BJSM Online First, published on April 20, 2016 as 10.1136/bjsports-2015-095835

Sports injury and illness epidemiology during the 2014 Youth Olympic Games: United States Olympic Team Surveillance

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Accepted 31 March 2016

ABSTRACT

Background To describe injury and illness incidence from the US Youth Olympic Team during the 2014 Youth Olympic Games (YOG).

Methods Electronic health records of Team USA athletes registered for the YOG were reviewed for patient encounters during the 2014 YOG. Medical encounters were defined as all medical services provided by a healthcare provider including evaluation, treatment and prophylactic services. All medical conditions were categorised by IOC Injury and Illness reporting criteria.

Results Team USA was comprised of 48 male and 46 female athletes, aged of 14–18 years, representing 20 sports. There were 346 total medical encounters among 54 of the 94 registered athletes for a rate of 3.7 medical encounters per athlete. A total of 40 injuries were recorded (14 time loss injuries, 26 non-time loss) and 20 illnesses. This equates to 43% of athletes sustaining an injury, and 21% sustaining an illness, with a frequency of 426 injuries and 213 illnesses per 1000 registered athletes. The most commonly involved body regions for time loss injuries were the knee (21%) and ankle (12%). Time loss injuries most frequently occurred in competition (71%) and the most common type of injury was a ligament sprain (43%). The most common illnesses were respiratory (35%) and dermatological conditions (30%).

Conclusions The rates of injury, illness and medical encounters per athlete were greater than in previous reports of medical service provisions at youth Olympic-level sporting events.

INTRODUCTION

Several studies have documented injury and illness during both Winter and Summer Olympics, but there has been limited research on the pre-Olympic athlete or youth elite athlete.[1–8]

The Summer Youth Olympic Games (YOG) are organised by the IOC as a quadrennial sporting event for elite athletes aged 14–18 years. The YOG has a cultural and educational emphasis, and it showcases high-level sports as a catalyst for improving the health of the youth.[9] The inaugural YOG were held in Singapore in 2010, where over 3500 athletes from 205 National Organizing Committee (NOC) participated in sport activities. The 2014 Summer YOG were held in Nanjing, China, and included over 3800 athlete participants from over 200 NOCs. The athletes competed in 30 disciplines of 28 Olympic sports, competing in 222 medal events over 13 days of competition.

Studies describing the incidence of injury and illness at the youth Olympic level are few in number and have not described all the sports represented.[8] In 2010, Steffen and Engebretsen[8] identified 13 studies on injury risk in eight youth Olympic sports. Eight of the 13 studies were specific to football. The local organising committee (LOC) medical committees from the 2010 Singapore YOG, 2014 Nanjing YOG, 2012 Innsbruck Winter YOG and 2013 European Youth Festivals each reported on medical service provision, including injury and illness data as recorded by the polyclinic for each event (table 1).[9–13] These studies did not include surveys of NOC medical staff injury and illness reports as has been done at the senior Olympic level since 2008.[2] While there is great value to understanding medical service provision at the polyclinic level, accurate medical surveillance at international games requires integration of NOC and LOC medical data.

In senior-level Olympic sport, the emphasis on injury prevention has resulted in successful implementation of medical surveillance systems during the period of the Summer and Winter Olympic Games (OG). At the 2008 Beijing Summer Olympics, the IOC instituted an injury and surveillance system that combined NOC and polyclinic reports.[2] This project was expanded at the 2010 Vancouver Winter Olympics and 2012 London Summer Olympics to include illnesses.[3 4] These projects have provided greater understanding of injury type by sport, mechanism, body region and illness incidence type.

Injury and illness prevention is a priority for the IOC, National Olympic Committees and National Sport Federations.[14] Team USA appreciates the value of the sports injury prevention model originally described by Van Mechelen *et al*[15] in 1992. This model consists of the following steps: (1) establishing the extent of the problem through injury surveillance and severity, (2) establishing the aetiology and mechanism of injury including identification of risk factors, (3) implementation of prevention strategies, and (4) assessing the effectiveness by repeating step 1. Epidemiological studies at major youth sporting events improve the understanding of relative risks of sports participation for specific populations and help medical professionals and administrators with medical planning for future events. Therefore, the purpose of our study was to describe injury and illness incidence from an NOC (US Olympic Team) during the 2014 YOG.

METHODS

Study procedures were approved by the Institutional Review Board of Southern California

To cite: Nabhan D, Walden T, Street J, *et al*. *Br J Sports Med* Published Online First: [*please include* Day Month Year] doi:10.1136/bjsports-2015-095835

Table 1 Injury, illness and number of medical encounters at youth Olympic-level mass sporting events

Event	Injury (per 1000 athletes)	Illness (per 1000 athletes)	Medical encounters (per athlete)
2010 Summer YOG Singapore (IOC)[9]	–	–	0.29
2012 Winter YOG Innsbruck (IOC)[13]	108.7	84.2	–
2013 European Youth Olympic Festival[12]	91.1	20.2	–
2014 Summer YOG Nanjing (IOC)[10]	207.1	25.3	0.27

(–) Represents data that has not been reported.
YOG, Youth Olympic Games.

University of Health Sciences. Athletes entered to compete for Team USA at the Nanjing YOG were registered prior to competition within a cloud-hosted Electronic Health Records (EHR) System (GE Centricity Software, General Electric, Fairfield, Connecticut, USA). The registration process required each athlete to access a secure web-based EHR patient portal where they provided demographic information, a pre-participation health history, and parental or guardian consent regarding the release of medical information.

During the period of the YOG, all medical encounters performed by Team USA medical staff were entered into the athlete's EHR. EHRs for 94 athletes were analysed by retrospective chart review for all patient encounters that occurred during the 2014 YOG in Nanjing, China. The YOG included 7 precompetition days and 11 competition days. Medical encounters were defined as all medical services provided by a healthcare provider including evaluation, treatment and prophylactic services. Medical encounters occurring at all sport venues, the YOG Polyclinic and regional medical facilities were documented in the EHR by Team USA medical staff.

Team USA utilised an integrated multiple disciplinary medical team for the YOG, consisting of a primary care medical physician with a certificate of additional qualification in sports medicine, a doctor of chiropractic with certificate of additional qualification in sports medicine and a certified athletic trainer. The Team USA medical clinic was located adjacent to the administrative offices of the Team USA building in the Youth Olympic Village. This clinic provided for diagnostic and therapeutic services including physical examinations, diagnostic ultrasonography, pharmacy, physiotherapy, taping and bracing. When possible, medical staff accompanied athletes to practices and competitions. Neurotrauma and combat sports were prioritised for medical coverage. In the events where the required level of medical service for an injury or illness extended beyond the capabilities of the USA medical clinic, athletes were accompanied by a Team USA medical staff personnel to the Youth Olympic Village Polyclinic or regional medical facilities for further evaluation and treatment. Medical treatments were recorded in the EHR system and characterised by treatment type, including the type of medicine dispensed.

Definition of injury and illness

Medical encounters were then classified using a system based on the IOC Illness and Injury survey by type of encounter, involved region or organ system, mechanism or cause, and classified as acute or overuse injury.[16] Time loss injury was defined as a neuromusculoskeletal condition that resulted in time lost from sports participation. Neuromusculoskeletal conditions that an athlete sought medical attention for but did not result in loss of sport were classified as non-time loss injuries. All injuries required medical attention by definition. Illness was defined as a non-musculoskeletal condition requiring medical evaluation.

Data analysis

After the close of the YOG, all recorded data regarding the medical encounters that occurred during the period of the games were de-identified and extracted into a database for analysis (Tableau Software, Seattle, Washington, USA). Data were summarised and frequency analysis was performed for all variables measured.

RESULTS

A total of 94 Team USA athletes participated in the games. There were 48 males and 46 females with an average age of 16.9 years (range 14–18). The registered athletes represented 20 International Federations (table 2). A total of 14 time loss injuries, 26 non-time loss injuries and 20 illnesses were reported, for a frequency of 425.5 injuries including 148.9 time loss injuries, 276.6 non-time loss injuries and 212.7 illnesses per 1000 registered athletes. The number of time loss injuries and illnesses by sport and gender is presented in table 2.

Three hundred and forty-six medical encounters were documented on 54 of the 94 registered athletes by three Team USA medical staff, for a rate of 3.7 medical encounters per registered athlete. The number of medical encounters per sport, by gender, is reported by number and percentage of total encounters in figure 1.

Time loss injuries

Fifteen per cent (N=14) of registered athletes had an injury resulting in time loss from sport. Injury frequency per 1000 athletes was greatest in rugby (291.7), followed by boxing (250), basketball (250), gymnastics (250), rowing (250) and athletics (117.7). The most commonly injury locations described by anatomic region, types of pathology and activity during which the injury occurred are reported in table 3.

Non-time loss injuries

Twenty-eight per cent of the registered athletes sustained non-time loss injuries. The involved body regions for non-time loss injuries (N=26) were lumbar spine (5), thoracic spine (5), thigh (3), foot (2), hip (2), leg (2), and 1 each of ankle, elbow, groin, hand, shoulder, Achilles tendon and sternum. The types of non-time loss injuries were strain/muscle injury (9), ligament sprains (8), impingement (4), tendinopathy (3), contusion (1) and bone stress injury (1).

Illness

Twenty-one per cent (N=20) of athletes received medical attention for an illness. No illness resulted in time loss from sport or hospitalisation. Respiratory (7) and dermatological (6) symptoms were the most frequently encountered. The types of illnesses encountered, their cause and main symptom are presented in table 4.

Table 2 Time loss injury and illness incidence by sport and gender

	Illness		Injury	
Sport	**F**	**M**	**F**	**M**
Athletics F (N=9); M (N=8)	1	1	4	5
Basketball F (N=4); M (N=0)	1	0	1	1
Boxing F (N=2); M (N=2)	0	1	2	1
Canoe-Kayak F (N=0); M (N=1)	0	0	0	1
Diving F (N=1); M (N=1)	0	0	1	0
Fencing F (N=2); M (N=3)	0	0	0	0
Gymnastics F (N=2); M (N=2)	1	0	2	2
Judo F (N=1); M (N=1)	0	1	0	0
Modern pentathlon F (N=0); M (N=1)	0	0	0	0
Rowing F (N=2); M (N=2)	1	1	0	1
Rugby F (N=12); M (N=12)	3	4	8	4
Sailing F (N=0); M (N=2)	0	0	0	1
Swimming F (N=4); M (N=4)	3	1	1	1
Table tennis F (N=1); M (N=1)	0	0	0	0
Taekwondo F (N=1); M (N=0)	0	0	0	0
Tennis F (N=1); M (N=1)	0	0	0	0
Triathlon F (N=1); M (N=1)	0	0	0	0
Volleyball F (N=2); M (N=2)	0	1	1	1
Weightlifting F (N=1); M (N=1)	0	0	0	0
Wrestling F (N=0); M (N=3)	0	0	0	2

F, female; M, male.

Medical treatments provided included dispensing of over-the-counter and prescription medications, manual therapy, taping and bracing, and provision of therapeutic physical therapy modalities. A total of 30 prescriptions for medication were provided to 22 Team USA athletes during the period of the games. Types of medications included non-steroidal anti-inflammatories (40%), antihistamines (17%), antimicrobials (10%), respiratory system drugs (10%), antipyretic/analgesics (17%), ear/nose/throat drugs (3%) and skin medications (3%). No patients were hospitalised, and no invasive procedures or surgeries were required.

DISCUSSION

The study described the rate of injury, illness and medical encounters per athlete at the youth Olympic level. There were 149 time loss injuries, 277 non-time loss injuries and 213 illnesses per 1000 registered athletes. The rates were greater in this population than previously published reports of medical service provision at youth Olympic-level sporting events (table 1).

No injury or illness incidence per 1000 athlete data is available from the one known report of medical services at the 2010 Summer YOG in Singapore.[9] For the 2012 Winter YOG and injury incidence of 108.7 per 1000 athletes and 84.2 illnesses per 1000 athletes.[11] At the 2013 European Youth Olympic Festival, injury and illness incidence were reported at 91.1 and 20.2 per 1000 athletes, respectively.[12] At the 2014 YOG, it has been reported that for all athletes there was a rate of 207.1 injuries per 100 athletes and 0.27 medical encounters per athlete by the LOC medical staff.[10] The number of patient encounters provided per athlete in this study was 10 times greater than reported at previous youth-level international games.

Key drivers of injury incidence

Rugby accounted for the greatest number of injuries, illnesses and medical encounters. Rugby was the only contact team sport included in the roster of the YOG, had the largest roster size of any sport and was a newly included sport at the YOG level. Five of the six direct contact time loss injuries reported by Team USA occurred in rugby. This is the first YOG that included rugby, and this appears to contribute to the higher injury rate reported by Team USA and the LOC's medical service provision at this event.[10] Team sports have high injury incidence at the senior and youth Olympic level.[2 3 9 10] In Summer OG,

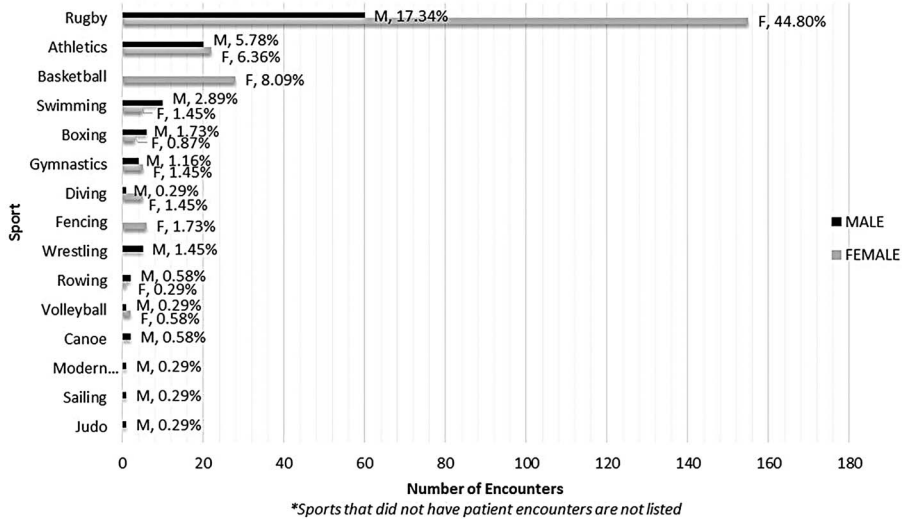

Figure 1 Number of medical encounters and percentage of total encounters per sport by gender.

Table 3 Time loss injury characteristics (location, type, cause) stratified by sport

	All (n=94)	Athletics (n=17)	Basketball (n=4)	Boxing (n=4)	Gymnastics (n=4)	Rowing (n=4)	Rugby (n=24)	Swimming (n=8)
Number of injuries	14	2	1	1	1	1	7	1
Injury location								
Ankle	3	–	1	–	–	–	2	–
Foot/toe	1	1	–	–	–	–	–	–
Groin	1	–	–	–	–	–	–	1
Head	2	–	–	1	–	–	1	–
Knee	3	–	–	–	–	–	3	–
Lumbar spine/lower back	1	–	–	–	1	–	–	–
Shoulder/clavicle	1	–	–	–	–	–	1	–
Thigh	1	1	–	–	–	–	–	–
Wrist	1	–	–	–	–	1	–	–
Injury cause								
Contact	6	–	–	1	–	–	5	–
Non-contact acute	5	1	1	–	–	1	1	1
Overuse	3	1	–	–	1	–	1	–
Injury type								
Concussion	2	–	–	1	–	–	1	–
Fracture (trauma, stress, other bone injuries)	2	1	–	–	1	–	–	–
Lesion of meniscus or cartilage	2	–	–	–	–	–	2	–
Sprain (dislocation, subluxation, ligamentous rupture)	6	–	1	–	–	1	4	–
Strain (muscle rupture, tear, tendon rupture)	2	1	–	–	–	–	–	1

*No injuries sustained by the following sports: Canoe-Kayak (n=1), diving (n=2), fencing (n=5), judo (n=2), modern pentathlon (n=1), sailing (n=2), table tennis (n=2), taekwondo (n=1), tennis (n=2), triathlon (n=2), volleyball (n=4), weightlifting (n=2), wrestling (n=3).

although the sports with the highest injury rates differ at each games, team and combat sports are generally higher risk. In 2008 Beijing OG soccer, taekwondo and field hockey reported the most injuries, while in 2012 London OG, taekwondo, soccer and BMX cycling had the highest injury occurrence.[2 3] Event planners and medical staff may wish to consider the high incidence in team sports such as rugby when preparing for future youth-level mass sporting events.

Small sample sizes and unequal distribution of sport roster sizes by gender did not allow for analysis of relative injury risk in different sport populations. Women's rugby required significantly more medical attention as measured by the number of patient encounters than men's rugby, and both teams had equal roster sizes. Women's rugby is a new sport at the youth Olympic level, and it may be speculated that inexperience in international competition may be a risk factor for injury.

When stratified by body region, the majority (9/14) of the time loss injuries reported occurred in the lower extremity. This is consistent with the injury incidence reports from the 2010 Singapore YOG, as well as the 2008 Beijing OG where lower limb injuries and sprains were the most prevalent injury location and type.[2 9] Prevention of acute-onset lower extremity injury such as ligament sprains has been well studied.[17] Programmes such as the FIFA 11+ reduce the incidence of injury.[18 19] The IOC's newly designed 'Get Set' injury prevention application, which was designed to provide injury prevention exercise programmes for 30 Olympic sports was presented to athletes at the Nanjing YOG Village.[20] While the efficacy of this specific intervention has yet to be measured, exercise-based injury prevention has proven effective for sports injury prevention.[21]

The majority of the injuries that resulted in time loss from competition were acute in nature. Two of the three injuries that were chronic in nature were stress fractures that were undiagnosed, but symptomatic, on arrival at the YOG. The third athlete had a chronic hamstring injury that worsened during the competition period to the point that the athlete was forced to withdraw. Although athletes were screened via questionnaire during the registration process, the screening did not identify these injuries. Medical teams planning for events with athletes at the youth level should consider that athletes may choose not to report injuries prior to a major event. Survey tools may not always be adequate for screening in this population; therefore, compulsory physical examinations in close temporal proximity to competition should be considered in an attempt to prevent registration of athletes with injuries that contraindicate participation in competition.

Illness incidence

Respiratory symptoms were the most commonly encountered illnesses by Team USA during the period of the YOG. This finding is consistent with illness reporting from other events and extends previous studies on elite athletes.[3 22 23] This team was dispersed geographically across the USA prior to the YOG. Travel greater than five time zones is a risk factor for illness.[24] Other proposed risk factors include low vitamin D status, high training load and training-associated immune system depression.[25–27] There is some evidence for illness prevention programmes, including the use of probiotics prior to travel, addressing micronutrient deficiency, and addressing the quantity and timing of macronutrient intake.[27] Education regarding illness prevention should be a priority in the planning stages for NOC's preparing for major events.

Medical service provision

Of the 346 patient encounters recorded, only 9% resulted in management requiring prescription or over-the-counter medication. The composition of a medical staff with an emphasis on conservative and non-pharmacological management of

Table 4 Illness characteristics (type, cause, main symptom) stratified by sport

	All (n=94)	Athletics (n=17)	Basketball (n=4)	Boxing (n=4)	Gymnastics (n=4)	Judo (n=2)	Rowing (n=4)	Rugby (n=24)	Swimming (n=8)	Volleyball (n=4)
Number of illnesses	20	2	1	1	1	2	2	6	2	3
Illness type										
Allergic/immunological	2	–	–	1	–	–	1	–	–	–
Dermatological	6	1	–	–	1	1	1	1	–	1
Dental	1	–	–	–	–	–	–	–	–	1
Gastrointestinal	1	–	–	–	–	–	–	–	1	–
Neurological/psychiatric	2	–	–	–	–	1	–	1	–	–
Other	1	–	–	–	–	–	–	1	–	–
Respiratory/ear; nose, throat	7	1	1	–	–	–	–	3	1	1
Cause of illness/symptom										
Environmental	8	1	1	1	1	–	–	4	–	–
Exercise induced	4	1	–	–	–	1	1	1	–	–
Infection	3	–	–	–	–	1	–	1	1	–
Other	3	–	–	–	–	–	1	–	–	2
Pre-existing (eg, asthma; allergy)	2	–	–	–	–	–	–	–	1	1
Main symptom										
Diarrhoea; vomiting	1	–	–	–	–	–	–	–	1	–
Dyspnoea; cough	4	–	–	–	–	–	1	2	1	–
Lethargy/dizziness	3	1	–	–	–	1	–	1	–	–
Other	6	–	1	1	–	1	1	1	–	1
Pain	6	1	–	–	1	–	–	2	–	2

*No illnesses sustained by the following sports: canoe-kayak (n=1), diving (n=2), fencing (n=5), modern pentathlon (n=1), sailing (n=2), table tennis (n=2), taekwondo (n=1), tennis (n=2), triathlon (n=2), weightlifting (n=2), wrestling (n=3).

musculoskeletal conditions appeared well balanced to manage the types of illness and injuries observed. In the planning of future summer YOG medical services, it may be advisable for sport administrators to emphasise staffing with practitioners competent in the evaluation and conservative management of sports injury. In theory, if sports medicine staff composition influences patient encounters, there also may be differences in the frequency and types of medical encounters reported for team medical staff when compared with polyclinic staff. Improved understanding of the epidemiology of sport participation at the youth level will help healthcare providers and sport administrators plan for the medical staffing and service line provisions associated with sporting events for adolescent athletes.

Methodological considerations

Several factors may explain the discrepancy in rate of injury, illness and medical encounters per athlete in this manuscript as compared with previous reports. NOC-level reports of injury and illness are influenced by small sample sizes; therefore, small changes in numbers of events are exaggerated in prevalence rates.[23] The patient encounters documented included evaluation of injuries, illnesses and non-time loss injuries as well as the documentation of any medical treatment including prophylactic treatments or services. The level of daily athlete engagements documented by an NOC medical team may not be more sensitive than those that occur with LOC medical team. For example, the United States Olympic Committee Sports Medicine Division requires that Team USA medical staff must document all athlete interactions including field of play medical encounters such as taping, strapping and basic wound care. This inclusive definition of medical encounter may create inflated rates of patient encounter per athlete. It can be proposed that this definition, due to its sensitivity, provides a more precise estimation of the use of medical resources by athletes at major events.

The inclusiveness of records achieved by creating EHRs through a cloud-based central repository may be one reason for the higher medical encounter rates reported here than previously reported in similar studies. After the 2012 London Olympics, Engebretsen *et al*[3] discussed the IOC's long-term goal of developing a customised EHR for use by both NOC's on a year round basis and the IOC.[3] The proposed benefits of this included improved surveillance of injury and illness, with potential to improve risk factor identification efforts and development of injury prevention measures. In this study, one NOC's use of a cloud-based EHR platform provided for improved recordings of interactions outside the clinic setting to include all NOC interactions at sport venues. Future surveillance projects may benefit from the use of EHR as a data collection tool for identification of variables that may be of interest in risk factor identification. Leveraging technology to improve EHR access removed some traditional barriers to injury surveillance and provide for more inclusive medical documentation in comparison to paper records or only documenting clinic-based encounters. Electronic documentation standards within clinical guidelines are likely to encourage comprehensive, accurate processing of data.[28] EHR may help produce more accurate and robust injury surveillance data than traditional injury surveillance methods.

Practical implications

Concerns with regard to injury in sport and physical activity can prevent youth from participating in sport.[16] Additional studies are needed to better understand the epidemiology of youth sport injury and illness in order to create effective injury management teams and effective youth injury prevention models. Prior reports of medical service provision by the IOC Medical Commission have shown that there are significant differences in the number of medical encounters between teams with an NOC

team doctor as compared with those that do not travel with medical support.[9] This implies that relying on LOC data to describe injury and illness incidence may result in a loss of data for care that occurs at the NOC level. The use of EHR systems for injury surveillance may be a key to improved integration of NOC and LOC medical data and progression from basic epidemiology studies to risk factor identification and injury and illness prevention programming.

LIMITATIONS

This study describes injury and illness occurrence for one NOC at one Summer YOG, and is limited by its relatively small sample size. Integrating data from NOC and LOC medical records at multiple youth Olympic-level sporting events would provide a more accurate assessment of injury and illness occurrence in this demographic. The methods of data collection used did not allow for identification of risk factors of injury or illness such as demographic, anthropometric, health history and training history.

CONCLUSIONS

The rates of injury, illness and medical encounters per athlete were greater in this population than previously published reports of medical service provisions at youth Olympic-level sporting events. EHRs can successfully be used in injury surveillance at major sporting events. Future work in this area should include more thorough data collection for development of medical event management, risk factor identification and injury prevention programmes.

What are the findings?

- Injury, illness and medical encounters per athlete were greater in this population than previously reported at the Youth Olympic Games (YOG) level.
- Electronic health records are an effective means of capturing injury and illness incidence at mass sporting events.
- For Olympic-related sporting events, the integration of local organising committee and National Olympic Committee data provides the most inclusive data on injury and illness.

How might it impact on clinical practice in the future?

- Strategies for medical service implementation may be built in response to anticipated injury and illness.
- Injury and illness prevention programmes should be considered for the most common conditions encountered.
- Electronic health records may be the preferred surveillance tool at future sporting events.

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Contributors DN provided leadership in concept design, data collection, interpretation and drafting of the manuscript. TW served as the project manager for data management, analysis and presentation. JS provided assistance in data collection and assisted in drafting of the manuscript. HL provided assistance in data collection and conceptual design of the project. BM provided leadership in conceptual design of the project, manuscript writing and final approval of the manuscript.

Competing interests None declared.

Ethics approval Southern California University of Health Sciences IRB.

Provenance and peer review Not commissioned; externally peer reviewed.

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Br J Sports Med published online April 20, 2016