How do the new Olympic sports compare with the traditional Olympic sports? Injury and illness at the 2018 Youth Olympic Summer Games in Buenos Aires, Argentina

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ABSTRACT

Objective To describe injuries and illnesses across traditional and new sports among the participating athletes of the Buenos Aires 2018 Youth Olympic Summer Games (BA YOG) (6–18 October 2018).

Methods We recorded the daily number 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 manned by the BA YOG 2018 medical staff.

Results In total, 3.984 athletes from 206 NOCs were observed. NOCs and BA YOG 2018 medical staff reported 619 injuries and 334 illnesses, equalling 15.5 injuries and 8.4 illnesses per 100 athletes over the 13-day period. The eight new sports on the Youth Olympic programme (futsal, beach handball, karate, roller speed skating, kitesurfing, BMX freestyle, climbing and break dancing) fell in between the other sports with respect to injury and illness risk. Injury incidence was highest in rugby (43% of all rugby players), followed by boxing (33%) and badminton (24%), and lowest in swimming, archery, roller speed skating, equestrian, climbing and rowing (<5%). The highest incidences of illness were recorded in golf (20%), followed by triathlon (16%), beach volleyball and diving (both 14%). Of the illnesses, 50% affected the respiratory system and 15% the gastrointestinal system. Injury and illness incidences varied between continents with athletes representing Europe having significantly fewer injuries and illnesses compared with other continents, apart from a similar illness incidence to Asian athletes.

Conclusion The overall injury incidence of 15.5 injuries per 100 athletes was higher, while the overall illness incidence of 8.4 illnesses per 100 athletes was similar to previous youth and Olympic Games. The new sports did not differ significantly compared with the other sports with respect to injury and illness risk.

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INTRODUCTION

Identifying high-risk sports is an important first step in developing and implementing evidence-based preventive measures.[1] In addition, minimising the risk of injuries and illnesses, especially those with severe and long-lasting consequences, will contribute to improved overall health[2 3] and may contribute to fewer athletes discontinuing their sport.[4]

To promote sports participation in young people, the IOC introduced the Youth Olympic Games (YOG) in 2007. Following the evaluation of medical care delivery models in the second Summer YOG in Nanjing in 2014, the IOC decided to implement an injury and illness surveillance programme to better understand the incidence of injuries and illnesses in this unique elite athlete population.[5]

Detailed prospective epidemiological data on young elite athletes' acute and overuse injuries are limited, and most often restricted to single sports.[6–14] Injuries and illnesses in youth elite multisport events have been systematically recorded in two 5-day Youth Festivals[15 16] and in two YOGs,[17 18] but never in large-scale Summer YOGs. There is a gap in the literature of the injury and illness risk in this young and highly competitive cohort of elite athletes.

In 2018, and for the first time ever, the YOGs were held outside Eurasia and in the southern hemisphere. Almost 4.000 young athletes from more than 200 countries participated in the third Youth Olympic Summer Games in Buenos Aires (BA), Argentina. They competed in 32 sports (36 disciplines), of which BMX freestyle, kitesurfing, cross-country running, beach handball, futsal, sport climbing, karate, breakdancing and roller speed skating were on the Youth Olympic programme for the first time.

The aim of this prospective cohort study was to describe injury and illness characteristics in traditional and new sports among the participating athletes of the Buenos Aires 2018 Youth Olympic Summer Games (BA YOG 2018) and to compare other factors such as sex and continental representation.

METHODS

We employed the IOC injury and illness surveillance system for multisport events.[19] A month before the Games, we had received contact information (names, roles, email addresses) from the Organizing Committee of the Youth Olympic Games Buenos Aires 2018 (BAYOGOC 2018) for those National Olympic Committees (NOC) who had applied for

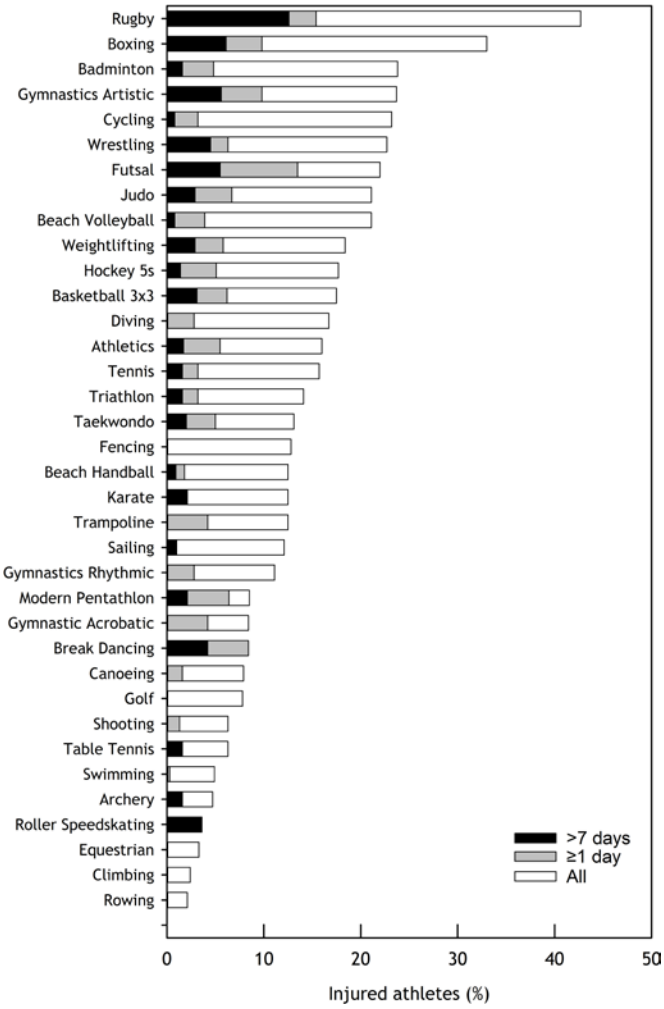

Figure 1 Proportions of athletes (%) in each sport with injury, injury with estimated time loss ≥1 day and injury with estimated time loss >7 days.

Argentine authorisation for their clinical staff (medical doctor (MD), physiotherapist (PT)) for the period of the Games. With the help of this contact list, we informed those NOCs about the study a week before the opening of the Olympic Village.

After arrival, 2 days before the opening ceremony, we organised a meeting for all present NOC medical staff to introduce the project, aims and procedures, and to answer any questions. The IOC research group had an office in the Polyclinic, centrally based in the Olympic Village as a meeting point for NOCs and the organiser's clinical staff (BAYOGOC), and the IOC research team.

Implementation

We invited all NOCs to report the daily occurrence (or non-occurrence) of athlete injuries and illnesses over the 13 days of the Games period (6–18 October 2018) by completing an injury and illness report form, on paper or electronically. We also checked the BAYOGOC athlete database for the participating athletes' age, sex, sport and NOC affiliation.

Throughout the data collection, we frequently visited NOCs with 10 or more participating athletes to address any questions and encourage continuous reporting during the Games. We recorded the response rate of all NOCs in the BA YOG 2018.

Concurrently, we retrieved information on all athletes treated for injuries and illnesses in the polyclinic and all other medical venues operated by BAYOGOC.

These data, covering the same variables as the NOC reporting form, were collected through an electronic medical record system (SIGEHOS, Health Ministry, Autonomous City of BA). In cases where athletes were treated for the same condition by both NOC and BA 2018 medical staff, we retained the most complete data source.

Injury and illness report form and information

The IOC injury and illness report form followed the template of that used in the previous Summer[20–22] and Winter Olympic Games (OG),[23–25] and Youth Olympic Winter Games.[17 18] The report form was available in eight languages: English, French, Arabic, Chinese, German, Japanese, Russian and Spanish.

With respect to injuries, we recorded the following data: accreditation number, name, sport, whether the injury occurred in competition or training, date, body part, type, cause and estimated time lost from competition or training. We recorded data on illnesses in a similar fashion, including affected system, main symptom(s) and causes.

Definition of injury and illness

We defined injuries and illnesses as new or recurring when they were incurred in competition or training during the BA YOG and received medical attention, regardless of the consequences with respect to absence from competition or training.[19] Pre-existing, not fully rehabilitated conditions were not recorded. For recurring injuries or illnesses to be included as a new incident, the athletes had to have returned to full participation after the previous condition resolved. Overuse injuries could be of

Box 1 Information on the 85 severe injuries (estimated absence >7 days), with the sports with the highest numbers in brackets.

- 24 ligament ruptures (11 knee, of which 8 ACL injuries, 10 ankle, 1 finger, 1 elbow, 1 shoulder): rugby (8), futsal (4), basketball (3).
  - 8 ACL injuries:
    - Futsal, female, 18 years, competition, contact.
    - Futsal, female, 16 years, competition, non-contact.
    - Futsal, male, 18 years, competition, contact.
    - Rugby, female, 17 years, training, ?
    - Rugby, female, 18 years, training, non-contact.
    - Wrestling, male, 16 years, competition, contact.
    - Basketball, female, 18 years, competition, contact.
    - Artistic gymnastics, male, 17 years, training, non-contact.
- 20 fractures (6 hand, including finger, thumb, 5 face, 1 foot, 1 lower leg, 1 forearm, 2 shoulder): futsal (4), boxing (3), judo (2), rugby (2).
- 11 sprains (8 ankle, 3 knee, 1 shoulder): futsal (2).
- 10 dislocations/subluxations (6 shoulder, 1 elbow, 1 wrist, 1 knee, 1 thoracic spine/upper back): basketball (2), weightlifting (2).
- 10 strains/muscle ruptures/tears: futsal (2).
- 4 concussions: rugby.
- 4 tendinosis/tendinitis: athletics (2).
- 1 fascitis/aponeurosis injury: rugby (1).
- 1 nerve/spinal cord injury: artistic gymnastics (1).

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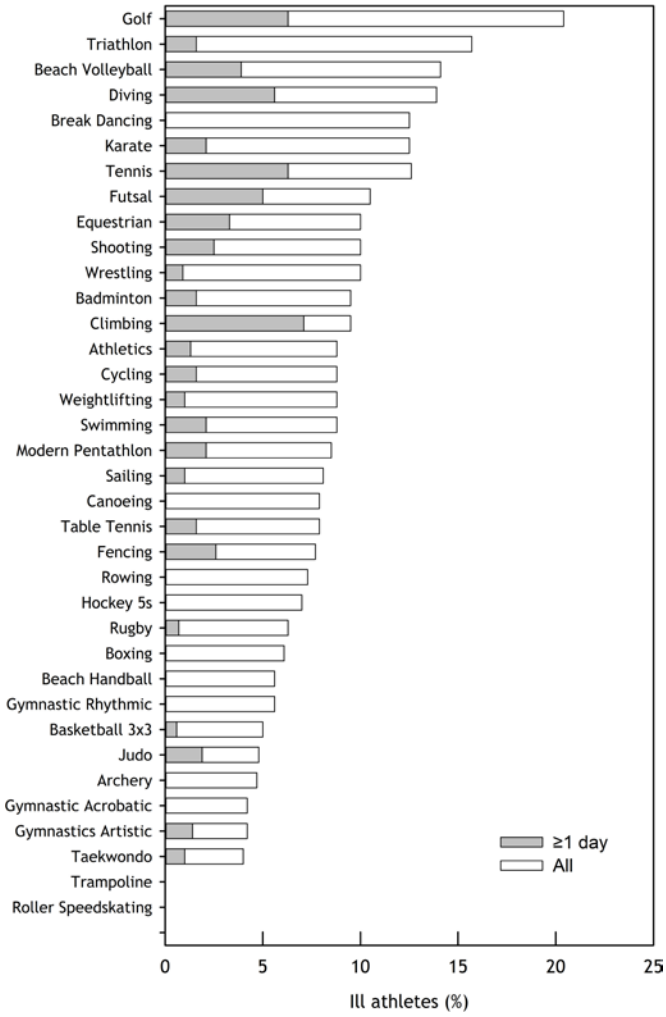

Figure 2 Proportions of athletes (%) in each sport with illness and illness with estimated time loss ≥1 day.

sudden or gradual onset, while acute injuries could be the result of contact (various options) or non-contact origin.

Injuries included musculoskeletal complaints, concussions and other non-musculoskeletal trauma, such as dental injuries. In cases where a single incident caused multiple injury types, we recorded only the most severe injury for analysis—as determined by our research team based on all available clinical data. Severe injuries and illnesses were defined based on clinical experience as those estimated to lead to more than 1 week of absence from training or competition.

Confidentiality and ethical approval

We treated all athlete information confidentially, and deidentified our database after the Games, ensuring anonymity of all athletes. The athlete's accreditation number was only used to avoid duplicate reporting from the NOCs and BAYOGOC.

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 during the study period and e 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 100 athlete-days, where athlete-days correspond to the total number of athletes multiplied by 13 days. We calculated CIs of the risk ratio (RR) of the number of injuries or illnesses between the two groups (healthy vs injured/ill) by a Poisson regression model, assuming constant hazard per group and adjusting for sport, sex, age, NOC size and continent where appropriate. We present injury and illness incidences as means and RR with 95% CIs. We regarded two-tailed p values <0.05 as significant.

RESULTS

In total, 3.984 athletes, aged 15–18 years, from 206 NOCs participated in the third Youth Olympic Summer Games in BA, equally distributed between sexes (1983 female and 2003 male athletes), and with most of them coming from Europe (37%), followed by Asia (21%), Africa (13%), South America (12%), North America (11%) and Oceania (6%). The 13-day Games period equals an exposure of 51.792 athlete-days.

Athletes' ages varied substantially between sports as per the regulations and qualification criteria given by each International Sports Federation before the Games (see distribution of age and sex across sports in online supplementary appendix 9). In general, female athletes were significantly younger (16.9 years (SD 0.9)) than male athletes (17.2 years (SD 0.8)) (p<0.001). For both sexes, more than half of the athletes were born during the first half of the year (January to June): females n=1126, 57%, males n=1226, 61%.

Injuries by sport and sex

We recorded a total of 619 injuries through daily NOC and BAYOGOC reports, equalling 15.5 injuries (95% CI 14.3 to 16.8) per 100 exposed athletes. This corresponds to 12.0 injuries per 100 athlete-days (95% CI 11.0 to 12.9). Of the 3.984 athletes, 3.436 (86%) remained free of injuries during the Games, while 548 (14%) athletes suffered from at least one injury with 63 athletes of those who have been treated for two injuries and four athletes for three injuries each.

Figure 1 describes the incidence proportion of injured athletes in each sport (additional details are available in online supplementary appendix 1). The incidence of injury was highest in rugby (42.7 injuries (95% CI 32.0 to 53.4) per 100 athletes), followed by boxing (32.9; 95% CI 20.5 to 45.4), badminton (23.8, 95% CI 11.8 to 35.9), artistic gymnastics (23.6, 95% CI 12.4 to 34.8), cycling (23.2, 95% CI 14.8 to 31.6), wrestling (22.7, 95% CI 13.8 to 31.6) and futsal (22.1, 95% CI 15.6 to 28.6). Injury incidence was lowest in swimming, archery, roller speed skating, equestrian, climbing and rowing (all fewer than 5 injuries per 100 athletes).

There was no difference in injury incidence between female athletes (15.0 injuries (95% CI 13.3 to 16.7) per 100 athletes) and male athletes (16.1, 95% CI 14.3 to 17.8; RR=0.96, 95% CI 0.82 to 1.13) (see distribution of injuries by sex across sports, online supplementary appendix 2).

Severity of injuries

While 70% (n=433) of the injuries were estimated to result in no time loss from sport, 30% of the injuries (n=186) were expected to prevent the athlete from participating in competition or training (online supplementary appendix 1). Of these 186 injuries, it was estimated that more than half of them (n=101 injuries, 54%) would result in an absence from sports from 1 to 7 days, while 85 injuries (14% of all 619 injuries) would result in an estimated absence from sport of more than 1 week.

These severe injuries were equally distributed between female (43 injuries) and male athletes (42 injuries). The three sports

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)	108 (419)	72 (1.610)	25 (1.814)	1 (141)	206 (3.984)
Injuries (injuries per 100 athletes)	73 (17.4)	235 (14.6)	296 (16.3)	15 (10.6)	619 (15.5)
Illnesses (illnesses per 100 athletes)	33 (7.9)	117 (7.3)	172 (9.5)	12 (8.5)	334 (8.4)
Daily reports submitted (n, %)	719 (51.2)	856 (91.5)	320 (98.5)	12 (92.3)	1.907 (71.2)
Medical NOC support* (n, %)	17 (15.7)	50 (69.4)	25 (100.0)	1 (100.0)	93 (45.1)
Physician (n, %)	14 (13.0)	41 (56.9)	25 (100.0)	1 (100.0)	81 (39.3)
Physiotherapist (n, %)	11 (10.2)	36 (50.0)	23 (92.0)	1 (100.0)	71 (34.4)
Recorded by NOC and BAYOGOC					
Injuries (n, %)	10 (13.7)	34 (14.5)	33 (11.1)	2 (13.3)	79 (12.7)
Illnesses (n, %)	2 (6.1)	12 (10.3)	1 (<0.1)	2 (16.7)	17 (5.1)
Recorded only by NOCs					
Injuries (n, %)	16 (21.9)	125 (53.2)	236 (79.7)	8 (53.3)	385 (62.1)
Illnesses (n, %)	8 (24.2)	64 (54.7)	154 (89.5)	6 (50.0)	232 (69.5)
Recorded only by BAYOGOC					
Injuries (n, %)	47 (64.4)	76 (32.2)	27 (9.1)	5 (33.3)	155 (25.0)
Illnesses (n, %)	23 (69.7)	41 (35.0)	17 (9.9)	4 (33.3)	85 (25.4)

*Either team physician or physiotherapist.
BAYOGOC, Organizing Committee of the Youth Olympic Games Buenos Aires; NOC, National Olympic Committee.

with the highest proportion of severe injuries were rugby (21% of all severe injuries and 30% of all rugby injuries), athletics (14% and 11%) and futsal (13% and 25%). In futsal, a total of 10 out of the 11 severe injuries occurred among female athletes. Box 1 presents the details of the 85 injuries classified as 'severe'.

Location and type of injuries

The most commonly injured locations were the knee (n=80, 13% of all injuries), ankle (n=72, 12%), thigh (n=66, 11%), lower leg and shoulder (both n=54, 9%). The most common injury types were sprain/ligament rupture (n=138, 22%), muscle cramps/spasm (n=90, 15%), bone contusion (n=83, 13%) and muscle strain injuries (n=79, 13%). The distribution of injury locations and injury types per sport are presented in online supplementary appendices 3 and 4, respectively.

Causes, mechanisms and onset of injury

While a total of 244 injuries (39%) were reported to occur by contact (either with another athlete, a moving or a stagnant object), 12% of injuries (n=77) were reported to occur from a non-contact trauma. Another 5% (n=30) were classified as recurrent or chronic and 3.5% (n=22) occurred as a result of field of play conditions, equipment failure and weather conditions, respectively. However, overuse (sudden or gradual onset) was reported as the cause for 34% of the injuries, most often by athletes competing in athletics (see online supplementary appendix 5).

Of the 619 injuries, 62% (n=385) occurred in competition. However, injuries in training and competition differed significantly in characteristics across sports (see online supplementary appendix 1).

Illnesses by sport, sex and severity

Among the 3.984 exposed athletes, a total of 334 illnesses were reported by 313 athletes, resulting in 8.4 illnesses (95% CI 7.5 to 9.3) per 100 athletes. This corresponds to 6.4 illnesses per 100 athlete-days (95% CI 5.8 to 7.1). A total of 21 athletes (14 females) reported two illnesses each.

Figure 2 shows the incidence proportion of illness in each sport (additional details are available in online supplementary appendix 1). Golf was the sport with the highest illness incidence (20.3 illnesses (95% CI 9.3 to 31.4) per 100 athletes), followed by triathlon (15.6, 95% CI 2.7 to 11.5), beach volleyball (14.1, 95% CI 7.6 to 20.6) and diving (13.9, 95% CI 1.7 to 26.1). The lowest incidences of illness were seen in judo, archery, acrobatic and artistic gymnastics, taekwondo and trampoline (all fewer than 5 illnesses per 100 athletes).

Female athletes (10.1 illnesses (95% CI 8.7 to 11.4) per 100 athletes) were at 55% higher risk of experiencing an illness than male athletes (6.7, 95% CI 5.6 to 7.9; RR=1.55, 95% CI 1.24 to 1.93).

One in five illnesses (n=66, 20%) were expected to result in absence from training or competition, most of them (n=52) with an estimated absence of 1–3 days.

Affected system, main symptoms and causes of illness

A total of 168 illnesses (50%) affected the respiratory system, followed by other frequently affected systems, such as the digestive system (n=51, 15%) and the skin and subcutaneous tissue (n=39, 12%). Of the 168 respiratory illnesses, 100 (60%) were caused by an infection. The distribution of affected systems, main symptoms and causes of illness per sport are presented in online supplementary appendices 6–8, respectively.

Data sources, injuries and illnesses per NOC size and continent

Throughout the 13 days of the Games, NOCs submitted 1.907 of a maximum of 2.678 daily reports, equalling a response rate of 71%. A total of 45 countries (22% of all countries) did not submit any data (table 1). The response rate of the 98 NOCs with ≥10 participating athletes (accounting for 90% of all the athletes) was 93% (1.188 out of 1.274 daily reports).

While 62% of the injuries and 70% of the illnesses were recorded solely by the NOCs, 25% of the injuries and illnesses, respectively, were recorded only by the BAYOGOC staff. Only 13% of the injuries and 5% of the illnesses were captured by both data sources (table 1).

Almost half of the NOCs (45%), covering 83% (n=3.307) of all athletes, brought medical support (physician and/or physiotherapist). Injury and illness risk was equally distributed between

Table 2 Injury and illness risk, expressed as per 100 athletes and risk ratios for comparisons between continents, adjusted for sport, sex, age, NOC, NOC size and medical NOC support availability (Europe used as reference group) and availability of medical support in all continents

	NOC (n)	Athletes (n)	Medical NOC support* (%)	Injuries (n)	Injuries per 100 athletes (95% CI)	Risk ratio (95% CI)	Illnesses (n)	Illnesses per 100 athletes (95% CI)	Risk ratio (95% CI)
Europe	47	1473	74	153	10.4 (8.7 to 12.0)	–	90	6.1 (4.9 to 7.4)	–
Asia	47	820	36	121	14.8 (12.1 to 17.4)	1.49 (1.17 to 1.89)	50	6.1 (4.4 to 7.8)	1.07 (0.75 to 1.52)
Oceania	16	248	25	64	25.8 (19.5 to 32.1)	1.62 (1.40 to 1.87)	41	16.5 (11.5 to 21.6)	1.66 (1.37 to 2.00)
Africa	56	500	32	125	25.0 (20.6 to 29.4)	1.38 (1.27 to 1.51)	54	10.8 (7.9 to 13.7)	1.30 (1.15 to 1.46)
North America	29	455	40	69	15.2 (11.6 to 18.7)	1.11 (1.03 to 1.19)	53	11.7 (8.5 to 14.8)	1.18 (1.09 to 1.29)
South America	11	488	75	87	17.8 (14.1 to 21.6)	1.12 (1.06 to 1.19)	46	9.4 (6.7 to 12.2)	1.08 (1.01 to 1.17)
All	206	3984	45	619	15.5 (14.3 to 16.8)	–	334	8.4 (7.5 to 9.3)	–

*Either team physician or physiotherapist.
NOC, National Olympic Committee.

smaller and larger NOCs, and irrespective of NOC medical support availability (table 1).

Injury and illness incidences varied between continents with athletes representing Europe having significantly fewer injuries and illnesses compared with other continents apart from a similar illness incidence to Asian athletes, respectively (table 2).

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DISCUSSION

With numerous new sports on the Olympic programme and only one small study published on young elite athletes' health during a summer multisport event,[16] there is a gap in the literature of the injury and illness risk in this young highly competitive population competing in traditional and new Olympic sports.

The main findings of this first ever prospective cohort study during Summer YOGs were that 14% and 8% of all the 3.984 athletes suffered from at least one injury or illness, with overall incidences of 15.5 injuries and 8.4 illnesses per 100 athletes, respectively.

While the figures on injury risk in the BA YOG were higher than previously reported from Winter YOGs,[17 18] Winter[15] and Summer Youth Olympic Festivals,[16] and higher than in Summer[20–22] and Winter OGs,[23–25] illness risk was comparable to previous youth and OGs.

The highest injury incidences were recorded in rugby (43% per 100 competing athletes) and boxing (33%), while the highest incidences of illness were seen in golf (20%) and triathlon (16%). The new sports—futsal, climbing, beach handball, BMX freestyle, kitesurfing, karate, cross-country running, breakdancing and roller speed skating—were evenly distributed among the other sports with respect to athletes' injury and illness risk.

Injury risk compared with athletes in OG

In the BA YOG, the overall injury incidence was higher compared with recent Summer OG (London 2012 and Rio 2016) for several sports, such as rugby 7s. In the BA YOG, 43% of the participating rugby athletes were affected versus 19% of rugby athletes in Rio 2016, while 13% of athletes in the BA YOG versus 3% of athletes in Rio suffered from severe injury risk. Other sports with higher injury risk in the BA YOG were wrestling (23% vs 13% in Rio and 12% in London 2012), basketball (18% vs 8% in Rio and 11% in London), judo (21% vs 11% in Rio and 12% in London), artistic gymnastics (24% vs 13% in Rio and 8% in London), badminton (24% vs 9% in Rio and 16% in London) and beach volleyball (21% vs in 7% Rio and 13% in London). In contrast, the injury incidence was lower in the BA YOG for taekwondo (13%) compared with 24% in Rio and 39% in London.[21 22]

Surprisingly, severe injury risk in the BA YOG (14% of all injuries) was comparable to previous Summer OGs (11%–20%).[20–22] Of interest, these findings do not follow the assumption that injury risk increases with age. Continuous surveillances during Summer YOGs will demonstrate whether these findings are confirmed at future events.

A direct comparison of risk between Olympic sports, or single-sport surveillances, was not always possible as the competition format between the YOG and the OGs varies. In the BA YOG, for example, 3×3 basketball, 5s hockey, beach handball (no indoor handball), futsal (no football), cross-country running and atypical rowing distances and relay concepts were on the competition programme.

Rugby 7s had the highest injury incidence of all sports in the BA YOG, more than twice that of the Rio OG.[22] One-third of these injuries were classified as severe: two out of the eight ACL injuries and four out of nine concussions registered in the BA YOG. Also, rugby represented 33% of all head injuries in the BA YOG. A 3-year study comparing different high school competitions in English Rugby Union showed that more injuries occurred at the highest level of competition, and that the concussion incidence was greater than that reported in any previously published study of youth rugby.[26] Given the high incidence and burden of concussion in BA, concussion prevention and management deserve specific focus.

Injury risk in new Olympic sports

A total of eight new sports, in addition to traditional sports in a new format compared with senior OGs (eg, 3×3 basketball, 5s hockey, selected athletic running distances), were on the competition programme in BA.

Futsal

Among all new sports, futsal showed the highest injury risk with 22%. Futsal is a fast-paced game in comparison to football and is played on a relatively small playing field, mostly relying on the lower extremity for ball control, sprinting and frequent changes in directions.[27] A team consists of six players. The ball can be played directly off the walls that surround the playing field.[28] With the nature of this high-intensity sport, the likelihood of twisting injuries and collisions between players is increased. One in four futsal injuries were classified as severe, including three ACL injuries, two of them by contact with another player. Other severe injuries were ankle and knee ligamentous injuries

and ankle fractures, mostly resulting from player contact. Female players suffered from 10 out of the 11 severe futsal injuries.

Compared with the injury risk in the OGs, futsal placed in between Rio 2016 (15%) and London 2012 (35%) with futsal revealing a higher risk of severe injuries (5.5%) than both OG football results (mean 2.3%). Unfortunately, there are no other epidemiological data available from youth futsal. From other high-speed pivoting sports, handball,[29] floorball[30] and lacrosse,[31] the literature consistently presents females being at higher knee injury risk. Preventive strategies highly recommend the application of neuromuscular injury prevention training.[32–35]

Beach handball

Based on one available injury surveillance held during the 2017 European Beach Handball Championships, including U17 players, beach handball seems to have a lower injury risk than that reported for indoor team handball.[36] With an overall injury incidence of 13% among beach handball players in the BA YOG, these results were comparable to those of handball players in Rio 2016 (15%),[22] but lower than of those in London 2012 (22%).[21] However, severe injuries were rare in the BA YOG (one concussion, one finger fracture and one knee sprain injury), and less frequent in comparison to indoor handball.[21 22 37] Those findings can likely be attributed to the sand requiring a different playing style, jump and landing techniques, lower impact forces from landings in addition to playing on a lower friction surface.[36] As for futsal played on artificial surface, high-friction forces are suggested to be associated with an increased ACL injury risk in indoor handball.[37] Proper warm-up routines are highly recommended to lessen the injury burden on the shoulder, knee and ankle joints.[32–35 38]

Karate

With 13 injuries per 100 athletes, karate was placed in between all other sports with respect to injury risk. A report gathering data from four consecutive World Championships revealed that junior elite karate athletes had lower total injury rates compared with elite adult athletes. In contrast to senior karate athletes,[39] youth athletes have been seen with a relatively large proportion of head injuries compared with the trunk, hip/pelvis and lower limbs.[40] However, no head injuries among karate athletes were recorded in the BA YOG.

Breakdancing

Based on a large retrospective study on breakdance injuries and overuse syndromes in amateur and professional dancers, breakdancing is considered as a high-risk dancing sport.[41] 'Headspin Hole' is described as a common overuse syndrome of the scalp specific to headspins causing hair loss, inflammation and lumps on the skull.[42] With only two injuries in the BA YOG (an overuse groin problem and a shoulder subluxation), equalling to 8.3 injuries per 100 athletes, breakdancing was on the lower end of the scale compared with other Olympic sports. Despite this, physicians should be aware of the common risks in this popular highly acrobatic kind of dancing.[41]

Climbing

Climbing made its Olympic debut with the competition formats of bouldering, speed, lead and combined. There is a paucity of epidemiological research examining injuries and risk factors in youth climbers specifically. The literature suggests climbers get injured mostly in their upper extremities with physiological adaptations in the fingers and bone stress injuries,[42–46] however, prospective data are still missing in the literature. In the BA YOG, only one time loss injury to the shoulder was recorded.

For the other three new sports, *roller speed skating*, *kitesurfing* and *BMX freestyle*, no comparisons to other data were available. However, roller speed skating and the acrobatic BMX freestyle have elements similar to winter sports as snowboard and ski cross/slopestyle, and short track. There, acute knee, shoulder and head injuries typically are results of high energy,[47–50] which gives substance to assume parallels in injury epidemiology. In the BA YOG, athletes' injury risk in roller speed skating, kitesurfing or BMX freestyle did not differ significantly compared with the other sports.

Illness risk among young elite athletes in youth Olympic summer sports

In preparation of athletes for major events, team physicians can anticipate that athletes travelling intercontinentally are at higher risk of illness.[51] With 8.4 illnesses per 100 athletes, illness risk in BA was similar to that reported in the two Winter YOGs[17 18] and slightly higher compared with the 5%–7% of affected athletes in London 2012[21] and Rio 2016 Summer OGs.[22] Also, consistent with recent reports,[52–56] female athletes experienced a higher risk than their male counterparts, and should be explored in more detail.[57]

Although slightly less frequent than in previous YOGs,[17 18] OGs,[21–25] Paralympic Games[52 53 58] and other single-sport events,[54–56] respiratory tract infections were the most common illness. We do not know the reasons for this, but potentially relevant factors may be the time of the year and climate in the southern hemisphere.[51]

Illnesses, however, can be mitigated through careful planning and diagnostic work prior to the Games. Education on hygiene is important and may be warranted through different channels to create awareness.[59–61] A recent IOC consensus statement on load in sport and risk of illness provided a list of general guidelines for illness prevention in athletes.[59]

NOC size, health risk and continent

In contrast to previous OG,[22 24 25] injury and illness incidences were similar between smaller and larger NOCs. This finding was surprising as larger delegations usually come from countries with well-developed exercise and sports medicine resources, generally been able to offer their athletes more comprehensive healthcare and closer medical follow-up both in the lead up to and during the Games.

According to official BAYOGOC reports, almost half of the NOCs (45%) supported their teams with medical staff (physician and/or physiotherapist). However, given the comparable health risk between NOCs, irrespective of size and health staff availability, also underlines the efficient logistics and management of the medical facilities in the BA YOG by the host country.

Injury and illness risk varied between continents with athletes representing Europe having the significantly lowest injury and illness risk compared with other continents. For illness risk, these discrepancies were less prominent. It would be interesting to explore potential associations between travel patterns across time zones and flying directions, time spent in precamps, health risk and healthcare availability.[51 59]

Methodological considerations

Response rate

With 71%, the response rate of daily submitted NOC forms was satisfactory, given the size of the Summer YOG and many NOCs

coming to the Games with young health support teams. The success of the response rate can be attributed to a combination of constructive communication pathways between the BAYOGOC and NOC medical leadership and the research team in all phases of the Games. Our strategically located office in the Polyclinic was staffed 8–10 hours daily with easy access for both NOCs as well as BAYOGOC staff. Also, NOCs and their athletes were present during the whole YOG period, which made follow-up communication with each country during the YOG easier than during the OG. Members of the research team frequently visited the NOCs to boost compliance, and daily meetings were performed between the research team and the BA medical leadership to enhance communication.

Though the proportion of injuries and illnesses captured by both the NOCs and the BAYOGOC medical staff was low, these data allowed us to improve data validity. These findings also underline the importance of two data sources for the scientific quality of a surveillance study such as in the BA YOG.[19]

Definitions

The high number of currently reported 'other' and 'overuse injuries' reflects limitations in the present methodology and coding system. Per definition, only '*new injuries and illnesses*' or '*recurring cases …. incurring in competition or training during the Games*' were to be recorded. Some of these injuries likely were '*new onset acute exacerbations of chronic or overuse injur*ies'. We are aware of athletes continuing to compete despite existing health complaints and do have different coping mechanisms to endure the demands of elite competition in such situations.

Athlete exposure

In the BA YOG, we expressed injuries and illnesses by means of absolute risk, meaning as counts of new cases per 100 exposed athletes (incidence proportion). Though appropriately adjusted, this approach erroneously assumes that the frequencies and lengths of exposure are identical in all sports. Interpretation of differences in injury incidences or patterns should therefore be made with caution.

Sparse data bias

With only few injury/illness cases present, we avouch the fact that subgroup comparisons in certain sports across sex, in specific, will have been affected by sparse data bias.[62] Sample sizes should reflect the expected effect of the risk factor on injury/illness risk, and to detect moderate to strong associations 20–50 injury cases are needed. For that reason, we did not consider subgroup comparisons between sex and single sports for both injury and illness risk.[63]

Reflections/practical implications

There is no knowledge available to substantiate whether injuries and burnout early in an athlete's career will result in premature departure of sport. The relative age effect is an often discussed topic, favouring those athletes born early in a calendar year.[64] There were different age classes across sports in BA YOG (online supplementary appendix 9), but these were more due to practical issues related to qualification events within each International Sports Federation to make up the final participants for BA.

The results of this study provide novel knowledge on injury and illness epidemiology in this young elite athlete cohort competing in new and traditional sports, which should improve injury and illness prevention measures. Ongoing surveillance to monitor trends over time is needed with the overall aim to mitigate health risk by ensuring the nature of the sport. Also, it is the role of the sports medicine community to protect athletes' overall health. An interdisciplinary health team is recommended for an athlete in development, comprising disciplines such as paediatrician and sports psychologist, to prepare the athletes for a top career.[65 66]

CONCLUSION

This study is the first multisport surveillance study on injuries and illnesses during Summer YOGs. While the overall injury risk with 15.5 injuries per 100 athletes was higher in the BA YOG compared with previous OGs, illness risk with 8.4 illnesses per 100 athletes was in line with former Games. The incidences and characteristics of injuries and illnesses varied substantially between sports and sex. However, new sports on the Olympic programme did not turn out to differ mentionably compared with the other sports with respect to injury and illness risk.

What are the findings?

- While the overall injury incidence with 15.5 injuries per 100 athletes was higher compared with previous Youth Olympic Games (YOG) and Olympic Games (OG), the illness incidence of 8.4 illnesses per 100 athletes was in line with former YOGs and OGs.
- The severe injury risk (2.1 injuries/100 athletes) was comparable to Winter and Summer OGs.
- New sports on the Youth Olympic programme have about the same injury and illness risk as did other sports.
- Injury and illness incidences were equally distributed among smaller and larger National Olympic Committees (NOC), and did not relate to the availability of NOC medical support.
- Injury and illness incidences varied among continents; athletes who represented Europe reported fewer injuries than athletes from other continents.

How might it impact on clinical practice in the future?

- Our injury and illness epidemiology data in this young elite athlete cohort may provide a foundation for efforts in injury and illness prevention.
- This study will help inform the planning of the medical programmes for future YOG organising committee medical teams.

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