Sports injuries

during the Summer Olympic Games 2008

Junge A[1], Engebretsen L[2,3], Mountjoy M[2,4], Alonso JM[5], Renström P[2, 6], Aubry M[7], Dvorak J[1,8]

From

[1] FIFA Medical Assessment and Research Centre (F-MARC), Zurich, Switzerland and Schulthess Klinik, Zurich, Switzerland

[2] International Olympic Committee (IOC), Lausanne Switzerland

[3] Oslo Sports Trauma Research Centre (OSTRC), Oslo, Norway and Ullevaal University Hospital and Medical School, University of Oslo, Norway

[4] Fédération International de Natation (FINA) Lausanne Switzerland

[5] International Association of Athletics Federations (IAAF), Monaco

[6] Karolinska Institutet, Stockholm, Sweden

[7] International Ice Hockey Federation (IIHF), Zurich, Switzerland

[8] Fédération Internationale de Football Association (FIFA), Zurich, Switzerland

*Address correspondence and reprint requests to Dr. Astrid Junge, Schulthess Klinik, Lengghalde 2, CH-8008 Zurich, Switzerland.

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Abstract

Objective: Survey on the frequency, characteristics and causes of injuries incurred in competition and/or training during the 2008 Beijing Olympic Games.

Design: Prospective recording of injuries.

Setting: 29th Olympic Games 2008 in Beijing, China.

Participants: National team physicians or responsible Chief Medical Officers of 92 national teams with 9672 (88%) athletes; all physicians of the medical stations at the Olympic venues and of the polyclinic in the Olympic village.

Main Outcome Measures: Frequency, characteristics and causes of injuries.

Results: 1055 injuries were reported, resulting in an incidence of 96.1 injuries per 1000 registered athletes. About half of the injuries (49.6%) were expected to prevent the athlete from participating in competition or training. The most prevalent diagnoses were ankle sprains and thigh strains. A quarter of the injuries were incurred during training and 72.5% in competition. One third of the injuries were caused by contact with another athlete, followed by overuse (22%) and non-contact incidences (20%). Injuries were reported from all sports but their incidence and characteristics varied substantially. In relation to the number of registered athletes, the risk of incurring an injury was highest in taekwondo, football, hockey, handball, weightlifting and boxing (all $\geq$15% of the athletes), and lowest for sailing, canoe/kayak, rowing, synchronised swimming, diving, fencing and swimming.

Conclusion: The data indicate that the injury surveillance system covered almost all of the participating athletes, and the results highlight areas of high risk for sport injury such as the in-competition period, the ankle and thigh, and specific sports. The identification of these factors should stimulate future research and subsequent policy change to prevent injury in elite athletes.

Keywords: injury surveillance, multi-sport event, top-level athletes, championships.

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INTRODUCTION

The Olympic Games are the largest world sport event with over 10´000 participating athletes from more than 200 countries. The International Olympic Committee (IOC) is increasingly emphasising the protection of the athletes' health and the prevention of injuries. As has been shown previously,[1 2] standardized assessment of sports injuries provides not only important epidemiological information, but also directions for injury prevention, and the opportunity for monitoring long-term changes in the frequency and circumstances of injury. As part of a long-term sports injury prevention project, the IOC decided to conduct an injury surveillance study during the Olympic Games 2008 in Beijing.

Injury surveillance studies have been performed in several single-sports tournaments, such as football,[1 3-8] rugby,[9-13] karate,[14-16] ice hockey,[17 18] volleyball,[19] beach volleyball,[20] handball,[21] tennis,[22] cycling,[23] and athletics[24]. For multi-sport events, however only eight studies were found in the literature, including three on disabled athletes.[25-27]

Martin et al[28] registered all medical contacts and encounters due to injuries and illnesses of 3028 athletes who participated in the 1985 Junior Olympics in 13 different sports. Laskowski et al[29] analysed all medical contacts and treatment required by the 6243 participants in 21 sports at the 1994 Star of the North Summer Games. Cunningham and Cunningham[30] surveyed the injuries of 5106 participants competing in 19 sports during the 1994 Australian University Games. Greene and Bernhardt[31] studied the injuries of 31580 athletes participating in ten sports of the Badger States Summer Games of three consecutive years 1994-96.

During the 2004 Olympic Games in Athens,[32] the incidence and characteristics of injuries in all eight team sport tournaments (football, handball, basketball, field hockey, baseball, softball, water polo and volleyball) were recorded using an injury surveillance system established in football[1 2 4-7] and handball.[21] Since the compliance with the procedure was excellent and the quality of the data obtained high,[32] the injury surveillance system was modified to be applicable for both individual and team sports.[33] The IOC injury surveillance system proved feasible and useful for individual sports in a pilot study during the 11th World Championship in Athletics.[24]

The aim of the present study was to analyse the frequency, characteristics and causes of injuries incurred in competitions and/or training during the Olympic Games 2008 in Beijing.

METHODS

A detailed description of the applied methodology has been published by the Beijing Olympics Study Group.[33] In summary, the physicians and/or Chief Medial Officers of the National Olympic Committees (NOCs) were asked to report daily all newly incurred injuries (or the non-occurrence of injuries) on a standardised injury report form. Injuries were additionally reported by the Local Organising Committee (LOC) physicians at the medical stations at the different Olympic venues and at the polyclinic in the Olympic Village.

Definition of Injury

An injury was defined as any musculo-skeletal complaint (traumatic and overuse) newly incurred due to competition and/or training during period of the XXIX. Olympiad in Beijing that received medical attention regardless of the consequences with respect to absence from competition or training.[33] This injury definition includes five aspects: (a) all injuries that received medical attention (not only time-loss injuries), (b) newly incurred (pre-existing, not fully rehabilitated injuries should not be reported; re-injuries (injuries of the same location and type) should be reported only if the athlete has returned to full participation after the previous injury), (c) in-competition and training injuries, (d) during the Olympic Games (9 to 24 August 2008, except football, for details see "Implementation"), and (e) exclusion of illnesses and diseases. If multiple body parts were injured or multiple types of injury in the same body part were incurred in one incident, this is counted as one injury with two diagnoses.[33]

Injury report form

The injury report form[33] required documentation of the following information: athlete's accreditation number, sport/discipline, round/heat/training, date and time of injury, injured body part, type and cause of injury and estimated duration of the subsequent absence from competition

and/or training. Definitions of these parameters were stated on the back of the form. The injury report form was available in seven languages (English, French, Chinese, Spanish, German, Russian, Arabic). The English version is published elsewhere.[33]

Confidentiality and ethical approval

The athletes' accreditation number was only used to avoid duplicate reporting from NOC and LOC physicians, and to provide information on age, gender, sport and national federation of the athlete from the IOC database. All information was treated strictly confidential, and the injury reports were made anonymous after the Olympic Games. Ethical approval was obtained from the Oslo University School of Medicine Ethical Committee.

Implementation and data collection

Three months prior the 2008 Olympic Games, the NOCs were informed about the study by the IOC. The medical representatives of all participating NOCs received a booklet with detailed information on the study one month before the Games and were requested to participate in the project. All NOC physicians and therapists and the chairpersons of the Medical Commissions of the Summer Olympic International Sports Federations were invited to an instructional meeting two days prior the opening of the Games in Beijing. During this meeting the NOC physicians were informed about the background and aims of the study, and instructed on the completion and return of the injury report form by the Study Group. Questions of the participants were answered, and the instructional booklet and the injury report forms were distributed. During the Olympic Games, members of the Study Group repeatedly met with or phoned the physicians of NOCs with more than 50 athletes to motivate daily compliance with form submission.

In general, the NOC chief physician was responsible for reporting the injuries of their athletes. For a few large NOCs more than one physician returned injury report forms (for calculation of response rate and coverage, these were counted as one report form). One NOC returned all forms at the last day of the Games. One NOC did not report the injuries in a specific sport, another NOC reported only injuries in two sports. The NOC physicians could submit the completed injury report forms to a locked mailbox at the IOC Medical Commission office in the Polyclinic of the Olympic Village, or submit them by email or fax to the IOC study office in Beijing. For

football, the collection of the forms was slightly different since the matches started prior the official opening, most venues were not in Beijing and all football team had their own physician. Following the established procedure in FIFA competitions,[1 2 4 6 7] the forms were collected after each match by the FIFA Medical Officer at the venue and returned to the IOC study office.

In order to receive also information about injured athletes of NOCs that did not have a team physician or therapist, injuries reports were additionally collected from the medical stations at the 38 different Olympic venues and the polyclinic in the Olympic Village. Medical stations at the venues were requested to report on a slightly modified injury report form (additional info on NOC of the injured athlete) on all days a competition took place in the respective venue. During the Games, a member of the Study Group visited the medical stations at the different venues in Beijing to instruct them on accurate completion of the forms and to motivate daily compliance of submission. Venues outside Beijing (football, sailing, equestrian) were contacted via email and phone. Daily injury information was also received from the polyclinic in the Olympic Village. However, this information was extracted from the local database and included only accreditation number of the athlete, location and type of injury. Thus, information on circumstance (competition/training) and cause of injury and resulting time-loss in sport are missing for these injuries. In case of duplicate reporting, information from the NOC physician was preferred to LOC physician´s report, and information from the venue and polyclinics were summarized.

Data analysis

The IOC provided a list of athletes registered for the 2008 Olympic Games; the competition schedule was available on the internet (http://en.beijing2008.cn). The response rate of the NOC physicians was determined by dividing the number of received forms by the number of expected forms (number of NOCs which returned at least one injury report form multiplied with 16 days). The coverage of athletes and of injuries was assessed regarding the number of athletes in the respective NOC in the analysis, and comparing the proportion of injuries reported by NOC physicians and other sources for NOCs of different sizes. The different mode of data collection in football and the reduced number of athletes reported on in two NOCs were regarded in these calculations.

All data were processed using Excel and SPSS. Statistical methods applied were descriptive statistics, frequencies, cross-tabulations, t-test and chi^2-test. Significance was accepted at $p<0.05$.

RESULTS

Response rate and coverage of athletes

The physicians or responsible therapists of 92 national teams with 9672 (88%) athletes took part in the study and returned a total 1314 injury report forms. With respect to the returned forms the average response rate of 75.1%, but regarding the number of athletes covered by the team physicians´ reports the response rate was 79.9%. In relation to all registered athletes the daily coverage by team physicians´ reports was 69.1%. In addition, 264 (72.5%) reports from medical stations at the different Olympic venues and all daily reports from the polyclinic in the Olympic Village were received.

Table 1: Response rate and number of injuries in relation to size of the national team

Size of NOC (no. of athletes)	**>200**	**100-200**	**50-99**	**25-49**	**10-24**	**<10**	**total**
No. of NOCs	16	13	26	23	30	96	**204**
No. of athletes	5679	1811	1821	763	452	451	**10977**
No. of NOCs with participating physician(s) [(a)]	16 100%	13 100%	24 92.3%	13 56.5%	8 26.7%	18 18.8%	**92 (45.1%)**
No. of forms returned by NOC physicians [(b)]	208 81.3%	169 81.3%	301 78.4%	141 67.8%	56 43.8%	174 60.4%	**1050 (72.1%)**
No. of injuries reported by NOC physicians	405	147	153	39	25	18	**787**
No. of injuries reported only by venue or polyclinic [(c), (d)]	49	20	49	41	31	68	**258**
% of injuries reported by NOC physicians [(c), (d)]	89.2%	88.0%	75.7%	48.8%	44.6%	20.9%	**74.7%**
Total no. of injuries [(d)]	**454**	**167**	**202**	**80**	**56**	**86**	**1055**
no. of injuries per 1000 registered athletes [(d)]	79.9	92.2	110.9	104.8	123.9	190.7	**96.1**

[(a)] NOCs of which the team physician returned at least one injury report form,
[(b)] except football (for football additional 264 of 294 (89.9%) forms were returned),
[(c)] injuries reported also by NOC physicians not included, [(d)] country is missing in 10 cases

The coverage of athletes by NOC physicians corresponded closely to the amount of injuries they reported (for details see Table 1). Overall, 787 (74.6%) injuries were reported by the NOC physicians, 16 by medical representatives of the international sport federation at the venue, 127 injuries from medical stations at the venues and 234 from the polyclinic (109 injuries by more than one source of information). The percentage of injuries reported by NOC physicians decreased with the size of the national team, since small teams often do not include a physician.

Frequency and diagnosis of injuries

A total of 1055 injuries were reported, equivalent to an incidence of 96.1 injuries per 1000 registered athletes. Since 46 injuries had multiple locations or types, 1108 diagnoses were named (for details see table 2). The most prevalent diagnoses were ankle sprains (n=81; 7.3%) and thigh strain (n=75; 6.8%). About half of the diagnoses (n=600; 54.2%) affected the lower extremity, upper extremity (n=218; 19.7%), trunk (n=176; 16.1%) and head (104; 94%). Thigh (13.3%) and knee (12.1%) were most commonly injured, followed by the lower leg and ankle. Head injuries (9.5%) were also frequent, mainly diagnosed as skin lesions or contusions.

Table 2: Diagnoses of injuries

	head, face	**neck cervical spine**	**thoracic spine, ribs, chest**	**lumbar spine**	**abdomen, pelvis, buttocks**	**shoulder**	**arm, elbow**	**wrist, hand, fingers**	**hip, groin**	**thigh**	**knee**	**lower leg, Achilles tendon**	**ankle**	**foot, toe**	**not specified**	**total**
concussion	12															12
fracture (traumatic)	4		3[(a)]	1 [(a)]		4	2	17[(a)]			2	1		7		41
stress fracture (overuse)					2			1				4		5		12
dislocation, subluxation	1					11	1	1			2		2			18
rupture of tendon or ligament						2	3	4	2		18	6	11			46
sprain (injury of joint, ligaments)		9	3	16	2	19	11	22		7	37	2	70	12	1	211
lesion of cartilage or meniscus						2		1			16					19
muscle injuries (strain, rupture)		4	9	16	7	7	6	1	11	75	2	21		3		162
contusion, bruise haematoma	36	3	20	5	8	9	15	16	7	35	16	26	7	17		220
tendinosis, tendinopathy, impingement		1	1	2		14	5	3	7	8	13	20	5	3		82
arthritis, synovitis, bursitis		1		4		3	3	15	4	1	21	1	3	8	1	65
skin lesion laceration, abrasion	43		2	2	1	2	5	9	2	3	3	8	2	9		91
nerve injury, protrusion		1		7	1		1								1	11
muscle cramps or spasm		4	4	8	3		1		2	17	1	20				60
others	8	6	2	17	2	1	1			1	3		1	9	2	53
not specified					1										4	5
total	**104**	**29**	**44**	**78**	**27**	**74**	**54**	**90**	**35**	**147**	**134**	**109**	**101**	**74**	**8**	**1108**

(a) including one avulsion fracture

Circumstances and causes of injury

Information on circumstance and cause of injury was available for 858 (81.3%) injuries. The majority of injuries (n= 623; 72.6%) were incurred in competition, ten during warm-up for competition and 225 (26.2%) during training. The injuries incurred during warm-up prior to competition were analysed as injuries during competition. Injuries in training and in competition differed significantly in all injury characteristics (location, type, cause and subsequent time-loss from sport) and with regard to the different sports (for details see Table 3).

One third of the injuries (n= 282; 32.9%) was caused by contact with another athlete. Non-contact trauma (n=172; 20.0%) and overuse either with gradual (n= 78; 9.1%) or sudden onset (n=110; 12.8%) were also frequent causes of injury. Some injuries were due to contact with an object (n= 115; 13.4%) and recurrence of previous injury (n=47; 5.5%). Other potential causes of injury (playing field conditions (n=15), weather conditions (n= 8), equipment failure (n=5), others (18)) were rarely stated.

Time-loss from sport after injury

Information in relation to time-loss from sport after injury was available for 844 (80%) injuries. About half of the injuries (n=419; 49.6%) were expected to prevent the athlete from participating in competition or training. Physicians estimated that 275 (33.0%) injuries would result in an absence from sports up to one week, 93 (11.2%) in an absence for more than a week but less than a month and 41 (4.9%) for more than 28 days absence. In ten cases the duration of absence was not specified.

The 41 injuries with an estimated time-loss of more than four weeks was comprised of 13 fractures (foot (n= 4), clavicle (n= 3), knee (n= 2), arm, wrist, hand and pelvis), eight ligament ruptures (knee (n= 6), ankle (n= 2)), five dislocations (shoulder (n= 2), knee, elbow and wrist), three ruptures of Achilles tendon, three sprains (ankle, knee and shoulder), six muscle injuries (thigh (n= 4), hip and lower leg), two complex lesions of the joints (shoulder, knee) and one concussion. Out of the 221 injuries for which information about time-loss was not specified at least further 22 were suspected to be severe based on the type of injury (10 fractures, 8 ligament ruptures, 4 complex injuries with ligament ruptures).

Injuries in different sports

Injuries were reported from all sports (for details see Table 3). In relation to the number of registered athletes, the risk of incurring an injury was highest in football, taekwondo, field hockey, handball, weightlifting and boxing; and lowest for sailing, canoe/kayak, rowing, synchronised swimming, diving, fencing and swimming.

For most sports, injuries in training and competition were reported, but in substantially different proportions. No in-competition injury was reported from archery, canoe/kayak, diving shooting and synchronised swimming. Although incidence of injuries in these sports was low, it is interesting to note that training injuries were reported. The proportion of trainings injuries was high in table tennis, tennis, swimming, gymnastics, beach volleyball, equestrian, modern pentathlon and athletics. A high percentage of competitions injuries were incurred in boxing, water polo, hockey, handball weightlifting, baseball and judo.

Consequently, also the causes of injury differed between the sports. Overuse was a frequent cause (>40% of the injuries) in rowing, modern pentathlon, sailing, shooting, tennis, beach volleyball, triathlon, athletics, weightlifting, swimming and badminton. Contact with another athlete was the cause of more than 50% of the injuries in boxing, judo, water polo, handball, taekwondo, wrestling and football. In baseball and hockey contact with a moving object (ball, stick) was the cause in more than half of the injuries. A non-contact trauma was frequently incurred by cyclists, riders, shooters, tennis, and volleyball players.

Time-loss injuries were reported from all sports except canoe flat-water, diving, sailing and synchronised swimming. The risk of incurring a time-loss injury was highest in football, taekwondo, handball, weightlifting, boxing, triathlon, and athletics (see table 3).

Table 3: Number of gold medals, athletes and injuries in different sports

Sports	Gold medals	Registered athletes	Total no. of injuries (% of athletes)	Estim. % of athletes with time-loss injuries	Injuries in training (% of injuries) [b]	Injuries in competition (% of injuries) [b]
Archery	4	128	9 (7.0%)	2.3%	6 (100%)	0
Athletics	47	2132	241 (11.3%)	7.3%	69 (42.6%)	93 (57.4%)
Baseball	1	189	21 (11.1%)	5.6%	2 (10.5%)	17 (89.5%)
Badminton	5	172	8 (4.7%)	3.1%	1 (14.3%)	6 (85.7%)
Basketball	2	287	38 (13.2%)	4.1%	6 (19.4%)	25 (80.6%)
Beach volleyball	2	96	8 (8.3%)	2.1%	4 (50.0%)	4 (50.0%)
Boxing	11	281	42 (14.9%)	8.1%	2 (5.3%)	36 (94.7%)
Canoe/kayak	16	324	4 (1.2%)	0.6%	4 (100%)	0
Cycling	18	518	30 (5.8%)	2.0%	10 (33.0%)	20 (66.7%)
Diving	8	145	3 (2.1%)	0	3 (100%)	0
Equestrian	6	193	10 (5.2%)	1.0%	5 (50.0%)	5 (50.0%)
Football	2	496	156 (31.5%)	16.4%	28 (18.2%)	126 (81.8%)
Fencing	10	206	5 (2.4)	0.8%	0	2 (100%)
Gymnastic	18	318	24 (7.5%)	2.5%	11 (52.4%)	10 (47.6%)
Handball	2	334	58 (17.4%)	13.4%	4 (7.4%)	50 (92.6%)
Hockey	2	382	78 (20.4%)	3.5%	5 (6.9%)	67 (93.1%)
Judo	14	385	53 (11.2%)	6.4%	5 (11.6%)	38 (88.4%)
Modern pentathlon	2	71	4 (5.6%)	4.2%	2 (50.0%)	2 (50.0%)
Rowing	14	548	10 (1.8%)	0.6%	1 (16.7%)	5 (83.3%)
Sailing	11	400	3 (0.8%)	0	1 (33.3%)	2 (66.7%)
Shooting	15	386	3 (7.8%)	3.9%	2 (100%)	0
Softball	1	119	16 (13.4%)	1.9%	2 (14.3%)	12 (85.7%)
Swimming	34	1046	36 (3.4%)	1.0%	15 (62.5%)	8 (34.8%)
Synchronised swimming	2	104	2 (1.9%)	0	2 (100%)	0
Tennis	4	168	10 (5.9%)	3.0%	5 (62.5%)	3 (37.5%)
Taekwondo	8	126	34 (27.0%)	16.2%	9 (36.0%)	16 (64.0%)
Triathlon	2	109	10 (9.2%)	8.0%	3 (33.3%)	6 (66.7%)
Table Tennis	4	172	9 (5.2%)	2.6%	5 (83.3%)	1 (16.7%)
Volleyball	2	287	23 (8.0%)	3.6%	4 (18.4%)	18 (81.8%)
Weightlifting	15	255	43 (16.9%)	11.4%	3 (10.3%)	26 (89.7%)
Water Polo	2	259	25 (9.7%)	3.7%	2 (9.5%)	19 (90.5%)
Wrestling	18	341	32 (9.4%)	6.1%	4 (20.0%)	16 (80.0%)
Total	**302**	**10977**	**1048** [a] **(9.6%)**	**4.7%**	**225** [b] **(26.2%)**	**633** [b] **(73.8%)**

[a] sport is missing for 7 injuries;
[b] information missing for 197 injuries

The fractures were incurred by six (4.8%) taekwondo, five (1.8%) boxers, ten (0.5%) track and field athletes, two track cyclists, two gymnasts, two judoka, two triathlon athletes, one rider, one synchronised swimmer, one wrestler, six (1.2%) football, four (3.0%) handball, two hockey, two water polo, two volleyball, one softball and one table tennis player. The dislocations and ruptures of tendon or ligament affected four (3.2%) taekwondo, eight (2.1%) judoka, five (2.0%) weightlifter, five (1.5%) wrestler, seven (0.3%) track and field athlete, two BMX and one mountain bike cyclists, a boxer, a diver, a fencer, a triathlon athlete, seven (2.1%) handball, four (1.4%) basketball, five (1.3%) hockey, three (0.6%) football, two volleyball, a baseball, a badminton, a beach volleyball, a table tennis and a water polo player. Concussions were reported from boxing (n= 2; 0.7%), football (n= 3; 0.6%), baseball, basketball, hockey judo, taekwondo, cycling road and slalom canoe/kayak (each n=1).

Age and gender of injured athletes

The age of the injured athletes ranged between 15 and 53 years with no significant difference between men and women (mean= 25.7; sd= 4.75; missing: 122). In 549 (54.2%) cases the gender of the injured athlete was male and in 464 (45.8%) female (missing: 42). These characteristics were similar to the age (mean= 25.9; sd= 5.48; range: 12-67) and gender distribution of all registered athletes (male: 57.6%; female: 42.4%).

DISCUSSION

This study aimed to analyse all sports injuries of athletes participating in the Olympic Games 2008. To the authors' knowledge this is the first survey on injuries during the Olympic Games including all sports.

The injury surveillance system[32] proved to be accepted by the NOC and the LOC medical personnel and to be feasible in a large multi-sport event. The data indicate that the injury surveillance system covered almost all participating athletes. The NOC physicians and therapists of 92 national teams covering 88% of the registered athletes took part in the study. The NOCs with more than fifty athletes returned 80% of the daily injury report forms. For NOCs with less

than fifty athletes, the response rate was lower, because some reported only if an athlete was injured. In addition to the injury reports from the NOCs, daily reports were received from the medical stations at the Olympic venues and the polyclinic in the Olympic Village. The percentage of injuries reported from the venues and the polyclinic increased for NOCs with fewer athletes, since small NOCs often do not have medical personnel. The total rate of injuries increased from large NOCs to smaller NOCs, probably for the same reason. It is assumed that due to the lack of own medical care in smaller teams, the athletes had more injuries and/or consulted the medical facilities offered during the Olympics also for pre-existing injuries. However, since athletes from NOC with less than ten athletes represented less than 5% of the total population, this bias can be neglected. On the other hand, some participating NOCs and some medical stations at the Olympic venues did not return forms on all days. Thus, it is estimated that the injury incidence is slightly higher than reported.

Approximately 10% of registered athletes incurred an injury during the 2008 Olympic Games. This injury rate was considerably lower than those of the 1985 Junior Olympic Games (25% of 2871 athletes sought medical attention)[28] and of the 1994 Australian University Games (19.5% of 5106 athletes incurred an injury which required medical attention),[30] but substantially higher than for the 1994 North Summer Games (55 of 6243 athletes received medical attention)[29] and for the Badger States Summer Games 199-96 (285 of 31,580 athletes suffered a reportable injury)[31]. Although these studies surveyed injuries in large multi-sport events, the characteristics of the athletes varied substantially between them and to the present study. Therefore, a comparison can only demonstrate the wide range of injury rates in different sport events. Only one study on sports injuries during the Olympic Games was found in literature.[32] At the 2004 Olympic Games in Athens, all injuries incurred during team sports competitions were recorded using the same injury definition and a similar mode of data collection.[32 33] The total number of matches (2004: 488; 2008: 498) as well as the number of all in-competition injuries (2004: 378; 2008: 333) and time-loss injuries in competition (2004: 147; 2008: 150) were similar in the 2004 Olympic Games and the present study. With respect to the single sports, the number of time-loss injuries in competition was similar in the 2004 and the 2008 Olympics for football, handball, baseball, softball and water polo; lower for basketball (which might be partly due to a rule change) and field hockey, and higher for volleyball. In comparison to previous studies using a similar injury definition and surveillance system during single sports tournaments, comparable injury rates have

been reported for football, [1 4 6 7] handball[21] and athletics[24].

About half of the injuries affected the lower extremity, with contusions, sprains and strains being the most common types. This is in agreement with most publications on sports injuries.[28 29 30 31 32] The diagnoses covered a wide spectrum, however ankle sprains and thigh strain were the most prevalent diagnoses as usually in sport. It is worth to mention, that 10% of the injuries affected the head, mainly diagnosed as skin lesions or contusions, but also twelve concussions were reported. The risk of concussion is a major concern in certain sport, and it diagnosis, treatment and return-to-play guidelines have been the focus of recent consensus statements.[34 35] About half of the injuries were reported to result in time-loss from sport, which is comparable to other studies using the same injury definition and similar assessment methods. [1 4 6 7 21 24 32]

The majority of injuries were incurred during competition and one quarter during training which is in agreement with a study on injuries during 2007 World Athletics Championships using the same injury surveillance system.[24] Injuries in training and in competition differed significantly in all injury characteristics and with regard to the different sports. In general, contact with another athlete was the most frequent cause of injury, followed by non-contact trauma and overuse. Other potential causes of injury such as equipment failure, field and weather conditions were rare. However, the causes of injury differed substantially between the sports, and thus injury prevention programmes should be tailor-made to the injury profile of the respective sport.

Injuries were reported from all sports with the highest injury risk in football, taekwondo, field hockey, handball, weightlifting, boxing, triathlon, and athletics. Laskowski et al[29] found the highest percentage of injured athletes in judo, power lifting, and track and field; Cunningham and Cunningham[30] in hockey, taekwondo, and football. Greene and Bernhardt[31] observed the highest injury rates in basketball, cycling, wrestling, roller hockey and football. Martin et al[28] reported the most encounters for field hockey and football players. Although there is a certain variation, it can be concluded that teams sports (such as football, handball, basketball and hockey) and martial sports (especially taekwondo and wrestling) have a relatively high injury risk. On the other hand, the lowest injury risk during the Beijing Olympics was observed for sailing,

canoe/kayak, rowing, synchronised swimming, diving, fencing and swimming which is also in agreement with the literature.[28 29 30 31]

Limitations of the study and future research

The injury definition and methods applied have been discussed in detail in another publication.[33] However, some limitations of the present study should be mentioned. Time-loss for sport was based on the physician´s estimate of the number of days that the athlete will not be able to undertake their normal training programme or will not be able to compete. A follow-up of the injured athletes could improve the validity of this data,[33] but was impractical because small NOCs have no associated medical personnel. The causes of injury were described in given categories, and a more sophisticate analysis of injury mechanisms might provide more detailed information for the development of preventive programmes.[36] For example, incidences of contact injuries should be studied with respect to the adequacy of rules to protect the athletes from injury and potential rule violation;[37 38] motion analysis might help to understanding of the mechanisms of non-contact injuries.[39] The present study focused exclusively on injuries incurred in training and competition. Future studies should also include pre-existing (chronic) injuries and other medical conditions (such as illnesses or disease) since they also can significantly affect the health and performance of the athletes.

CONCLUSION

The injury surveillance system proved to be accepted by all involved medical personnel and to be feasible in a large multi-sport event. The data indicate that the injury surveillance system covered almost all participating athletes. The consistent findings with previous studies demonstrate the high quality of the data obtained. About 10% of the athletes incurred an injury during the 2008 Beijing Olympic Games, half of them a time-loss injury. The diagnoses, causes and risk of injury differed substantially between the sports. Therefore, injury prevention programmes should be tailor-made to the injury profile of the respective sport. In future Olympic Games, the injury surveillance should be continued and, if possible, extended with respect to follow-up of severe injuries, more sophisticated analysis of injury mechanisms, and the inclusion of chronic injuries and sport-related illnesses.

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