

Sports injury and illness incidence in the Rio de Janeiro 2016 Olympic Summer Games: A prospective study of 11 274 athletes from 207 countries

Torbjørn Soligard,^{1,2} Kathrin Steffen,³ Debbie Palmer,^{4,5} Juan Manuel Alonso,⁶ Roald Bahr,³ Alexandre Dias Lopes,⁷ Jiri Dvorak,⁸ Marie-Elaine Grant,⁹ Willem Meeuwisse,² Margo Mountjoy,¹⁰ Leonardo Oliveira Pena Costa,¹¹ Natalia Salmina,¹² Richard Budgett,¹ Lars Engebretsen^{1,3,13}

► Additional material is published online only. To view please visit the journal online (<http://dx.doi.org/10.1136/bjsports-2017-097956>).

For numbered affiliations see end of article.

Correspondence to

Torbjørn Soligard, Department of Medical & Scientific, International Olympic Committee, Château de Vidy, 1007 Lausanne, Switzerland; torbjorn.soligard@olympic.org

Received 19 April 2017
 Revised 28 June 2017
 Accepted 29 June 2017

ABSTRACT

Objective To describe the pattern of injuries and illnesses sustained during the Games of the XXXI Olympiad, hosted by Rio de Janeiro from 5 to 21 August 2016.

Methods We recorded the daily incidence of athlete injuries and illnesses (1) through the reporting of all National Olympic Committee (NOC) medical teams and (2) in the polyclinic and medical venues by the Rio 2016 medical staff.

Results In total, 11 274 athletes (5089 women, 45%; 6185 men, 55%) from 207 NOCs participated in the study. NOC and Rio 2016 medical staff reported 1101 injuries and 651 illnesses, equalling 9.8 injuries and 5.4 illnesses per 100 athletes over the 17-day period. Altogether, 8% of the athletes incurred at least one injury and 5% at least one illness. The injury incidence was highest in BMX cycling (38% of the athletes injured), boxing (30%), mountain bike cycling (24%), taekwondo (24%), water polo (19%) and rugby (19%), and lowest in canoe slalom, rowing, shooting, archery, swimming, golf and table tennis (0%–3%). Of the 1101 injuries recorded, 40% and 20% were estimated to lead to ≥ 1 and > 7 days of absence from sport, respectively. Women suffered 40% more illnesses than men. Illness was generally less common than injury, with the highest incidence recorded in diving (12%), open-water marathon (12%), sailing (12%), canoe slalom (11%), equestrian (11%) and synchronised swimming (10%). Illnesses were also less severe; 18% were expected to result in time loss. Of the illnesses, 47% affected the respiratory system and 21% the gastrointestinal system. The anticipated problem of infections in the Rio Olympic Games did not materialise, as the proportion of athletes with infectious diseases mirrored that of recent Olympic Games (3%).

Conclusion Overall, 8% of the athletes incurred at least one injury during the Olympic Games, and 5% an illness, which is slightly lower than in the Olympic Summer Games of 2008 and 2012.

of disease and hospital admission.^{3–7} However, concomitantly, they run a higher risk of musculoskeletal disorders and long-term disability after the end of their careers.^{4 8–11}

Systematic injury and illness surveillance is a prerequisite to effective protection of the health of the athletes. Epidemiological data contribute to better planning and provision of athlete health-care and, importantly, inform the development of measures to prevent injury and illness.^{12 13}

Some International Sports Federations or research institutes have set up injury and illness surveillance systems either longitudinally, over one or more seasons, or in certain main events.^{14–76} For Beijing 2008, the IOC developed the IOC injury surveillance system^{77 78} which, to account for all health aspects, was expanded for Vancouver 2010 to also include illnesses.⁷⁹ Since then, the surveillance system has been implemented in London 2012⁸⁰ and Sochi 2014.⁸¹ In these Games, the injury and illness incidences have ranged from 9.6 to 14.0 injuries and from 7.2 to 8.9 illnesses per 100 athletes.

Our aim was to describe the incidence and characteristics of the sports injuries and illnesses occurring during the Rio 2016 Olympic Summer Games.

METHODS

We employed the IOC injury and illness surveillance system for multi-sport events in this prospective cohort study.⁷⁷ We asked all National Olympic Committee (NOC) medical teams to report the daily occurrence (or non-occurrence) of athlete injuries and illnesses on a standardised medical report form (online appendix 1). Concurrently, we retrieved the same information on all athletes treated for injuries and illnesses in the polyclinic and all other medical venues operated by the Organizing Committee of the Olympic and Paralympic Games Rio 2016 (Rio 2016) medical staff. These data were collected through an electronic medical record system (GE Centricity Practice Solution), which was used for the first time in the Games.

We used the athlete accreditation number to control for duplicates resulting from athletes being treated for the same condition by both NOC and Rio 2016 medical staff. In such cases, we retained the NOC data.

INTRODUCTION

Routine physical activity elicits a number of health benefits, including a reduction in the risk of numerous chronic diseases and premature death.^{1 2} Compared with the general population, elite athletes seem to reap additional health benefits in the form of greater life expectancy and lower risk



CrossMark

To cite: Soligard T, Steffen K, Palmer D, et al. *Br J Sports Med* Published Online First: [please include Day Month Year]. doi:10.1136/bjsports-2017-097956

Implementation

Four months in advance, we informed the NOCs about the study by letter. The day before the opening of the Games, we organised an information meeting for all NOC medical staff, where we also distributed the daily injury and illness report forms, as well as an instructional booklet detailing the study protocol (online appendix 2).

Throughout the data collection, we actively followed up the NOCs comprising more than 10 participating athletes with frequent visits to address any questions and encourage continuous reporting during the games. We recorded the response rate of all the 207 NOCs.

Definition of injury and illness

We defined injuries and illnesses as new (ie, pre-existing, not fully rehabilitated conditions were not recorded) or recurring (athletes having returned to full participation after a previous condition) musculoskeletal complaints, concussions or other medical conditions (injuries) or illnesses incurred in competition or training during the Rio Olympic Games (5–21 August 2016) receiving medical attention, regardless of the consequences with respect to absence from competition or training.⁷⁷ In cases where a single incident caused multiple injury types, we retained only the most severe diagnosis, as determined by our research team based on all available clinical data, for analysis.⁸⁰ Severe injuries and illnesses were defined as injuries or illnesses estimated to lead to absence from training or competition of more than 1 week.

Injury and illness report form

Our NOC injury and illness report form was identical to the one we used in the 2010 (Vancouver), 2012 (London) and 2014 (Sochi) Olympic Games.^{79–81} With respect to injuries, we recorded the following data: accreditation number, sport and event, whether the injury occurred in competition or training, date and time, body part, type, cause and estimated time lost from competition or training. We recorded data on illnesses in a similar fashion: accreditation number, sport and event, date, affected system, main symptom(s), cause and estimated time loss.

We provided instructions and examples on how to complete the form correctly in the instructional booklet. Furthermore, we distributed the injury and illness report form in English, French, Arabic, Chinese, German, Japanese, Russian and Spanish.

Confidentiality and ethical approval

We used the athlete accreditation number to query the IOC athlete database for the age, gender and nationality of the injured or ill athlete. We treated all information confidentially and deidentified our database after the Games.

The study was reviewed by the Medical Research Ethics Committee of the South-Eastern Norway Regional Health Authority (2011/388).

Data analysis

We calculated the summary measures of injury and illness incidences (i) according to the formula $i=n/e$, where n is the number of injuries or illnesses in competition, training or in total during the study period and e is the respective number of exposed (participating) athletes, with incidence proportions presented as injuries/illnesses per 100 athletes. We also calculated the summary measures of injury and illnesses per 1000 athlete-days, where athlete-days correspond to the total number of athletes multiplied by 17 days. We calculated CIs of the risk ratio (RR) of the number of injuries or illnesses between two groups by a simple Poisson model, assuming constant hazard per group. We present injury and illness incidences as means and RRs with 95% CIs. We regarded two-tailed p values <0.05 as significant.

RESULTS

In total, 11 274 athletes took part in the Rio Olympic Games. Of these, 5089 were women (45%) and 6185 men (55%). There were eight double-starters, meaning athletes who participated in two different sports, giving a total of 11 289 athlete exposures to injury or illness.

Throughout the 17 days of the Rio Games, the 207 NOCs submitted 1590 of a maximum of 3519 forms (45%; 97 countries did not submit any data) (table 1). The response rate of the

Table 1 Response rates, injuries and illnesses in NOCs of different sizes (measured by number of athletes)

	<10	10–49	50–99	>99	All
NOCs (athletes)	93 (502)	56 (1341)	24 (1635)	34 (7796)	207 (11 274*)
Injuries (injuries per 100 athletes)	61 (12.2)	191 (14.2)	139 (8.5)	679 (8.7)	1101† (9.8)
Illnesses (illnesses per 100 athletes)	27 (5.4)	90 (6.7)	51 (3.1)	429 (5.5)	613‡ (5.4)
Report forms submitted (%)	151 (10.0)	584 (61.3)	337 (82.6)	518 (89.6)	1590 (45.2)
Recorded by both NOC and Rio 2016					
Injuries (%)	2 (3.2)	12 (6.3)	16 (11.4)	36 (5.3)	66‡ (6.0)
Illnesses (%)	-	1 (1.0)	2 (3.8)	7 (1.5)	10‡ (1.5)
Recorded only by NOCs					
Injuries (%)	12 (19.7)	120 (62.8)	72 (51.4)	422 (62.2)	654‡ (59.3)
Illnesses (%)	6 (22.2)	57 (63.3)	34 (66.6)	313 (73.0)	426‡ (69.5)
Recorded only by Rio 2016					
Injuries (%)	47 (75.8)	53 (27.6)	48 (34.3)	145 (21.2)	293‡ (26.6)
Illnesses (%)	21 (77.8)	24 (24.2)	13 (24.5)	37 (8.1)	95‡ (14.5)

*15 double-starters excluded.

†NOC is missing for 31 injuries and 16 illnesses.

‡Test for duplicate not possible for 88 injuries and 82 illnesses where accreditation number was missing. NOC, National Olympic Committee.

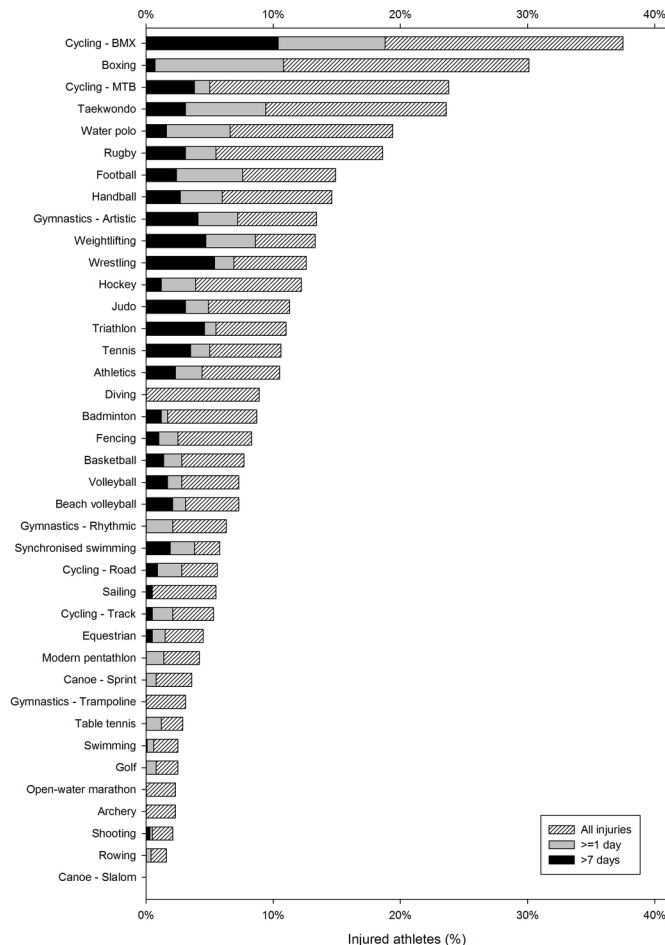


Figure 1 Proportions of athletes (%) in each sport with injury, injury with estimated time loss ≥ 1 day, and injury with estimated time loss > 7 days.

114 NOCs with > 10 participating athletes (accounting for 10 772/96% of all the athletes) was 74% (1439 of 1938 forms).

Injuries overall, by sport and gender

We recorded a total of 1101 injuries, equalling 9.8 injuries (95% CI 9.2 to 10.3) per 100 participating athletes. This corresponds to 5.7 injuries per 1000 athlete-days. On average, 8% ($n=931$) of the athletes sustained at least one injury. In addition, there were 70 and 10 athletes with two and three injuries each, respectively.

Figure 1 shows the incidence proportion of injured athletes in each sport (additional details are available in online appendix 3). The incidence of injury was highest in BMX cycling (37.5 injuries (95% CI 20.2 to 54.8) per 100 athletes), boxing (30.1 (23.7–36.4)), mountain bike cycling (23.8 (13.1–34.4)), taekwondo (23.6 (15.2–32.1)), water polo (19.4 (14.0–24.8)) and rugby (18.6 (13.6–23.5)), and lowest in canoe slalom, rowing, shooting, archery, swimming, golf and table tennis (ranging from 0 to 3 injuries per 100 athletes).

The injury incidences for women (9.3 injuries (95% CI 8.4 to 10.1) per 100 athletes) and men (9.4 (8.6–10.1), RR=0.99 (0.87–1.11)) were nearly identical (online appendix 4). However, women were at significantly higher risk of injury in sailing (RR=5.33 (1.78–15.93)), shooting (RR=5.14 (1.67–15.78)) and mountain bike cycling (RR=3.61 (1.37–9.50)).

Box 1 Information on the 221 severe injuries (estimated absence > 7 days), with the sports with the highest numbers in brackets.

- ▶ 65 muscle strains (33 in athletics, six in football, six in weightlifting)
- ▶ 57 ligament sprains/ruptures (eight in wrestling, six in athletics, six in judo, five in artistic gymnastics, five in weightlifting)
- ▶ 24 fractures (three in hockey, three in rugby, two in boxing, two in artistic gymnastics, two in mountain bike cycling, two in road cycling, two in water polo)
- ▶ 15 dislocations or subluxations (four in wrestling, three in judo, two in boxing)
- ▶ 12 lesions of meniscus or cartilage
- ▶ nine concussions (out of 12 in total: seven in boxing, two in rugby, one each in BMX cycling, mountain bike cycling, and handball)
- ▶ seven stress fractures (three in athletics, two in tennis, one each in boxing and triathlon)
- ▶ six tendon ruptures
- ▶ five contusions, haematomas or bruises
- ▶ five lacerations, abrasions or other skin lesions (three in boxing, two in triathlon)
- ▶ four nerve or spinal cord injuries
- ▶ four tendinopathies (three in athletics)
- ▶ two arthritis, synovitis or bursitis injuries
- ▶ two impingements
- ▶ two 'other bone injuries'

Injury type was missing for two of the severe injuries.

There was no statistical difference in the incidence of injury between the NOCs that did not report any NOC data (ie, Rio 2016 data only) and the NOCs that reported data (7.9 vs 9.8 injuries per 100 athletes; RR=1.24 (0.72–2.14)).

Severity of injuries

While almost two thirds of the injuries were estimated to result in no time loss from sport ($n=662$, 60%), 40% of the injuries ($n=438$) were expected to prevent the athlete from participating in competition or training (online appendix 3). Figure 1 shows the incidence of injuries estimated to lead to ≥ 1 day and > 7 days of absence in each sport. It was estimated that 14% of the injuries ($n=153$) would result in an absence from sports from 1 to 3 days, 6% ($n=64$) in an absence from 4 to 7 days, 10% ($n=106$) in an absence from 8 to 28 days and 10% ($n=115$) in an absence for more than 28 days. Information on severity was missing for one injury.

A total of 221 injuries (20%) were classified as severe, with an estimated absence from training or competition of more than 1 week (box 1, online appendix 3).

Location and type of injuries

The most commonly injured anatomical locations were the knee ($n=130$), thigh ($n=108$), ankle ($n=103$), face ($n=94$) and lower leg ($n=90$). The most common injury types were sprain/ligament rupture ($n=187$), contusion/haematoma/bruise ($n=178$), strain/muscle rupture/tear ($n=168$), laceration/abrasion/skin lesion ($n=152$) and tendinosis/tendinopathy ($n=112$). The distribution of injury locations and injury types per sport is presented in online appendices 5 and 6, respectively.

Causes, mechanisms and onset of injury

While 71% (n=781) of the injuries were reported to occur acutely, 27% (n=301) were reported to be caused by overuse (information missing for 19 injuries). The three most commonly reported injury causes/mechanisms were contact with another athlete (28%), non-contact trauma (21%) and overuse with gradual onset (19%). The distribution of injury causes/mechanisms in each sport is detailed in online appendix 7. Of all overuse injuries (gradual and sudden onset) occurring in the Games, 72% were recorded with no estimated absence from competition or training.

In terms of onset, 59% of the injuries were sustained in competition (5.8 (5.3–6.2) injuries per 100 athletes) and 37% during training (3.6 (3.2–3.9) injuries per 100 athletes; RR=1.61 (1.42–1.82)) (information on training/competition was missing for 45 injuries; online appendix 3). However, when analysing only the severe injuries, those estimated to result in at least 7 days of absence, the difference was greater (RR=2.22 (1.69–2.96)).

Injuries in training and in competition differed significantly in characteristics (location, type, mechanism and subsequent time loss from sport) and in terms of incidence in different sports (online appendix 3). The injury incidence was higher in competition than in training in boxing (RR=7.50 (3.88–14.51)), tennis (RR=6.00 (1.77–20.37)), hockey (RR=5.71 (2.56–12.76)), rugby (RR=5.38 (2.53–11.43)), handball (RR=3.90 (1.95–7.81)), football (RR=3.63 (2.08–6.31)), water polo (RR=3.56 (1.70–7.45)), BMX cycling (RR=3.50 (1.15–10.63)), basketball (RR=3.40 (1.25–9.22)), fencing (RR=3.25 (1.06–9.97)) and judo (RR=2.91 (1.47–5.77)). Swimming was the only sport in which the incidence of injury was significantly higher in training than in competition (RR=0.29 (0.11–0.80)).

Illnesses overall, by gender, sport and severity

Among the 11 289 exposed athletes, a total of 613 illnesses were reported, resulting in 5.4 illnesses (95% CI 5.0 to 5.9) per 100 athletes. This corresponds to 3.2 illnesses per 1000 athlete-days. On average, 5% (n=587) of the athletes incurred an illness, as there were 26 athletes with two illnesses each. Women (5.7 illnesses (5.0–6.3) per 100 athletes) were at significantly higher risk of contracting an illness than men (4.0 (3.5–4.5), RR=1.41 (1.19–1.67)).

Figure 2 shows the incidence proportion of ill athletes in each sport (additional details are available in online appendix 3). Diving was the sport with the highest illness incidence (11.9 illnesses (95% CI 6.0 to 17.7) per 100 athletes), followed by open-water marathon (11.8 (2.4–21.2)), sailing (11.8 (8.4–15.3)), canoe slalom (10.8 (3.8–17.9)), equestrian (10.5 (6.0–15.0)) and synchronised swimming (9.6 (3.7–15.6)). The illness incidence was low in a number of sports, with the lowest incidences recorded in trampoline and artistic gymnastics, golf and handball (ranging from 0 to 2 illnesses per 100 athletes).

One in five illnesses (n=113, 18%) were expected to result in absence from training or competition. Of these, two illnesses (0.3%) were expected to result in an estimated time loss of more than 7 days (chickenpox and conjunctivitis).

Affected system, main symptoms and causes of illness

A total of 292 illnesses (47%) affected the respiratory system. The second, third and fourth most frequently affected systems were the digestive system (n=131, 21%, 1% of the athletes affected), skin and subcutaneous tissue (n=53, 9%), nervous system (n=38, 6%) and genitourinary system (n=27, 4%), respectively. Infection was the most common cause of illness (n=346, 56%

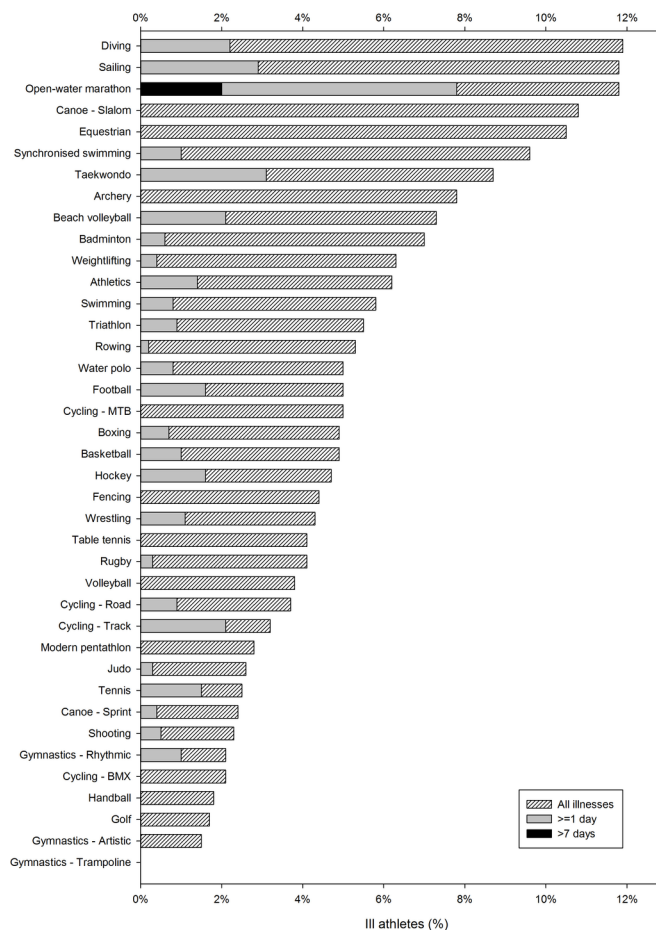


Figure 2 Proportions of athletes (%) in each sport with illness, illness with estimated time loss ≥ 1 day and illness with estimated time loss > 7 days.

of the illnesses, 3% of the athletes incurred an infection). Of the 292 respiratory illnesses, 223 (76%) were caused by an infection. The distribution of affected systems, main symptoms and causes of illness per sport are presented in online appendices 8, 9 and 10, respectively.

Data sources, and injuries and illnesses per NOC size

Only 6% of the injuries and 2% of the illnesses were captured by both the NOCs and the Rio 2016 staff. While 59% of the injuries and 70% of the illnesses were recorded solely by the NOCs, 27% and 15% of the injuries and illnesses, respectively, were recorded only by the Rio 2016 staff.

Whereas the majority of injured and ill athletes from the larger NOCs were seen internally by the NOC medical staff, athletes from small NOCs were to a greater extent relying on diagnosis and treatment from the Rio 2016 medical staff (table 1).

There was also an inverse relationship between NOC size (measured in number of participating athletes) and the risk injuries, with athletes from smaller NOCs suffering more injuries (NOCs with < 10 athletes: 12.2 (9.1–15.2) injuries per 100 athletes versus NOCs with > 99 athletes: 8.7 (8.1–9.4) injuries per 100 athletes, injury RR=1.40 (1.07–1.81)).

DISCUSSION

The aim of the present paper was to describe and analyse the incidence and characteristics of the sports injuries and illnesses in the Rio 2016 Olympic Games. The main findings of this

17-day-long prospective cohort study were that 8% and 5% of all the 11 274 athletes suffered from at least one injury or illness, with overall incidences of 9.8 injuries and 5.4 illnesses per 100 athletes, respectively. The magnitude and characteristics of the injuries and illnesses varied substantially between sports and gender.

Injury incidences varied from high to low across sports, with the highest incidences found in BMX cycling, boxing, mountain bike cycling, taekwondo, water polo and rugby. Illness incidences were generally lower, with the highest incidences seen in diving, open-water marathon, sailing, canoe slalom, equestrian and synchronised swimming.

Injuries in the Olympic sports

The incidence of injury in the Rio Games (8%) was lower than those in Beijing 2008 (10%),⁷⁸ Vancouver 2010 (11%),⁷⁹ London 2012 (11%)⁸⁰ and Sochi 2014 (12%).⁸¹ It was also lower than the injury incidences reported from recent Paralympic Games.^{33–36 38}

When comparing each sport in Rio 2016 with Beijing 2008, higher injury incidences were found in diving (9% vs 2% of the athletes injured), water polo (19% vs 10%), boxing (30% vs 15%), fencing (8% vs 2%) and sailing (6% vs 1%), while the injury incidences were lower in basketball (8% vs 13%), football (15% vs 32%) and hockey (12% vs 20%).

Likewise, when doing a similar comparison with London 2012, the injury incidences in Rio were higher in boxing (30% vs 9%) but lower in athletics (11% vs 18%), football (15% vs 35%), handball (15% vs 22%), sailing (6% vs 15%), swimming (3% vs 5%) and taekwondo (24% vs 39%).

Some sports have collected and published data on injury incidences in their world championships or other main events. The incidence of football injury in Rio 2016 was similar to those in the 2014 World Cup,²⁰ 2004²⁹ and 2008³¹ European championships, but half of that in the 2010 World Cup.¹⁹ In athletics, as well as in diving, swimming and synchronised swimming, the injury incidences in Rio were similar to those reported from recent world championships.^{40–47} In contrast, the Rio injury incidences in open-water marathon and water polo were lower and higher, respectively, than previously reported from the aquatics world championships.^{46 47} In rugby sevens, the injury incidence in Rio was less than half than previously found in the Rugby Sevens World Cup and World Series.²³ Similarly, the proportions of injured athletes in the beach volleyball tournaments in the three latest summer Olympic Games constitute about one third of that reported earlier in the beach volleyball world championships.¹⁴ In handball, the incidence of injuries in Rio was about half of that found in the men's world championship in 2015.⁶⁴ Interestingly, and in contrast, the BMX cycling injury incidence in Rio was about six times higher than that documented in the 1989 BMX European championships.⁷⁰

A change in injury incidence can be the result of changes in the composition of the Olympic Games programme (eg, two new sports in Rio), environmental factors, venue or track design, competition rules or changes in equipment. Recorded injury frequencies are also likely to be influenced by the response rate and reporting accuracy by the NOC and organising committee medical staff. However, our analysis comparing the injury incidences of the NOCs that reported data and those that did not (other than the data recorded by the Rio 2016 staff) indicated no significant difference between the two. In addition, in Rio 2016, a new electronic medical record was used for the first time by the organising committee medical staff. Also, incidence differences (lower or higher) may simply be the result of a natural variability

of athletes' exposure to risk, an observation that emphasises the value of ongoing surveillance to monitor trends over time, for example, the effect of venue design, rule or equipment changes in the period between major sports events.

Severity of injuries

In major sports events, like the Olympic Games, injuries or illnesses of even minor severity with or without time loss have the potential to be both participation limiting and performance inhibiting, and thus prevent athletes from possibly fulfilling their potential and reaching their life-time achievement. In the Rio Games, 40% of the injuries were estimated to result in time loss from competition or training of at least 1 day. This places Rio 2016 between London 2012 and Beijing 2008, in which the equivalent numbers were 35% and 50%, respectively. In contrast, athletes in Rio incurred more injuries of higher severity (20% of the injuries estimated to result in absence greater than 7 days) than the athletes in London 2012 and Beijing 2008 (both 13%).

The sports with the highest incidences of injuries entailing a prolonged absence from training or competition (>7 days) were BMX cycling (10% of the athletes), wrestling (5%), weightlifting (5%) and triathlon (5%), which is similar to the data from the London Games.

Causes, mechanisms and onset of injury

The causes, mechanisms and circumstances of injuries in competition and training differed significantly between the different sports. Overall, the distribution of injuries in competition and training (59% vs 37%) was similar to that of London 2012,⁸⁰ the 2009 and 2013 Aquatics World Championships,^{46 47} the 2010 men's Football World Cup,¹⁹ and the 2011 Athletics World Championships,⁴² but not Beijing 2008,⁷⁸ the 2007 or 2009 Athletics World Championships,^{40 41} or the 2015 men's Handball World Championships,⁶⁴ where the incidence of competition injuries was higher. In Rio 2016, the majority of injuries were reported to be acute, whereas overuse injuries with either a gradual or sudden onset accounted for a quarter of the injuries. Although similar distributions were reported from London 2012 and Beijing 2008, these numbers should be interpreted with caution, due to the limitations in the recording of overuse injuries in the current methodology.^{82–86}

Illness risk during the Olympics

In the lead up to the Rio Games, there were concerns about the risk of gastroenteritis and other infections from various water-borne viruses and bacteria, as well as the mosquito-borne Zika virus, with some calling for the Games to be cancelled.⁸⁷ However, the overall proportion of athletes with illness in the Rio Games (5%) was actually lower than those reported from London 2012 (7%),⁸⁰ Vancouver 2010 (7%)⁷⁹ and Sochi 2014 (8%).⁸¹ While the majority of illnesses in Rio (56%) were caused by an infection, the proportion of athletes contracting an infection (3%) was identical to London 2012 (3%) and lower than Sochi 2014 (5%). Similarly, the incidence of digestive system illness (1%) was identical to London 2012 (also 1%). In terms of the Zika virus, no cases were reported among either athletes or the general population during the Olympic Games in Rio.⁸⁸

As in previous Olympic Games,^{79–81} female athletes contracted more illnesses than male athletes. The same disproportion has previously been reported in the 2009 Athletics⁴¹ and Aquatics⁴⁶ World Championships, but not in the 2011 Athletics⁴² or 2013 Aquatics⁴⁷ World Championships, in the 1994–2009 US Open

Tennis Championships,⁸⁹ or in the Winter or Summer Paralympic Games.^{37 39}

Methodological considerations

In studies on sports injury, it is usually recommended to express incidences using a measure of time exposed to risk as the denominator.^{35–37 90 91} However, considering the inherent complexity and size of the Olympic Games, this was not feasible in the present study. Instead, we expressed the injuries or illnesses by means of absolute risk: the number of new cases per 100 registered athletes (incidence proportion). This approach erroneously assumes that the frequencies and lengths of exposure are identical in all sports and that the number of athletes at risk in each NOC is constant throughout the Games. Interpretation of differences in injury incidences or patterns should therefore be made with caution.

In the current study, we defined injuries and illnesses as new or recurring injuries or illnesses receiving medical attention, regardless of the consequences with respect to absence from competition or training. By using such a definition, predominantly the moderate and severe acute injuries will be recorded. The less serious injuries may be overlooked, since such injuries do not always require medical attention,^{92 93} albeit our results show that the majority of reported injuries were not estimated to involve any absence from the sport. In the Olympic Games, all athletes can get healthcare through the athletes' village polyclinic and the venue medical clinics. However, the availability, size and quality of the NOCs' own medical teams vary among countries, meaning that not all athletes benefit from identical healthcare, which may bias the injury and illness recording.

Throughout the 17 days of data collection in the Olympic Games, we collected 45% of all the NOC injury and illness report forms. If including only the NOCs which we actively followed up (those with more than 10 athletes), as done in previous Olympic Games, the response rate was 74%, which is lower than in previous Games (99.7% in Sochi; 96% in London). It is difficult to speculate as to what the potential causes are. In the future, transitioning to an electronic data collection system, similar to that used in the Paralympics,³⁵ may help to improve the response rate among the NOCs, as well as the accuracy of the data.

A mere 6% of the injuries and 2% of the illnesses were captured by both the NOC and the Rio 2016 medical personnel, underlining the importance of both recorder groups. Our study also shows that in particular athletes from smaller NOCs benefit from diagnosis and treatment from the local organising committee's medical staff, whereas the majority of athletes from larger NOCs are seen by their own NOC medical staff. More importantly, we once again identified an inverse relationship between NOC size and the risk of health problems, with athletes from the smallest NOCs experiencing significantly more injuries compared with the largest NOCs. It is difficult not to see this finding in light of distinct differences in resources available to the NOC. Large delegations usually come from countries with well-developed exercise physiology and sports medicine communities and are generally able to offer their athletes more comprehensive healthcare and closer medical follow-up both in the lead up to and during the Games, potentially giving them a competitive advantage.

Practical implications

The continuously accumulating evidence that injuries and illnesses vary substantially between sports demonstrates the need

for tailoring preventive measures to the specific context of each sport. Sport bodies such as the IOC, International Paralympic Committee, International Sports Federations (IFs) and NOCs have the responsibility to protect the health of their athletes. The Olympic Movement Medical Code encourages all stakeholders to take measures to ensure that sport is practised with minimal risks of physical injury and illness or psychological harm.⁹⁴ For IFs, a critical component of this responsibility is the implementation of a scientifically sound injury and illness surveillance system in all major events. Some sports federations have put increasing effort into working systematically and scientifically to protect their athletes' health.^{15–20 22–47 49–61 68} We encourage other IFs and sports organisations to follow their example.

CONCLUSION

In summary, 8% of the athletes had a reported medical encounter for a new or recurrent injury and 5% an illness during the Rio Olympic Summer Games. The incidences and characteristics of injuries and illnesses in training and competition varied substantially between sports and gender.

What are the findings?

- ▶ Overall, 8% and 5% of the athletes incurred at least one injury or illness, respectively, during the Rio 2016 Olympic Games.
- ▶ BMX cycling (38%), boxing (30%), mountain bike cycling (24%), taekwondo (24%), water polo (19%) and rugby (19%) were the sports with the highest incidence of injury.
- ▶ Diving (12%), open-water marathon (12%), sailing (12%), canoe slalom (11%), equestrian (11%) and synchronised swimming (10%) were the sports with the highest illness incidence.
- ▶ The rate of infectious diseases in Rio was low and consistent with previous Olympic Games.

How might it impact on clinical practice in the near future?

- ▶ These injury and illness data can help inform policy and planning of major multi-sport events (eg, Asian Games, Commonwealth Games, Pan American Games, European Games).
- ▶ These data can directly inform the focus and development of injury prevention measures in sport

Author affiliations

¹Medical and Scientific Department, International Olympic Committee, Lausanne, Switzerland

²Sport Injury Prevention Research Centre, University of Calgary, Calgary, Alberta, Canada

³Department of Sports Medicine, Norwegian School of Sport Sciences, Oslo Sports Trauma Research Center, Oslo, Norway

⁴School of Applied Sciences, Edinburgh Napier University, Edinburgh, UK

⁵Division of Rheumatology, Orthopaedics and Dermatology, School of Medicine, University of Nottingham, Nottingham, UK

⁶Department of Sports Medicine, Aspetar Qatar Orthopedics and Sports Medicine Hospital, Doha, Qatar

⁷Department of Physical Therapy, University of Massachusetts Lowell, Lowell, Massachusetts, USA

⁸Department of Neurology, Spine Unit, Schulthess Clinic, Zurich, Switzerland

⁹Institute of Sport and Health, University College Dublin, Dublin, Ireland

¹⁰Fédération Internationale de Natation (FINA), Lausanne, Switzerland

¹¹Masters and Doctoral Programs in Physical Therapy, Universidade Cidade de São Paulo, São Paulo, Brazil

¹²GE Healthcare, Moscow, Russia

¹³Department of Orthopaedic Surgery, University of Oslo, Oslo, Norway

Acknowledgements The authors would like to acknowledge the contribution and support of the Rio 2016 staff throughout the different stages of this study. The authors also sincerely thank all the NOC medical staff contributing to the data collection: Dr Loughraieb Mok Amine (ALG), Dr Maria Stella Cristiano (ANG), Dr Hugo Rodrigues Papini (ARG), Dr Davit Mosinyan (ARM), Dr Carolyn Broderick (AUS), Dr Alfred Engel (AUT), Dr Guliyeva Ludmila (AZE), Dr Virgil Rene Best (BAR), Dr Johan Bellemans (BEL), Dr Henadzi Zaharodny (BLR), Dr Roberto Nahon (BRA), Dr André Pedrinelli (BRA), Dr Stefan Strugarov (BUL), Dr Bob McCormack (CAN), Dr Joshua Ferguson (CAN), Dr Jaques Nguonimba Goulou (CGO), Dr Alejandro Orizola (CHI), Dr Minhao Xie (CHN), Dr Ngiebe Mubiala (COD), Dr Juan Carlos Quiceno (COL), Dr Karen Nait Cifuentes Rodríguez (COL), Dr Humberto Evora (CPV), Dr Max Moreira (CRC), Dr Damir Jemendzic (CRO), Dr Dinko Pivalica (CRO), Dr Miroslav Smerdej (CRO), Dr Pablo Castillo Diaz (CUB), Dr Constantinos Schizas (CYP), Dr Petr Sikora (CZE), Dr Lars Juel Andersen (DEN), Dr Francis Sanchez (DOM), Dr Pablo Sarmiento Panchana (ECU), Dr Haile Ghirmasion (ERI), Dr Rosario Urena Duran (ESP), Dr Mihkel Mardua (EST), Dr Ayalew Tilahun Beshaha (ETH), Dr Maarit Valtonen (FIN), Dr Philippe Le Van (FRA), Dr Fabrice Bryand (FRA), Dr Niall Elliott (GBR), Dr Mike Rossiter (GBR), Dr Zurab Kakhabrshvili (GEO), Dr Bernd Wolfarth (GER), Dr Odysseas Paxinos (GRE), Dr Georgios Marinos (GRE), Dr Greg Varigos (GRN), Dr Luis Cruz (GUM), Dr Mukkuaka Oda (HAI), Dr Julian Wei Chang (HKG), Dr Eva Vinalti (HON), Dr Peter Barlogh (HUN), Dr Antonius Andi Kurniawan (INA), Dr Leone Suniar Manuruna (INA), Dr Pawanddeep Singh Kohli (IND), Dr Gholamreza Norouzi (IRI), Dr Rod McLoughlin (IRL), Dr Ghaleb Abbas Salih (IRQ), Dr Örnólfur Valoimarsson (ISL), Dr Lubov Galitskaya (ISR), Dr Antonio Spataro (ITA), Dr Derrick McDowell (JAM), Dr Kohei Nakajima (JPN), Dr Tomohiro Manabe (JPN), Dr Shuichi Nakayama (JPN), Dr Hiroshi Takagi (JPN), Dr Serikkazy Mazenkov (KAZ), Dr Natalia Kudashova (KAZ), Dr Elena Galtis (KAZ), Dr Daniel Langat (KEN), Dr Baktygul Alisheva (KGZ), Dr Jungjoong Yoon (KOR), Dr Liga Circule (LAT), Dr Axel Urhausen (LIE), Dr Dalius Barkauskas (LTU), Dr Axel Urhausen (LUX), Dr Christian Nührenbörger (LUX), Dr Semmar Sahar (MAR), Dr Arshad Bin Puji (MAS), Dr Balmus Dorin (MDA), Dr Viridiana Silva Quiroz (MEX), Dr Chuluun Nasanbat (MGL), Dr Bayartuya Bayarsaikhan (MGL), Dr Licienne Attard (MLT), Dr Predrag Dabovic (MNE), Dr Flezer Tomadote (MOZ), Dr Jürgen Hofmann (NAM), Dr Aniya-Mart Kruger (NAM), Dr Cees-Rein van den Hoogenband (NED), Dr Sarub Shrestha (NEP), Dr Abdulkadir Mu'azu (NGR), Dr Thomas Torgalsen (NOR), Dr Lars Haugvad (NOR), Dr Anne Froholdt (NOR), Dr Bruce Hamilton (NZL), Dr Mark Fulcher (NZL), Dr Victor Carpio Quintana (PER), Dr Bernie Amof (PNG), Dr Hubert Krysztofiak (POL), Dr Maria Joao Cascasais (POR), Dr Kim Yumi (PRK), Dr Rebecca Rodriguez (PUR), Dr Juan Manuel Alonso (QAT), Dr Carlo Bagutti (ROT), Dr Tanase Dan (ROU), Dr Kevin Subban (RSA), Dr Andrej Sereda (RUS), Dr Seydina Omar Diagne (SEN), Dr Darren Leong (SIN), Dr Matjaz Vogrin (SLO), Dr Martin Zorko (SLO), Dr Katja Azman Juvan (SLO), Dr Dragan Radovanovic (SRB), Dr Goran Vasic (SRB), Dr Patrick Noack (SUI), Dr Branislav Delej (SVK), Dr Per Andersson (SWE), Dr Fredrik Bergström (SWE), Dr Mats Börjesson (SWE), Dr Nassoro Matuzya (TAN), Dr Hilary Meechai Inwood (THA), Dr Lin Yzn Chou (TPE), Dr Tonya Welch (TTO), Dr Ayachi Saida (TUN), Dr Tugba Kocahan (TUR), Dr Hassan Kamal (TUR), Dr Abdulhameed Alattar (UAE), Dr Robert Zavuga (UGA), Dr Oleksandr Varvinskyi (UKR), Dr Daniel Zarrillo (URU), Dr Bill Moreau (USA), Dr Svetlana Suyatskaya (UZB), Dr Joze German Medina (VEN), Dr Phu Nguyen Van (VIE), Dr Mulenga Davie (ZAM), Dr Austin Jeans (ZIM), Dr Dorothy Masawi (ZIM) and Dr Nicholas Munyonga (ZIM).

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

Funding The study was funded by the International Olympic Committee.

Competing interests None declared.

Ethics approval The study was reviewed by the Medical Research Ethics Committee of the South-Eastern Norway Regional Health Authority (2011/388).

Provenance and peer review Not commissioned; externally peer reviewed.

© Article author(s) (or their employer(s) unless otherwise stated in the text of the article) 2017. All rights reserved. No commercial use is permitted unless otherwise expressly granted.

REFERENCES

- World Health Organization. Global recommendations on physical activity for health. 2010 <http://www.who.int/dietphysicalactivity/publications/9789241599979/en/>.
- Centers for Disease Control and Prevention. Physical activity and health - the benefits of physical activity. <http://www.cdc.gov/physicalactivity/everyone/health/index.html>.
- Sarna S, Sahi T, Koskenvuo M, et al. Increased life expectancy of world class male Athletes. *Med Sci Sports Exerc* 1993;25:237–244.
- Kujala UM, Sarna S, Kaprio J, et al. Hospital care in later life among former world-class Finnish Athletes. *JAMA* 1996;276:216–20.
- Teramoto M, Bungum TJ. Mortality and longevity of elite Athletes. *J Sci Med Sport* 2010;13:410–6.
- Clarke PM, Walter SJ, Hayen A, et al. Survival of the fittest: retrospective cohort study of the longevity of Olympic medalists in the modern era. *BMJ* 2012;345:e8308.
- Zwiers R, Zantvoord FW, Engelaer FM, et al. Mortality in Former Olympic Athletes: retrospective cohort analysis. *BMJ* 2012;345:e7456.
- Drawer S, Fuller CW. Propensity for osteoarthritis and lower limb joint pain in retired professional soccer players. *Br J Sports Med* 2001;35:402–8.
- Drawer S, Fuller CW. Evaluating the level of injury in English professional football using a risk based assessment process. *Br J Sports Med* 2002;36:446–51.
- Lohmander LS, Osterberg A, Englund M, et al. High prevalence of knee osteoarthritis, pain, and functional limitations in female soccer players twelve years after anterior cruciate ligament injury. *Arthritis Rheum* 2004;50:3145–52.
- von Porat A, Roos EM, Roos H. High prevalence of osteoarthritis 14 years after an anterior cruciate ligament tear in male soccer players: a study of radiographic and patient relevant outcomes. *Ann Rheum Dis* 2004;63:269–73.
- van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med* 1992;14:82–99.
- Finch C. A new framework for research leading to sports injury prevention. *J Sci Med Sport* 2006;9(1-2):3–9.
- Bahr R, Reeser JC. Injuries among world-class professional beach volleyball players. The Fédération Internationale de Volleyball beach volleyball injury study. *Am J Sports Med* 2003;31:119–25.
- Junge A, Dvorak J, Graf-Baumann T, et al. Football injuries during FIFA tournaments and the Olympic Games, 1998-2001: development and implementation of an injury-reporting system. *Am J Sports Med* 2004;32:805–9.
- Junge A, Dvorak J, Graf-Baumann T. Football injuries during the World Cup 2002. *Am J Sports Med* 2004;32:235–7.
- Dvorak J, Junge A, Grimm K, et al. Medical report from the 2006 FIFA World Cup Germany. *Br J Sports Med* 2007;41:578–81.
- Junge A, Dvorak J. Injuries in female football players in top-level international tournaments. *Br J Sports Med* 2007;41 Suppl 1(Suppl 1):i3–i7.
- Dvorak J, Junge A, Derman W, et al. Injuries and illnesses of football players during the 2010 FIFA World Cup. *Br J Sports Med* 2011;45:626–30.
- Junge A, Dvořák J. Football injuries during the 2014 FIFA World Cup. *Br J Sports Med* 2015;49:599–602.
- Best JP, McIntosh AS, Savage TN. Rugby World Cup 2003 injury surveillance project. *Br J Sports Med* 2003;39:812–7.
- Fuller CW, Laborde F, Leather RJ, et al. International Rugby Board Rugby World Cup 2007 injury surveillance study. *Br J Sports Med* 2008;42:452–9.
- Fuller CW, Taylor A, Molloy MG. Epidemiological study of injuries in International Rugby Sevens. *Clin J Sport Med* 2010;20:179–84.
- Taylor AE, Fuller CW, Molloy MG. Injury surveillance during the 2010 IRB Women's Rugby World Cup. *Br J Sports Med* 2011;45:1243–5.
- Fuller CW, Sheerin K, Targett S, et al. International Rugby Board injury surveillance study. *Br J Sports Med* 2011;47:1184–91;47:1184–91.
- Fuller CW, Taylor A, Raftery M. 2016 Rio Olympics: an epidemiological study of the men's and women's Rugby-7s tournaments. *Br J Sports Med* 2017.
- Häggglund M, Waldén M, Bahr R, et al. Methods for epidemiological study of injuries to professional football players: developing the UEFA model. *Br J Sports Med* 2005;39:340–6.
- Waldén M, Häggglund M, Ekstrand J. UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season. *Br J Sports Med* 2005;39:542–6.
- Waldén M, Häggglund M, Ekstrand J. Football injuries during European championships 2004-2005. *Knee Surg Sports Traumatol Arthrosc* 2007;15:1155–62.
- Ekstrand J, Häggglund M, Waldén M. Injury incidence and injury patterns in professional football: the UEFA injury study. *Br J Sports Med* 2011;45.
- Häggglund M, Waldén M, Ekstrand J. UEFA injury study--an injury audit of European championships 2006 to 2008. *Br J Sports Med* 2009;43:483–9.
- Häggglund M, Waldén M, Magnusson H, et al. Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med* 2013;47:738–42.
- Webborn N, Willick S, Reeser JC. Injuries among disabled Athletes during the 2002 Winter Paralympic Games. *Med Sci Sports Exerc* 2006;38:811–5.
- Webborn N, Willick S, Emery CA. The injury experience at the 2010 winter paralympic games. *Clin J Sport Med* 2012;22:1–9.
- Derman W, Schweltnus M, Jordaan E, et al. Illness and injury in Athletes during the competition period at the London 2012 Paralympic Games: development and implementation of a web-based surveillance system (WEB-ISS) for team medical staff. *Br J Sports Med* 2013;47:420–5.
- Willick SE, Webborn N, Emery C, et al. The epidemiology of injuries at the London 2012 Paralympic Games. *Br J Sports Med* 2013;47:426–32.
- Schweltnus M, Derman W, Jordaan E, et al. Factors associated with illness in Athletes participating in the London 2012 Paralympic Games: a prospective cohort study involving 49,910 athlete-days. *Br J Sports Med* 2013;47:433–40.

- 38 Derman W, Schweltnus MP, Jordaan E, *et al.* High incidence of injury at the Sochi 2014 Winter Paralympic Games: a prospective cohort study of 6564 athlete days. *Br J Sports Med* 2016;50:1069–74.
- 39 Derman W, Schweltnus MP, Jordaan E, *et al.* The incidence and patterns of illness at the Sochi 2014 Winter Paralympic Games: a prospective cohort study of 6564 athlete days. *Br J Sports Med* 2016;50:1064–8.
- 40 Alonso JM, Junge A, Renström P, *et al.* Sports injuries surveillance during the 2007 IAAF World Athletics Championships. *Clin J Sport Med* 2009;19:26–32.
- 41 Alonso JM, Tscholl PM, Engebretsen L, *et al.* Occurrence of injuries and illnesses during the 2009 IAAF World Athletics Championships. *Br J Sports Med* 2010;44:1100–5.
- 42 Alonso JM, Edouard P, Fischetto G, *et al.* Determination of future prevention strategies in elite track and field: analysis of Daegu 2011 IAAF championships injuries and illnesses surveillance. *Br J Sports Med* 2012;46:505–14.
- 43 Alonso JM, Jacobsson J, Timpka T, *et al.* Preparticipation injury complaint is a risk factor for injury: a prospective study of the Moscow 2013 IAAF championships. *Br J Sports Med* 2015;49:1118–24.
- 44 Feddermann-Demont N, Junge A, Edouard P, *et al.* Injuries in 13 International Athletics championships between 2007–2012. *Br J Sports Med* 2014;48:513–22.
- 45 Timpka T, Jacobsson J, Bargoria V, *et al.* Preparticipation predictors for championship injury and illness: cohort study at the Beijing 2015 International Association of Athletics Federations World Championships. *Br J Sports Med* 2017;51:271–6.
- 46 Mountjoy M, Junge A, Alonso JM, *et al.* Sports injuries and illnesses in the 2009 FINA World Championships (Aquatics). *Br J Sports Med* 2010;44:522–7.
- 47 Mountjoy M, Junge A, Benjamin S, *et al.* Competing with injuries: injuries prior to and during the 15th FINA World Championships 2013 (aquatics). *Br J Sports Med* 2015;49:37–43.
- 48 Prien A, Mountjoy M, Miller J, *et al.* Injury and illness in aquatic sport: how high is the risk? A comparison of results from three FINA World Championships. *Br J Sports Med* 2017;51:277–82.
- 49 Flørenes TW, Bere T, Nordsletten L, *et al.* Injuries among male and female world Cup alpine skiers. *Br J Sports Med* 2009;43:973–8.
- 50 Flørenes TW, Heir S, Nordsletten L, *et al.* Injuries among World Cup freestyle skiers. *Br J Sports Med* 2010;44:803–8.
- 51 Flørenes TW, Nordsletten L, Heir S, *et al.* Recording injuries among World Cup skiers and snowboarders: a methodological study. *Scand J Med Sci Sports* 2011;21:196–205.
- 52 Flørenes TW, Nordsletten L, Heir S, *et al.* Injuries among World Cup ski and snowboard Athletes. *Scand J Med Sci Sports* 2012;22:58–66.
- 53 Bakken A, Bere T, Bahr R, *et al.* Mechanisms of injuries in World Cup Snowboard Cross: a systematic video analysis of 19 cases. *Br J Sports Med* 2011;45:1315–22.
- 54 Bere T, Flørenes TW, Nordsletten L, *et al.* Sex differences in the risk of injury in World Cup alpine skiers: a 6-year cohort study. *Br J Sports Med* 2014;48:36–40.
- 55 Major DH, Steenstrup SE, Bere T, *et al.* Injury rate and injury pattern among elite world Cup snowboarders: a 6-year cohort study. *Br J Sports Med* 2014;48:18–22.
- 56 Randjelovic S, Heir S, Nordsletten L, *et al.* Injury situations in Freestyle Ski Cross (SX): a video analysis of 33 cases. *Br J Sports Med* 2014;48:29–35.
- 57 Steenstrup SE, Bere T, Bahr R. Head injuries among FIS World Cup alpine and freestyle skiers and snowboarders: a 7-year cohort study. *Br J Sports Med* 2014;48:41–5.
- 58 Tuominen M, Stuart MJ, Aubry M, *et al.* Injuries in men's international ice hockey: a 7-year study of the International Ice Hockey Federation Adult World Championship Tournaments and Olympic Winter Games. *Br J Sports Med* 2015;49:30–6.
- 59 Tuominen M, Stuart MJ, Aubry M, *et al.* Injuries in women's international ice hockey: an 8-year study of the World Championship tournaments and Olympic Winter Games. *Br J Sports Med* 2016;50:1406–12.
- 60 Tuominen M, Hänninen T, Parkkari J, *et al.* Concussion in the international ice hockey world championships and olympic Winter Games between 2006 and 2015. *Br J Sports Med* 2017;51:244–52.
- 61 Tuominen M, Stuart MJ, Aubry M, *et al.* Injuries in world junior ice hockey championships between 2006 and 2015. *Br J Sports Med* 2017;51:36–43.
- 62 Park KJ, Brian Byung S. Injuries in elite korean fencers: an epidemiological study. *Br J Sports Med* 2017;51:220–5.
- 63 Lystad RP, Graham PL, Poulos RG. Exposure-adjusted incidence rates and severity of competition injuries in australian amateur taekwondo Athletes: a 2-year prospective study. *Br J Sports Med* 2013;47:441–6.
- 64 Bere T, Alonso JM, Wangensteen A, *et al.* Injury and illness surveillance during the 24th men's Handball World Championship 2015 in Qatar. *Br J Sports Med* 2015;49:1151–6.
- 65 Loosemore M, Lightfoot J, Palmer-Green D, *et al.* Boxing injury epidemiology in the Great Britain team: a 5-year surveillance study of medically diagnosed injury incidence and outcome. *Br J Sports Med* 2015;49:1100–7.
- 66 Siewe J, Rudat J, Zarghooni K, *et al.* Injuries in competitive boxing. A prospective study. *Int J Sports Med* 2015;36:249–53.
- 67 Westermann RW, Giblin M, Vaske A, *et al.* Evaluation of men's and Women's Gymnastics Injuries: A 10-Year Observational Study. *Sports Health* 2015;7:161–5.
- 68 Theilen TM, Mueller-Eising W, Wefers Bettink P, *et al.* Injury data of Major international field hockey tournaments. *Br J Sports Med* 2016;50:657–60.
- 69 Kim KS, Park KJ, Lee J, *et al.* Injuries in national olympic level judo Athletes: an epidemiological study. *Br J Sports Med* 2015;49:1144–50.
- 70 Brøgger-Jensen T, Hvass I, Bugge S. Injuries at the BMX Cycling European Championship, 1989. *Br J Sports Med* 1990;24:269–70.
- 71 Jayanthi NA, O'Boyle J, Durazo-Arvizu RA. Risk factors for medical withdrawals in United States tennis association junior national tennis tournaments: a descriptive epidemiologic study. *Sports Health* 2009;1:231–5.
- 72 Lynall RC, Kerr ZY, Djoko A, *et al.* Epidemiology of National Collegiate Athletic Association men's and women's tennis injuries, 2009/2010–2014/2015. *Br J Sports Med* 2016;50:1211–6.
- 73 Maquirriain J, Baglione R. Epidemiology of tennis injuries: an eight-year review of Davis Cup retirements. *Eur J Sport Sci* 2016;16:266–70.
- 74 McCurdie I, Smith S, Bell PH, *et al.* Tennis injury data from the championships, Wimbledon, from 2003 to 2012. *Br J Sports Med* 2017;51.
- 75 Pluim BM, Loeffen FG, Clarsen B, *et al.* A one-season prospective study of injuries and illness in elite junior tennis. *Scand J Med Sci Sports* 2016;26:564–71.
- 76 Pluim BM, Clarsen B, Verhagen E. Injury rates in recreational tennis players do not differ between different playing surfaces. *Br J Sports Med* 2017;bjsp.orts-2016-097050.
- 77 Junge A, Engebretsen L, Alonso JM, *et al.* Injury surveillance in multi-sport events: the International Olympic Committee approach. *Br J Sports Med* 2008;42:413–21.
- 78 Junge A, Engebretsen L, Mountjoy ML, *et al.* Sports injuries during the Summer Olympic Games 2008. *Am J Sports Med* 2009;37:2165–72.
- 79 Engebretsen L, Steffen K, Alonso JM, *et al.* Sports injuries and illnesses during the Winter Olympic Games 2010. *Br J Sports Med* 2010;44:772–80.
- 80 Engebretsen L, Soligard T, Steffen K, *et al.* Sports injuries and illnesses during the London Summer Olympic Games 2012. *Br J Sports Med* 2013;47:407–14.
- 81 Soligard T, Steffen K, Palmer-Green D, *et al.* Sports injuries and illnesses in the Sochi 2014 Olympic Winter Games. *Br J Sports Med* 2015;49:441–7.
- 82 Bahr R. No injuries, but plenty of pain? on the methodology for recording overuse symptoms in sports. *Br J Sports Med* 2009;43:966–72.
- 83 Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. *Br J Sports Med* 2013;47:495–502.
- 84 Clarsen B, Rønsen O, Myklebust G, *et al.* The Oslo Sports Trauma Research Center questionnaire on health problems: a new approach to prospective monitoring of illness and injury in elite Athletes. *Br J Sports Med* 2014;48:754–60.
- 85 Clarsen B, Bahr R. Matching the choice of injury/illness definition to study setting. *purpose and design: one size does not fit all!* *Br J Sports Med* 2014;48:510–2.
- 86 Mountjoy M, Junge A, Alonso JM, *et al.* Consensus statement on the methodology of injury and illness surveillance in FINA (aquatic sports). *Br J Sports Med* 2016;50:590–6.
- 87 Attaran A. Off the Podium: why Public Health concerns for global spread of Zika virus means that Rio de Janeiro's 2016 Olympic Games Must Not Proceed. *Harvard Public Health Review* 2016 <http://harvardpublichealthreview.org/off-the-podium-why-rios-2016-olympic-games-must-not-proceed/>.
- 88 World Health Organization. Zika situation report. 2016. <http://www.who.int/emergencies/zika-virus/situation-report/25-august-2016/en/>.
- 89 Sell K, Hainline B, Yorio M, *et al.* Illness data from the US open tennis championships from 1994 to 2009. *Clin J Sport Med* 2013;23:25–32.
- 90 Fuller CW, Ekstrand J, Junge A, *et al.* Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Br J Sports Med* 2006;40:193–201.
- 91 Bahr R, Holme I. Risk factors for sports injuries--a methodological approach. *Br J Sports Med* 2003;37:384–92.
- 92 Inklaar H, injuries S. I: incidence and severity. *Sports Med* 1994;18:55–73.
- 93 Finch CF. An overview of some definitional issues for sports injury surveillance. *Sports Med* 1997;24:157–63.
- 94 The Olympic Movement Medical Code. *International Olympic Committee* 2016 http://www.olympic.org/PageFiles/61597/Olympic_Movement_Medical_Code_eng.pdf.



Sports injury and illness incidence in the Rio de Janeiro 2016 Olympic Summer Games: A prospective study of 11 274 athletes from 207 countries

Torbjørn Soligard, Kathrin Steffen, Debbie Palmer, Juan Manuel Alonso, Roald Bahr, Alexandre Dias Lopes, Jiri Dvorak, Marie-Elaine Grant, Willem Meeuwisse, Margo Mountjoy, Leonardo Oliveira Pena Costa, Natalia Salmina, Richard Budgett and Lars Engebretsen

Br J Sports Med published online July 29, 2017

Updated information and services can be found at:
<http://bjsm.bmj.com/content/early/2017/07/29/bjsports-2017-097956>

These include:

References

This article cites 85 articles, 57 of which you can access for free at:
<http://bjsm.bmj.com/content/early/2017/07/29/bjsports-2017-097956#BIBL>

Email alerting service

Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Notes

To request permissions go to:
<http://group.bmj.com/group/rights-licensing/permissions>

To order reprints go to:
<http://journals.bmj.com/cgi/reprintform>

To subscribe to BMJ go to:
<http://group.bmj.com/subscribe/>