Sports Injuries During the Summer Olympic Games 2008

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Background: Standardized assessment of sports injuries provides important epidemiological information and also directions for injury prevention.

Purpose: To analyze the frequency, characteristics, and causes of injuries incurred during the Summer Olympic Games 2008.

Study Design: Descriptive epidemiology study.

Methods: The chief physicians and/or chief medical officers of the national teams were asked to report daily all injuries newly incurred during the Olympic Games on a standardized injury report form. In addition, injuries were reported daily by the physicians at the medical stations at the different Olympic venues and at the polyclinic in the Olympic Village.

Results: Physicians and/or therapists of 92 national teams covering 88% of the 10 977 registered athletes took part in the study. In total, 1055 injuries were reported, resulting in an incidence of 96.1 injuries per 1000 registered athletes. 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. The majority (72.5%) of injuries were incurred in competition. One third of the injuries were caused by contact with another athlete, followed by overuse (22%) and noncontact 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 soccer, taekwondo, hockey, handball, weightlifting, and boxing (all ≥15% of the athletes) and lowest for sailing, canoeing/kayaking, rowing, synchronized 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; multisport event; top-level athletes; championships

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 emphasizing the protection of the athletes' health and the prevention of injuries. As has been shown previously,[12,18] 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-sport tournaments, such as soccer,[9,10,17-19,36,39]

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rugby,[6,13,16,22,38] karate,[3,30,31] ice hockey,[33,34] volleyball,[35] beach volleyball,[5] handball,[25] tennis,[15] cycling,[7] and athletics.[1] For multisport events, however, only 8 studies were found in the literature, including 3 on disabled athletes.[28,32,37] Sports injuries were surveyed at the 1985 Junior Olympics (13 sports),[27] the 1994 Star of the North Summer Games (21 sports),[26] the 1994 Australian University Games (19 sports),[8] the Badger States Summer Games 1994-1996 (10 sports),[14] and the 2004 Olympic Games (8 sports).[21]

During the 2004 Olympic Games,[21] the incidence and characteristics of injuries in all team sport tournaments (soccer, handball, basketball, field hockey, baseball, softball, water polo, and volleyball) were recorded using an injury surveillance system established in soccer[9,12,17-19,39] and handball.[25] Because the compliance with the procedure was excellent and the quality of the data obtained high,[21] the injury surveillance system was modified to be applicable for both individual and team sports.[20] The IOC injury surveillance system proved feasible and useful for individual sports in a pilot study during the 11th World Championship in Athletics.[1]

The aim of the present study was to analyze 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.[20] In summary, the physicians and/or chief medical officers of the National Olympic Committees (NOCs) were asked to report daily all newly incurred injuries (or the nonoccurrence of injuries) on a standardized injury report form. Injuries were additionally reported by the Local Organizing 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 musculoskeletal complaint (traumatic and overuse) newly incurred due to competition and/or training during the XXIXth Olympiad in Beijing that received medical attention regardless of the consequences with respect to absence from competition or training.[20] This injury definition includes 5 aspects: (1) all injuries that received medical attention (not only time loss injuries), (2) newly incurred injuries (pre-existing, not fully rehabilitated injuries should not be reported) and reinjuries (injuries of the same location and type should be reported only if the athlete has returned to full participation after the previous injury), (3) in-competition and training injuries, (4) during the Olympic Games (August 9-24, 2008, except soccer; for details, see "Implementation"), and (5) 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 2 diagnoses.[20]

Injury Report Form

The injury report form[20] 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 7 languages (English, French, Chinese, Spanish, German, Russian, and Arabic). The English version is published elsewhere.[20]

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 before 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 1 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 2 days before 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 met on several occasions with or telephoned the physicians of NOCs with more than 50 athletes to motivate daily compliance with form submission.

The NOC chief physician was responsible for reporting the injuries of their athletes. One NOC did not report the injuries in a specific sport; another NOC reported only injuries in 2 sports. For soccer, the collection of the forms was slightly different because the matches started before the official opening, most venues were not in Beijing, and all soccer teams had their own physicians. Following the established procedure in FIFA competitions,[9,12,17-19] the forms were collected after each match by the FIFA Medical Officer at the venue and returned to the IOC study office.

To also receive information about injured athletes of NOCs that did not have a team physician or therapist, injury 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

TABLE 1
Response Rate and Number of Injuries in Relation to Size of the National Team[a]

	Size of NOC (No. of Athletes)						
	>200	100-200	50-99	25-49	10-24	<10	Total
NOCs, n	16	13	26	23	30	96	204
Athletes, n	5679	1811	1821	763	452	451	10977
NOCs with participating physician(s),[b] n (%)	16 (100)	13 (100)	24 (92.3)	13 (56.5)	8 (26.7)	18 (18.8)	92 (45.1)
Forms returned by NOC physicians,[c] n (%)	208 (81.3)	169 (81.3)	301 (78.4)	141 (67.8)	56 (43.8)	174 (60.4)	1050 (72.1)
Injuries reported by NOC physicians, n	405	147	153	39	25	18	787
Injuries reported only by venue or polyclinic,[d,e] n	49	20	49	41	31	68	268
Injuries reported by NOC physicians,[e] %	89.2	88.0	75.7	48.8	44.6	20.9	74.6
Total injuries,[e] n	454	167	202	80	56	86	1055
Injuries per 1000 registered athletes,[e] n	79.9	92.2	110.9	104.8	123.9	190.7	96.1

[a]NOC, National Olympic Committee.
[b]NOCs of which the team physician returned at least 1 injury report form.
[c]Except soccer (for soccer, an additional 264 of 294 [89.9%] forms were returned).
[d]Injuries reported also by NOC physicians are not included.
[e]Country is missing in 10 cases.

venues were requested to report on a slightly modified injury report form (additional information on the 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 (soccer, sailing, equestrian) were contacted via e-mail and telephone. 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 the accreditation number of the athlete and the location and type of injury. Thus, information on the circumstance (competition/training) and cause of injury and resulting time loss in sport was missing for these injuries. In case of duplicate reporting, information from the NOC physician was preferred to the LOC physician's report, and information from the venue and polyclinics was 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 that 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 soccer and the reduced number of athletes reported on in 2 NOCs were regarded in these calculations.

All data were processed using Excel (Microsoft, Redmond, Washington) and SPSS (Chicago, Illinois). Statistical methods applied were descriptive statistics, frequencies, crosstabulations, t test, and χ^2 test. Significance was accepted at $P < .05$.

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. In addition, 264 injury report forms from medical stations at the different Olympic venues and all daily reports from the polyclinic in the Olympic Village were received.

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 because 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. Because 46 injuries had multiple locations or types, 1108 diagnoses were named (for details, see online appendix for this article at http://ajs.sagepub.com/supplemental/). The

TABLE 2
Athletes and Injuries in Different Sports

Sports	Registered Athletes, n	Total Injuries, n (% of Athletes)	Estimated Athletes With Time Loss Injuries, %	Injuries in Training,[a] n (%)	Injuries in Competition,[a] n (%)
Archery	128	9 (7.0)	2.3	6 (100)	0
Athletics	2132	241 (11.3)	7.3	69 (42.6)	93 (57.4)
Baseball	189	21 (11.1)	5.6	2 (10.5)	17 (89.5)
Badminton	172	8 (4.7)	3.1	1 (14.3)	6 (85.7)
Basketball	287	38 (13.2)	4.1	6 (19.4)	25 (80.6)
Beach volleyball	96	8 (8.3)	2.1	4 (50.0)	4 (50.0)
Boxing	281	42 (14.9)	8.1	2 (5.3)	36 (94.7)
Canoeing/kayaking	324	4 (1.2)	0.6	4 (100)	0
Cycling	518	30 (5.8)	2.0	10 (33.0)	20 (66.7)
Diving	145	3 (2.1)	0	3 (100)	0
Equestrian	193	10 (5.2)	1.0	5 (50.0)	5 (50.0)
Football	496	156 (31.5)	16.4	28 (18.2)	126 (81.8)
Fencing	206	5 (2.4)	0.8	0	2 (100)
Gymnastics	318	24 (7.5)	2.5	11 (52.4)	10 (47.6)
Handball	334	58 (17.4)	13.4	4 (7.4)	50 (92.6)
Hockey	382	78 (20.4)	3.5	5 (6.9)	67 (93.1)
Judo	385	53 (11.2)	6.4	5 (11.6)	38 (88.4)
Modern pentathlon	71	4 (5.6)	4.2	2 (50.0)	2 (50.0)
Rowing	548	10 (1.8)	0.6	1 (16.7)	5 (83.3)
Sailing	400	3 (0.8)	0	1 (33.3)	2 (66.7)
Shooting	386	3 (7.8)	3.9	2 (100)	0
Softball	119	16 (13.4)	1.9	2 (14.3)	12 (85.7)
Swimming	1046	36 (3.4)	1.0	15 (62.5)	8 (34.8)
Synchronized swimming	104	2 (1.9)	0	2 (100)	0
Tennis	168	10 (5.9)	3.0	5 (62.5)	3 (37.5)
Taekwondo	126	34 (27.0)	16.2	9 (36.0)	16 (64.0)
Triathlon	109	10 (9.2)	8.0	3 (33.3)	6 (66.7)
Table tennis	172	9 (5.2)	2.6	5 (83.3)	1 (16.7)
Volleyball	287	23 (8.0)	3.6	4 (18.4)	18 (81.8)
Weightlifting	255	43 (16.9)	11.4	3 (10.3)	26 (89.7)
Water polo	259	25 (9.7)	3.7	2 (9.5)	19 (90.5)
Wrestling	341	32 (9.4)	6.1	4 (20.0)	16 (80.0)
Total	10977	1048[b] (9.6)	4.7	225[a] (26.2)	633[a] (73.8)

[a]Information is missing for 197 injuries.
[b]Sport is missing for 7 injuries.

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 = 149; 13.4%), and head/neck (n = 133; 12.0%). The thigh (13.3%) and knee (12.1%) were most commonly injured, followed by the lower leg and ankle. Head injuries (9.4%) were also frequent, mainly diagnosed as skin lesions or contusions.

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, 10 during warm-up for competition, and 225 (26.2%) during training. The injuries incurred during warm-up before competition were analyzed 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 2).

One third of the injuries (n = 282; 32.9%) were caused by contact with another athlete. Noncontact 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], and others [n = 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 1 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 10 cases, the duration of absence was not specified.

The 41 injuries with an estimated time loss of more than 4 weeks comprised 13 fractures (foot [n = 4], clavicle [n = 3], knee [n = 2], arm, wrist, hand, and pelvis), 8 ligament ruptures (knee [n = 6], ankle [n = 2]), 5 dislocations (shoulder [n = 2], knee, elbow, and wrist), 3 ruptures of Achilles tendon, 3 sprains (ankle, knee, and shoulder), 6 muscle injuries (thigh [n = 4], hip, and lower leg), 2 complex lesions of the joints (shoulder, knee), and 1 concussion. Out of the 221 injuries for which information about time loss was not specified, at least a 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 2). In relation to the number of registered athletes, the risk of incurring an injury was highest in soccer, taekwondo, field hockey, handball, weightlifting, and boxing and lowest for sailing, canoeing/kayaking, rowing, synchronized 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, canoeing/kayaking, diving, shooting, and synchronized swimming. Although the incidence of injuries in these sports was low, it is interesting to note that training injuries were reported. The proportion of training injuries was high in table tennis, tennis, swimming, gymnastics, beach volleyball, equestrian, modern pentathlon, and athletics. A high percentage of competition injuries were incurred in boxing, water polo, hockey, handball, weightlifting, baseball, and judo.

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 noncontact trauma was frequently incurred by cyclists, riders, shooters, tennis players, and volleyball players.

Time loss injuries were reported from all sports except flat-water canoeing, diving, sailing, and synchronized swimming. The risk of incurring a time loss injury was highest in soccer, taekwondo, handball, weightlifting, boxing, triathlon, and athletics (Table 2).

The fractures were incurred by 6 (4.8%) taekwondo athletes, 5 (1.8%) boxers, 10 (0.5%) track and field athletes, 2 track cyclists, 2 gymnasts, 2 judoka athletes, 2 triathlon athletes, 1 rider, 1 synchronized swimmer, 1 wrestler, 6 (1.2%) football players, 4 (3.0%) handball players, 2 hockey players, 2 water polo players, 2 volleyball players, 1 softball player, and 1 table tennis player. The dislocations and ruptures of the tendon or ligament affected 4 (3.2%) taekwondo athletes, 8 (2.1%) judoka athletes, 5 (2.0%) weightlifters, 5 (1.5%) wrestlers, 7 (0.3%) track and field athletes, 2 BMX and 1 mountain bike cyclists, a boxer, a diver, a fencer, a triathlon athlete, 7 (2.1%) handball players, 4 (1.4%) basketball players, 5 (1.3%) hockey players, 3 (0.6%) football players, 2 volleyball players, a baseball player, a badminton player, a beach volleyball player, a table tennis player, and a water polo player. Concussions were reported from boxing (n = 2; 0.7%), football (n = 3; 0.6%), baseball, basketball, hockey, judo, taekwondo, road cycling, and slalom canoeing/kayaking (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) and gender distribution of all registered athletes (male, 57.6%; female, 42.4%).

DISCUSSION

This study aimed to analyze 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[20] was accepted by the NOC and the LOC medical personnel and is feasible in a large multisport event. The data indicate that the injury surveillance system covered almost all participating athletes. The NOC physicians and/or therapists of 92 national teams covering 88% of the registered athletes took part in the study. The NOCs with more than 50 athletes returned 80% of the daily injury report forms. For NOCs with fewer than 50 athletes, the response rate was lower because some reported only if an athlete was injured and did not submit the daily report when no injury had occurred. 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 because 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 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, because athletes from NOCs with fewer than 10 athletes represented less than 5% of the total population, this bias may 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)[27] and of the 1994 Australian University Games (19.5% of 5106 athletes incurred an injury that required medical attention)[8] but substantially higher than for the 1994 North Summer Games (55 of 6243 athletes received medical attention)[26] and for the Badger States Summer Games 1994-1996 (285 of 31580 athletes suffered a reportable injury).[14] Although these studies surveyed injuries in large multisport events, the characteristics of the athletes varied substantially between them and the present study. Therefore, a comparison can only demonstrate the wide range of injury rates in different sports events. Only one study on sports injuries during the Olympic Games exists in the literature.[21] 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.[20,21] 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 soccer, handball, baseball, softball, and water polo; lower for basketball (which might be partly due to rule changes regarding elbowing, blocks, and contact without ball possession) and field hockey; and higher for volleyball. In comparison to previous studies using a similar injury definition and surveillance system during single-sport tournaments, comparable injury rates have been reported for soccer,[9,17-19] handball,[25] and athletics.[1]

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.[8,14,21,26,27] The diagnoses covered a wide spectrum; however, ankle sprains and thigh strain were the most prevalent diagnoses. It is worth mentioning that 10% of the injuries affected the head, mainly diagnosed as skin lesions or contusions, but also 12 concussions were reported. The risk of concussion is a major concern in certain sports, and its diagnosis, treatment, and return-to-play guidelines have been the focus of recent consensus statements.[4,29] About half of the injuries were reported to result in time loss from sport, which is comparable with other studies using the same injury definition and similar assessment methods.[1,9,17-19,21,25]

The majority of injuries were incurred during competition and one quarter during training, which is in agreement with a study on injuries during the 2007 World Athletics Championships using the same injury surveillance system.[1] 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 noncontact trauma and overuse. Other potential causes of injury such as equipment failure and field and weather conditions were rare. However, the causes of injury differed substantially between the sports, and thus injury prevention programs should be tailor made to the injury profile of the respective sport.

Injuries were reported from all sports with the highest injury risk in soccer, taekwondo, field hockey, handball, weightlifting, boxing, triathlon, and athletics. Laskowski et al[26] found the highest percentage of injured athletes in judo, power lifting, and track and field, while Cunningham and Cunningham[8] found the highest percentage in hockey, taekwondo, and soccer. Greene and Bernhardt[14] observed the highest injury rates in basketball, cycling, wrestling, roller hockey, and soccer. Martin et al[27] reported the most encounters for field hockey and soccer players. Although there is a certain variation, it can be concluded that some team sports (such as soccer, handball, basketball, and hockey) and some 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, canoeing/kayaking, rowing, synchronized swimming, diving, fencing, and swimming, which is also in agreement with the literature.[8,14,26,27]

Limitations of the Study and Future Research

The injury definition and methods applied have been discussed in detail in another publication.[20] 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 his or her normal training program or will not be able to compete. A follow-up of the injured athletes could improve the validity of these data[20] but was impractical because small NOCs have no associated medical personnel. The causes of injury were described in given categories, and a more sophisticated analysis of injury mechanisms might provide more detailed information for the development of a preventive program.[23] 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,[2,11] and video analysis might help in the understanding of the mechanisms of noncontact injuries.[24] 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) because they also can significantly affect the health and performance of the athletes.

CONCLUSION

The injury surveillance system was accepted by all involved medical personnel and is feasible in a large multisport 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 risks of injury differed substantially between the sports. Therefore, injury prevention programs 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 sports-related illnesses.

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REFERENCES

1. Alonso JM, Junge A, Renstrom P, Engebretsen L, Mountjoy M, Dvorak J. Sports injury surveillance during the 2007 IAAF World Athletics Championships. *Clin J Sport Med.* 2009;19(1):26-32.
2. Andersen TE, Larsen O, Tenga A, Engebretsen L, Bahr R. Football incident analysis: a new video based method to describe injury mechanisms in professional football. *Br J Sports Med.* 2003;37(3):226-232.
3. Arriaza R, Leyes M. Injury profile in competitive karate: prospective analysis of three consecutive World Karate Championships. *Knee Surg Sports Traumatol Arthrosc.* 2005;13(7):603-607.
4. Aubry M, Cantu R, Dvorak J, et al. Summary and agreement statement of the First International Conference on Concussion in Sport, Vienna 2001: recommendations for the improvement of safety and health of athletes who may suffer concussive injuries. *Br J Sports Med.* 2002;36(1):6-10.
5. 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(1):119-125.
6. Best JP, McIntosh AS, Savage TN. Rugby World Cup 2003 injury surveillance project. *Br J Sports Med.* 2005;39(11):812-817.
7. Brogger-Jensen T, Hvass I, Bugge S. Injuries at the BMX Cycling European Championship, 1989. *Br J Sports Med.* 1990;24(4):269-270.
8. Cunningham C, Cunningham S. Injury surveillance at a national multisport event. *Aust J Sci Med Sport.* 1996;28(2):50-56.
9. Dvorak J, Junge A, Grimm K, Kirkendall D. Medical report from the 2006 FIFA World Cup Germany. *Br J Sports Med.* 2007;41(9):578-581, discussion 581.
10. Elias SR. 10-year trend in USA Cup soccer injuries: 1988-1997. *Med Sci Sports Exerc.* 2001;33(3):359-367.
11. Fuller CW, Junge A, Dvorak J. An assessment of football referees' decisions in incidents leading to player injuries. *Am J Sports Med.* 2004;32(1 Suppl):17S-22S.
12. Fuller CW, Junge A, Dvorak J. A six year prospective study of the incidence and causes of head and neck injuries in international football. *Br J Sports Med.* 2005;39 Suppl 1:i3-9.
13. Fuller CW, Laborde F, Leather RJ, Molloy MG. International Rugby Board Rugby World Cup 2007 injury surveillance study. *Br J Sports Med.* 2008;42(6):452-459.
14. Greene JJ, Bernhardt D. Medical coverage analysis for Wisconsin's Olympics: the Badger State Games. *Wis Med J.* 1997;96(6):41-44.
15. Hutchinson MR, Laprade RF, Burnett QM 2nd, Moss R, Terpstra J. Injury surveillance at the USTA Boys' Tennis Championships: a 6-yr study. *Med Sci Sports Exerc.* 1995;27(6):826-830.
16. Jakoet I, Noakes TD. A high rate of injury during the 1995 Rugby World Cup. *S Afr Med J.* 1998;88(1):45-47.
17. Junge A, Dvorak J. Injuries in female football players in top-level international tournaments. *Br J Sports Med.* 2007;41 (Suppl 1):i3-7.
18. Junge A, Dvorak J, Graf-Baumann T. Football injuries during the World Cup 2002. *Am J Sports Med.* 2004;32(1 Suppl):23S-27S.
19. Junge A, Dvorak J, Graf-Baumann T, Peterson L. 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(1 Suppl):80S-89S.
20. Junge A, Engebretsen L, Alonso JM, et al. Injury surveillance in multisport events: the International Olympic Committee approach. *Br J Sports Med.* 2008;42(6):413-421.
21. Junge A, Langevoort G, Pipe A, et al. Injuries in team sport tournaments during the 2004 Olympic Games. *Am J Sports Med.* 2006;34(4):565-576.
22. King DA, Gabbett TJ, Dreyer C, Gerrard DF. Incidence of injuries in the New Zealand national rugby league sevens tournament. *J Sci Med Sport.* 2006;9(1-2):110-118.
23. Krosshaug T, Andersen TE, Olsen OE, Myklebust G, Bahr R. Research approaches to describe the mechanisms of injuries in sport: limitations and possibilities. *Br J Sports Med.* 2005;39(6):330-339.
24. Krosshaug T, Slauterbeck JR, Engebretsen L, Bahr R. Biomechanical analysis of anterior cruciate ligament injury mechanisms: three-dimensional motion reconstruction from video sequences. *Scand J Med Sci Sports.* 2007;17(5):508-519.
25. Langevoort G, Myklebust G, Dvorak J, Junge A. Handball injuries during major international tournaments. *Scand J Med Sci Sports.* 2007;17(4):400-407.
26. Laskowski ER, Najarian MM, Smith AM, Stuart MJ, Friend LJ. Medical coverage for multievent sports competition: a comprehensive analysis of injuries in the 1994 Star of the North Summer Games. *Mayo Clin Proc.* 1995;70(6):549-555.
27. Martin RK, Yesalis CE, Foster D, Albright JP. Sports injuries at the 1985 Junior Olympics: an epidemiologic analysis. *Am J Sports Med.* 1987;15(6):603-608.
28. McCormick DP, Niebuhr VN, Risser WL. Injury and illness surveillance at local Special Olympic Games. *Br J Sports Med.* 1990;24(4):221-224.
29. McCrory P, Johnston K, Meeuwisse W, et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Br J Sports Med.* 2005;39(4):196-204.
30. Muller-Rath R, Bolte S, Petersen P, Mommsen U. [Injury profile in modern competitive karate: analysis of 1999 WKC-Karate World Championship Games in Bochum]. *Sportverletz Sportschaden.* 2000;14(1):20-24.
31. Muller-Rath R, Miltner O, Mamarvar M, Mumme T. [Risk of injury in adolescent and junior competitive karate]. *Sportverletz Sportschaden.* 2005;19(4):191-194.
32. Nyland J, Snouse SL, Anderson M, Kelly T, Sterling JC. Soft tissue injuries to USA paralympians at the 1996 summer games. *Arch Phys Med Rehabil.* 2000;81(3):368-373.
33. Roberts WO, Brust JD, Leonard B. Youth ice hockey tournament injuries: rates and patterns compared to season play. *Med Sci Sports Exerc.* 1999;31(1):46-51.

34. Roberts WO, Brust JD, Leonard B, Herbert BJ. Fair-play rules and injury reduction in ice hockey. *Arch Pediatr Adolesc Med.* 1996;150(2):140-145.
35. Schafle MD, Requa RK, Patton WL, Garrick JG. Injuries in the 1987 national amateur volleyball tournament. *Am J Sports Med.* 1990;18(6):624-631.
36. Walden M, Hagglund M, Ekstrand J. Football injuries during European Championships 2004-2005. *Knee Surg Sports Traumatol Arthrosc.* 2007;15(9):1155-1162.
37. Webborn N, Willick S, Reeser JC. Injuries among disabled athletes during the 2002 Winter Paralympic Games. *Med Sci Sports Exerc.* 2006;38(5):811-815.
38. Wekesa M, Asembo JM, Njororai WW. Injury surveillance in a rugby tournament. *Br J Sports Med.* 1996;30(1):61-63.
39. Yoon YS, Chai M, Shin DW. Football injuries at Asian tournaments. *Am J Sports Med.* 2004;32(1 Suppl):36S-42S.