolute injury risk is highly relevant for the present study, where injuries and illnesses are expressed as the total number of injuries/illnesses per registered athletes for each sport/discipline.

Thus, in relation to the number of registered athletes, the risk of sustaining an injury was highest for bobsleigh, ice hockey, short track, alpine, and freestyle and snowboard cross. Here, 15–35% of the registered athletes were affected. All these sports are characterised by a high speed, but except for skiing,[21] snowboarding[20 21] and ice hockey,[22] there are few data available on Winter sports regarding elite athletes' injury risk.

Compared with a recently published study on elite alpine skiers,[23] the present data did not allow a differentiation of injury risk in different alpine disciplines. However, 2 years of injury registration of the four alpine World Cup disciplines revealed that injury risk increased with increasing speed; for example, the injury risk was almost four times higher in downhill than in slalom.[23]

Injury risk was also high in freestyle and snowboard cross. To position themselves in the front through their heats while competing against three other skiers/boarders, athletes had to pass several challenges—for example, turns, jumps and waves. Combined with the speed component, these external factors may contribute to an increased injury risk. In addition, body contact within the rules of the sport occurs and may force the athlete to have an unanticipated reaction, loss of control and probably higher-risk situations. Competing for positions is also typical for short track races where four skaters are competing in elimination heats.

The risk of injury was low for athletes in the Nordic Skiing disciplines (cross-country skiing, biathlon, ski jumping, Nordic Combined). These findings are in accordance with a two-seasons report from World-Cup skiing athletes.[22] The low injury risk for these athletes compared with alpine, freestyle and snowboard athletes is not surprising, as they are not exposed to icy surfaces, high speed and spectacular jumps with minimal protection. Therefore, it is more surprising that the injury risk for skeleton and luge athletes is as low as that reported in the present study, which may raise the question of underestimation of injury risk for these sports.

Table 4 Number and proportions of injuries in different sports

	Severity	Circumstance	
	Time loss n (%)	Training n (%)	Competition n (%)
Bob			
Bob	9 (28.1)	16 (53.3)	14 (46.7)
Skeleton	1 (33.3)	3 (100.0)	–
Luge	1 (50.0)	1 (50.0)	1 (50.0)
Curling	–	–	4 (100.0)
Ice hockey	16 (19.5)	17 (21.8)	61 (78.2)
Skating			
Figure	–	17 (89.4)	2 (10.6)
Short track	2 (10.0)	15 (83.3)	3 (16.7)
Speed	1 (20.0)	3 (60.0)	2 (40.0)
Alpine and snowboarding			
Alpine	12 (26.1)	24 (52.2)	19 (43.2)
Freestyle			
Cross	3 (23.1)	8 (61.5)	5 (38.5)
Aerials	2 (22.2)	4 (50.0)	4 (50.0)
Moguls	1 (100.0)	1 (100.0)	–
Snowboard			
Cross	8 (40.0)	15 (78.9)	4 (21.1)
Half pipe	2 (22.2)	8 (88.9)	1 (11.1)
Slalom	2 (50.0)	3 (75.0)	1 (25.0)
Nordic skiing			
Biathlon	1 (33.3)	3 (100)	–
Cross country	2 (22.2)	5 (62.5)	3 (37.5)
Ski jumping	2 (66.7)	2 (66.7)	1 (33.3)
Nordic combined	–	1 (100.0)	–
Total	65 (34.8)*	147 (54.0)†	125 (46.0)†

*Information is missing for 100 injuries. Percentage values are related to the number of injuries within each sport.
†Information is missing for 15 injuries.

In accordance with a previous report,[21] the knee and the head were the most frequent body parts injured among alpine and freestyle skiers, and snowboarders. Also, a concern should be that every fifth registered injury in the Winter Olympic Games affected the head, neck and cervical spine, mainly diagnosed as abrasion, skin lesion, contusion, fracture or concussion. A total of 20 concussions were diagnosed, affecting 7% of all athletes. These figures are twice as high as those reported from the Summer Olympic Games.[14] The diagnosis of concussions, its treatment and return-to-play guidelines have been the focus of a recent consensus statement.[24] In many cases, head and knee injuries result in long absence from training and competition, and the prevention of concussions and severe knee ligament sprains, including anterior cruciate ligament ruptures, is important.

For snowboard cross and freestyle cross, a surprisingly high proportion of injuries occurred during training runs, where the athlete was skiing/boarding alone through the course without perceiving stress from additional competitors and poor course choices. The high injury rates in training, also observed for snowboard half pipe athletes, may be caused by a combination of a fast track, and high and difficult jumps. Compared with the Beijing Olympics,[14] more injuries occurred during official training compared with competition (54% in Vancouver vs 27% in Beijing).

Not surprisingly, ice hockey, one of the few contact sports in the Winter Games, turned out to be the sport with the highest incidence of injuries caused by athlete-to-athlete contact. In addition, a high proportion of injuries were caused by trauma from being hit by the puck. While unintended body contact is permitted in the women's sport, active body contact is a major characteristic of the men's game. A recent review on injury risk factors in youth ice hockey players by Emery *et al*[25] identified body checking as a significant risk factor for all injuries and concussions.

Incidence and distribution, type and cause of illnesses

The illnesses incidence in Vancouver was 72.1 illnesses per 1000 athletes. Theses findings are consistent with data from aquatics[9] and other multisport events.[16–18] Almost two-thirds of the illnesses affected the respiratory system (62.3%) caused by infections (63.8%), which is a higher rate than that reported in swimming (respiratory system 50.3%, infection 49.2%).[9]

Elite athletes are repeatedly exposed to cold air during winter training and competitions in addition to many inhalant irritants and allergens all year round, situations, which may expose them to an increased risk for upper-respiratory-tract infections.[26] Airway inflammation has often been shown to affect elite swimmers, ice hockey players and cross-country skiers.[26]

In Vancouver, a total of 58% of respiratory illnesses were suffered by Nordic skiing and skating athletes, who themselves represented 40% of all registered athletes. Upper-respiratory-tract infections are also typical for athletes who are exposed to overcrowded venues or high training and competition stress by induced immunosuppression.[27]

Upper-respiratory-tract infections were the most frequently treated illnesses encountered. Improving the education of athletes and their entourage on infectious disease prevention strategies as well as the provision of more hand-sanitisation stations at training and competitive venues should help to reduce this problem. Attention to decreasing overcrowding and ensuring the circulation of fresh air in the venues and living quarters will also be beneficial strategies to reduce the spread of airborne infectious diseases.

Data-collection procedures

The high compliance of the NOCs with the reporting procedures indicates that the IOC surveillance system was feasible and accepted by the NOC physicians. With a response rate of 82%, compliance was higher than in Beijing where all NOCs were included.[14] Similar to Beijing, compliance decreased with the size of the NOCs. This observation may be due to fewer medical staff members in smaller NOCs to take care of all tasks and challenges occurring during major tournaments, compared with the larger countries. The IOC has a research group working on improvements in the data-collection system.

Despite this encouraging response rate from the NOCs, the quality and completeness of the reported data still remain unknown. No discrepancies were found between the injury databases of the IIHF and the IOC. However, a comparison with injury data from the FIS Injury Surveillance System (FIS ISS) over the Olympic Game period revealed missing data reported by the NOC (data not published). By using the same injury definition (medical attention), retrospective athletes' interviews, aimed at reviewing injuries throughout the whole World Cup season, and under the leadership of the FIS ISS, we identified a total of 31% more injuries (eight injuries) for the period of the Vancouver Games than the NOC reports did. Two of these eight injuries caused an absence of more than a month (data not published, personal communication). A recent study by Bjørneboe *et al*[28] showed that in Norwegian professional male football, prospective injury surveillance by team medical staff underestimates the incidence of time-loss injuries by at least one-fifth. These results were similarly detected by performing retrospective interviews with the players at the end of the football season. These experiences from other injury surveillance systems should be taken into consideration when future IOC injury surveillance approaches are planned.

Injury and illness severity as absence from training or competition (time loss) was in the present study based on the estimate of the NOC or clinic physicians. Ideally, severe injuries and illnesses should be followed up until the athlete is fully recovered to gain better knowledge on sport-specific injury and illness severity.[14]

Practical implications and further research

Before preventive measures can be suggested, injury risk factors and mechanisms need to be characterised[1]—for example, whether an injury in freestyle cross occurs in a landing after a jump, resembles the boot-induced anterior drawer mechanism with deep knee flexion, or is due to collisions with other skiers or the skier coming out of balance by fighting for a better position in the course need to be investigated. In addition, slope, snow and weather conditions, the athlete's speed, as well as equipment may play an active role in describing the injury mechanisms. By using video analysis and a model-based image-matching technique, detailed information on joint kinematics and kinetics can be obtained from uncalibrated injury video recordings.[29] This approach will help to better understand injury mechanisms.

As the cause of injury varied substantially between sports, successful preventive strategies need to be tailored to the respective sport and athlete at risk.[14 30] Based on the experiences from the Vancouver Olympics, where more than half of the injuries in the bobsleigh run and skiing/snowboarding slopes occurred as a result of contact with a stationary object, preventive measures need to address the importance of creating safe sports arenas (optimal preparation of the skating ring, bobsleigh run, freestyle and snowboard courses/pipes). In addition, the high proportion of training injuries in the skiing and snowboarding speed disciplines may suggest additional training runs and optimising training facilities.

The IOC is currently developing a periodic health exam system which will be offered to the NOCs prior to future Olympic Games. This should improve pregames knowledge on both injuries and illnesses, and will help NOCs to maximise the health protection of their elite athletes.[31] Furthermore, the IOC research group is analysing the injury data from the most serious injuries in Vancouver in an effort to improve the knowledge on injury risk factors and mechanisms in high-risk sports.

Based on the experiences from injury surveillance during major multisports events, such as the 2004 and 2008 Olympics,[2 14] and now the 2010 Winter Olympics in Vancouver, new events for elite youth athletes such as the Winter and Summer Youth Olympic Games, should be evaluated for the feasibility of establishing systematic injury and illness surveillance in this population. Little is known on injury epidemiology among young elite athletes,[32] and systematic injury and illness surveillance will facilitate the identification of sports and athletes at risk at an early stage.

CONCLUSION

The data-collection procedures were accepted by the medical staff of the NOCs as demonstrated by the high response rates of returned injury and illness forms. Nevertheless, checking with other injury surveillance systems suggests that not all injuries were reported. At least 11% of the athletes incurred an injury during the games, and 7% of the athletes an illness. The incidence of injuries and illnesses varied substantially between sports. In the future, analyses of injury mechanisms in high-risk Olympic Winter sports are essential to better direct injury-prevention strategies.

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