High precompetition injury rate dominates the injury profile at the Rio 2016 Summer Paralympic Games: a prospective cohort study of 51 198 athlete days

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Accepted 12 September 2017
Published Online First 13 October 2017

ABSTRACT

Objectives To describe the incidence of injury in the precompetition and competition periods of the Rio 2016 Summer Paralympic Games.

Methods A total of 3657 athletes from 78 countries, representing 83.4% of all athletes at the Games, were monitored on the web-based injury and illness surveillance system over 51 198 athlete days during the Rio 2016 Summer Paralympic Games. Injury data were obtained daily from teams with their own medical support.

Results A total of 510 injuries were reported during the 14-day Games period, with an injury incidence rate (IR) of 10.0 injuries per 1000 athlete days (12.1% of all athletes surveyed). The highest IRs were reported for football 5-a-side (22.5), judo (15.5) and football 7-a-side (15.3) compared with other sports ($p<0.05$). Precompetition injuries were significantly higher than in the competition period (risk ratio: 1.40, $p<0.05$), and acute traumatic injuries were the most common injuries at the Games (IR of 5.5). The shoulder was the most common anatomical area affected by injury (IR of 1.8).

Conclusion The data from this study indicate that (1) IRs were lower than those reported for the London 2012 Summer Paralympic Games, (2) the sports of football 5-a-side, judo and football 7-a-side were independent risk factors for injury, (3) precompetition injuries had a higher IR than competition period injuries, (4) injuries to the shoulder were the most common. These results would allow for comparative data to be collected at future editions of the Games and can be used to inform injury prevention programmes.

INTRODUCTION

Paralympic sport continues to grow with increased popularity among competitors and spectators alike. Indeed, the Rio 2016 Summer Paralympic Games saw the largest cohort of athletes participating at this pinnacle event, namely 4378 athletes competing in 22 sports.[1] The protection of the health of the athlete and efforts to reduce both injury and illness in this population remain foremost on the agenda of the International Paralympic Committee (IPC)[2] and ongoing efforts to collect epidemiological data to better inform injury prevention programmes has remained a strong focus.[3–8]

It is important that before comprehensive injury prevention programmes can be instituted, adequate baseline data must be collected to allow for the eventual determination of the success of implemented prevention strategies.[9 10] The first large prospective study of injury epidemiology in athletes with impairment, that expressed injury rates and injury proportions per 1000 athlete days, was reported following the London 2012 Summer Paralympic Games.[6 7] In that study, 633 injuries were reported in 10.9% of the total number of athletes monitored over the Games period. Furthermore, the injury incidence rate (IR) was 12.7 (95% CI 11.7 to 13.7) injuries per 1000 athlete days. The incidence of injury was highest in the sports of football 5-a-side (IR of 22.4 (95% CI 14.1 to 33.8)),[11] goalball (IR of 19.5 (95% CI 13.2 to 27.7)) and Para powerlifting (IR of 19.3 (95% CI 14.0 to 25.8)).[12] Furthermore, the most commonly affected anatomical area was the shoulder (IR of 2.1 (95% CI 1.7 to 2.6)), which is in accordance with previous literature describing the epidemiology of injury in both the Summer and Winter Paralympic Games settings.[5 13 14] Additionally, acute injuries were the most commonly reported injury in terms of onset (IR of 6.3 (95% CI 5.6 to 7.2)).

The aim of this study was to establish further baseline data regarding the incidence of injury in a Summer Paralympic Games setting.[5 6] This study described the profile of injuries, including factors associated with injury risk, in a cohort of 3657 athletes whose attending physicians used the web-based injury and illness surveillance system (WEB-IISS) at the Rio 2016 Summer Paralympic Games. Furthermore, the data presented in this study, in combination with the data gathered from the London 2012 Summer Paralympic Games, allow for comparative data to be used when following the efficacy of longitudinal injury prevention programmes and specific prevention programmes at future editions of the Summer Games.

METHODS

Setting

This study was conducted by members of the IPC Medical Committee as part of the ongoing prospective study examining injury and illness epidemiology in both the Summer and Winter Paralympic Games settings and was conducted during the 3-day precompetition period and 11-day competition period of the Rio 2016 Summer Paralympic Games.

To cite: Derman W, Runciman P, Schwellnus M, *et al*. *Br J Sports Med* 2018;**52**:24–31.

Participants

Before research activities were initiated, approval was granted by the University of Brighton (FREGS/ES/12/11) and Stellenbosch University (N16/05/067) Research Ethics Committees. Informed consent was obtained for the use of deidentified data from all athletes during registration for the Games.

The present study used the WEB-IISS, which was successfully implemented at both the London 2012 Summer Paralympic Games and Sochi 2014 Winter Paralympic Games. The system was designed for teams with their own medical support at the Games. A more detailed description of the WEB-IISS can be found in the previous literature.[6]

The organising committee medical facilities were used predominantly by countries who did not have their own medical support. However, given that the WEB-IISS was not used by the Rio local organising committee, we were unable to obtain reliable data regarding injuries in this athlete group. Therefore, data regarding injury collected at the Rio organising committee polyclinic and other medical facilities could not be included in this study.

The study was promoted by providing introductory information via email to all National Paralympic Committees (NPCs) chefs de mission (n=160) and further communication was sent to all attending Chief Medical Officers and team physicians of the teams competing at the Games (n=81). Detailed information about the study was provided to the team physicians of all delegations at the medical briefing held during the precompetition period of the Games and through individualised training sessions at the polyclinic facility. Compliance from participating team medical staff was facilitated by the provision of a tablet computer (Samsung, Korea) for data entry. This was provided to each participating country that had more than five athletes competing at the Games. The remainder of the countries with accompanying medical staff reported their data within the Paralympic Village, via laptop computers and wireless internet connection, through the same portal used on the tablets.

Data collection

Athlete information (age, sex and sport) was obtained from an IPC database of competitors. Information gathered from the team physicians with regard to the injury to be captured on the WEB-IISS included the chronicity of the injury, mechanism of acute and acute on chronic injuries, contributing factors to the injury, stage of the Games in which the injury occurred, time of occurrence of the injury (training or competition), protective gear worn by the athlete, date of onset of symptoms, decision to return to play, severity of the injury, special investigations used in the assessment of the injury, primary anatomical area injured, final diagnosis, anticipated time loss as a result of the injury and the impairment type and class of the athlete.[6] A new aspect of this study was the inclusion of specific questions regarding concussion, which were posed to the physician if they reported a head, face or neck injury. All data were linked for statistical analyses and subsequently delinked to provide a deidentified database.

Definition of injury

The general definition accepted for reporting an injury was described as 'any athlete experiencing an injury that required medical attention, regardless of the consequences with respect to absence from competition or training'.[6] An injury was specifically defined as 'any newly acquired injury as well as exacerbations of pre-existing injury that occurred during training and/or competition of the Games period of the Rio 2016 Summer Paralympic Games'. Acute traumatic, acute on chronic and chronic injuries were reported. An acute traumatic injury was defined as 'an injury that was caused by an acute precipitating traumatic event'. An acute on chronic injury was defined as 'an acute injury in an athlete with symptoms of a chronic injury in the same anatomical area'. A chronic (overuse) injury was defined as 'an injury that developed over days, weeks or months and was not associated with any acute precipitating event'.[6]

Calculation of athlete days

Team size was captured per day by each team's physician at the same time as registration of any injuries. However, an analysis of these data showed very little variation from each country's team size as published in the IPC master list of athletes attending the Games. These data were used as denominator data for the calculation of IR per 1000 athlete days. Accurate denominator data are essential to correct reporting and analysis of the epidemiology of injuries in this setting, with multiple teams with constantly changing team sizes.

Calculation of the injury incidence rate and injury proportion

Injury IR was calculated as injuries per 1000 athlete days. The number of athlete days was reported separately by precompetition and competition periods, sport, age-group and sex. The IR per 1000 athlete days was reported for all injury types, onset of injury as well as injuries in different sports and anatomical areas. The proportion of athletes with an injury refers to the percentage of athletes reporting an injury and was calculated as follows: number of athletes with an injury/the total number of athletes competing in the relevant subgroup multiplied by 100.

Statistical analysis of the data

Standard descriptive statistical analyses were reported for each injury outcome, including number of athletes participating, the number of athlete days, number of injuries, number and proportion of athletes with an injury. For the overall injury outcome, descriptive statistics were reported by period, sport discipline, age group (12–25 years, 26–34 years and 35–75 years) and sex of the athlete (male or female).

As some athletes participated in more than one sport and/or more than one event, the primary sport of the athlete was used (track cycling and road cycling were combined due to small numbers of participating athletes). Where athletes incurred multiple injuries during the 14 days, each injury was reported as a distinct injury encounter. Thus, the outcome was in the form of counts, that is, the number of injuries each athlete reported. A number of outcomes were considered in the analysis, namely precompetition/competition injuries (period), acute traumatic/acute on chronic/chronic injuries (onset) and various anatomical areas of injury (lower limb, upper limb, head/neck/face, chest/trunk/abdomen, spine and other areas of injury). Details of the analysis of injuries by anatomical area were restricted to sport related injuries (n=440) and excluded the non-sport-related injuries (n=70).

Multiple regression analysis was performed to determine whether the sports identified as having significantly higher IRs were also independent risk factors for injury in this athlete cohort. The model included four sport discipline categories: (1) football-5-a-side and football-7-a-side, (2) judo, (3) wheelchair basketball, wheelchair fencing and wheelchair rugby and (4) all other sport disciplines. These sport groupings were determined by the IRs in grouped sports, sex differences between the sports

Table 1 Number of athletes participating in each sport at the Rio 2016 Summer Paralympic Games

Sport	All athletes	Females	Males	Age 12–25	Age 26–34	Age 35–75
All	3657	1389	2268	996	1320	1341
Archery	113	48	65	10	25	78
Boccia	99	30	69	23	34	42
Canoe	52	26	26	12	17	23
Cycling (track and road)	204	66	138	25	55	124
Equestrian	71	55	16	11	22	38
Football 5-a-side	70	0	70	23	36	11
Football 7-a-side	112	0	112	52	51	9
Goalball	102	54	48	34	46	22
Judo	115	41	74	26	60	29
Para athletics	894	354	540	294	354	246
Para powerlifting	141	62	79	13	50	78
Para swimming	492	217	275	287	141	64
Rowing	88	44	44	13	28	47
Sailing	76	15	61	3	16	57
Shooting Para sport	130	43	87	8	19	103
Sitting volleyball	127	70	57	22	46	59
Table tennis	223	78	145	43	68	112
Triathlon	58	29	29	10	20	28
Wheelchair basketball	228	96	132	49	107	72
Wheelchair fencing	72	30	42	12	34	26
Wheelchair rugby	96	2	94	8	52	36
Wheelchair tennis	94	29	65	18	39	37

(footballs restricted to male athletes) and similarities in athlete profile within sports (wheelchair sports).

Generalised linear Poisson's regression modelling was used to model the number of injuries for each injury outcome and was corrected for overdispersion and included the independent variables of interest (sport discipline, age category, sex). Results were reported as injury IRs per 1000 athlete days (IR with 95% CIs). Results for injury IRs were reported by period, onset of injury, sex, age group and sport discipline. For the comparison between the London and Rio injury IRs, the correlation for athletes competing in both games could not be built into the model since we did not have information linking the athletes who competed at both Games. Results for impairment data were reported via total number of injuries (%) only, as the impairment data of all the athletes participating at the Games were not available.

RESULTS

Participants

This study details the injuries reported by the team physicians of countries who had their own medical support. Of these countries, 78 countries chose to participate in the study and three chose not to participate. During the total Games period, 3657 athletes were monitored for a period of 51 198 athlete days. This athlete sample represented 48.8% of all countries participating at the Games (160 teams) and yet represented 83.5% of the total number of all athletes at the Games (4378 athletes).

A description of the number of athletes per sport, sex of the athletes and age group of the athletes is presented in table 1. Most athletes were male (62%) and older than 25 years (73%). The sports with the highest number of athletes competing were Para athletics (24%), Para swimming (13%) and wheelchair basketball (6%). The sports of football 5-a-side and football 7-a-side were only participated in by male athletes.

Overall incidence of injury and proportion of athletes injured

The total number of injuries incurred by 441 athletes was 510. Therefore, the overall incidence of injury at the Rio 2016 Summer Paralympic Games was 10.0 injuries per 1000 athlete days (95% CI 9.1 to 10.9). The proportion of the total number of athletes being monitored on the WEB-IISS with an injury was 12.1% (males=11.4%, females=13.2%) (table 2).

Table 2 Incidence of injury by sex and age group for athletes competing at the Rio 2016 Summer Paralympic Games

Sex/age group (years)	Total number of injuries (percentage of total number of injuries)	Number of athletes with an injury	Total number of athletes competing	Total number of athlete days	Proportion of athletes with an injury	Injury incidence rate: number of injuries/1000 athlete days (95% CI)
All	510 (100%)	441	3657	51 198	12.1	10.0 (9.1 to 10.9)
Female	208 (40.8%)	183	1389	19 446	13.2	10.7 (9.3 to 12.3)
Male	302 (59.2%)	258	2268	31 752	11.4	9.5 (8.5 to 10.7)
Age 12–25	120 (23.5%)	104	996	13 944	10.4	8.6 (7.2 to 10.3)
Age 26–34	192 (37.6%)	168	1320	18 480	12.7	10.4 (9.0 to 12.0)
Age 35–75	198 (38.8%)	169	1341	18 774	12.6	10.6 (9.2 to 12.1)

Table 3 Incidence of injury in the precompetition and competition periods for athletes competing at the Rio 2016 Summer Paralympic Games

Period	Total number of injuries (percentage of total number of injuries)	Number of athletes with an injury	Total number of athletes competing	Total number of athlete days	Proportion of athletes with an injury	Injury incidence rate: number of injuries/1000 athlete days (95% CI)
All	510	441	3657	51 198	12.1	10.0 (9.1 to 10.9)
Precompetition period	141	134	3657	10 971	3.7	12.9 (10.9 to 15.2)*
Competition period	369	325	3657	40 227	8.9	9.2 (8.3 to 10.2)

*Significantly higher than injuries in the competition period (p<0.01).

Incidence of injury by sex and age group

The overall incidence of injury by sex (female, male) and age group (12–25, 26–34, 35–75 years) is presented in table 2. There were no significant differences between sex and age group with regard to injury rate in the overall Games period.

Incidence of injury in the precompetition (3 days) and competition period (11 days)

There were 141 injuries recorded in 134 athletes (IR of 12.9 (95% CI 10.9 to 15.2)) in the precompetition period, while 369 injuries were recorded in 325 athletes (IR of 9.2 (95% CI 8.3 to 10.2)) during the competition period of the Rio 2016 Summer Paralympic Games (table 3). Thus, significantly higher rates of injury were found in the precompetition period, compared with the competition period (risk ratio: 1.40 (95% CI 1.51 to 1.71), p=0.003).

Incidence of injury by sport

Table 4 presents the total number of injuries as well as injuries per sport in 22 sports. There was a significantly higher rate of injury in football 5-a-side (IR of 22.5 (95% CI 14.8 to 34.1), p=0.001), judo (IR of 15.5 (95% CI 10.5 to 23.0), p=0.02) and football 7-a-side (IR of 15.3 (95% CI 10.3 to 22.8), p=0.03) compared with all other sports. Additionally, significantly lower IR was reported for the sports of boccia (IR of 4.3 (95% CI 1.9 to 9.6), p=0.04) and Para swimming (IR of 7.1 (95% CI 5.4 to 9.4), p=0.03).

The multiple regression analysis found that, when adjusted for age and sex, the three groupings of sports were independent risk factors for injury, indicating that all three categories of sport disciplines had a significantly higher IR compared with the category 'all other sport disciplines' (table 4). The results were as follows: (1) football-5-a-side and football-7-a-side (p=0.0001), (2) judo (p=0.004) and (3) wheelchair basketball, wheelchair fencing and wheelchair rugby (p=0.0002).

Incidence of sport and non-sport-related injury

There were 440 sport-related and 70 non-sport-related injuries during the total Games period. The incidence of sport-related injuries was 8.6 (95% CI 7.8 to 9.4) injuries per 1000 athlete days, while the incidence of non-sport related injuries was 1.4 (95% CI 1.1 to 1.7).

Table 4 Incidence of injury by sport for athletes competing at the Rio 2016 Summer Paralympic Games in descending order of injury incidence rate

Sport	Total number of injuries (percentage of total number of injuries)	Number of athletes with an injury	Total number of athletes competing	Total number of athlete days	Proportion of athletes with an injury	Injury incidence rate: number of injuries/1000 athlete days (95% CI)
All	510 (100%)	441	3657	51 198	12.1	10.0 (9.1 to 10.9)
Football 5-a-side	22 (4.3%)	17	70	980	24.3	22.5 (14.8 to 34.1)*
Wheelchair fencing	16 (3.1%)	13	72	1008	18.1	15.9 (9.7 to 25.9)
Judo	25 (4.9%)	19	115	1610	16.5	15.5 (10.5 to 23.0)*
Football 7-a-side	24 (4.7%)	21	112	1568	18.8	15.3 (10.3 to 22.8)*
Wheelchair rugby	20 (3.9%)	16	96	1344	16.7	14.9 (9.6 to 23.1)
Wheelchair basketball	41 (8.0%)	32	228	3192	14.0	12.8 (9.5 to 17.4)
Sitting volleyball	21 (4.1%)	17	127	1778	13.4	11.8 (7.7 to 18.1)
Wheelchair tennis	15 (2.9%)	13	94	1316	13.8	11.4 (6.9 to 18.9)
Para powerlifting	22 (4.3%)	22	141	1974	15.6	11.1 (7.3 to 16.9)
Para athletics	126 (24.7%)	111	894	12 516	12.4	10.1 (8.5 to 12.0)
Archery	16 (3.1%)	14	113	1582	12.4	10.1 (6.2 to 16.5)
Triathlon	8 (1.6%)	7	58	812	12.1	9.9 (4.9 to 19.7)
Canoe	7 (1.4%)	6	52	728	11.5	9.6 (4.6 to 20.2)
Table tennis	27 (5.3%)	24	223	3122	10.8	8.6 (5.9 to 12.6)
Sailing	9 (1.8%)	8	76	1064	10.5	8.5 (4.4 to 16.3)
Rowing	9 (1.8%)	8	88	1232	9.1	7.3 (3.8 to 14.0)
Para swimming	49 (9.6%)	42	492	6888	8.5	7.1 (5.4 to 9.4)†
Cycling (track and road)	20 (3.9%)	20	204	2856	9.8	7.0 (4.5 to 10.9)
Equestrian	7 (1.4%)	7	71	994	9.9	7.0 (3.4 to 14.8)
Shooting Para sport	12 (2.4%)	11	130	1820	8.5	6.6 (3.7 to 11.6)
Goalball	8 (1.6%)	7	102	1428	6.9	5.6 (2.8 to 11.2)
Boccia	6 (1.2%)	6	99	1386	6.1	4.3 (1.9 to 9.6)†

*Significantly higher than all other sports (p<0.03).
†Significantly lower than all other sports (p<0.05).

Table 5 Incidence of sport-related injury by each anatomical area for athletes competing at the Rio 2016 Summer Paralympic Games

Anatomical area	Total number of injuries (percentage of total number of injuries)	Number of athletes with an injury	Proportion of athletes with an injury (%)	Injury incidence rate: number of injuries/1000 athlete days (95% CI)
All	440 (100%)	382	10.4	8.6 (7.8 to 9.4)
Head and face	7 (1.6%)	7	0.2	0.1 (0.1 to 0.3)
Neck	37 (8.4%)	36	1.0	0.7 (0.5 to 1.0)
Shoulder	90 (20.5%)	84	2.3	1.8 (1.4 to 2.2)
Upper arm	5 (1.1%)	4	0.1	0.1 (0.0 to 0.2)
Elbow	20 (4.5%)	18	0.5	0.4 (0.3 to 0.6)
Forearm	8 (1.8%)	7	0.2	0.2 (0.1 to 0.3)
Wrist, hand and finger	53 (12.0%)	47	1.3	1.0 (0.8 to 1.4)
Chest wall	8 (1.8%)	8	0.2	0.2 (0.1 to 0.3)
Trunk and abdomen	5 (1.1%)	5	0.1	0.1 (0.0 to 0.2)
Thoracic spine	8 (1.8%)	8	0.2	0.2 (0.1 to 0.3)
Lumbar spine	29 (6.6%)	29	0.8	0.6 (0.4 to 0.8)
Pelvis/buttock	9 (2.0%)	9	0.2	0.2 (0.1 to 0.3)
Hip/groin	9 (2.0%)	9	0.2	0.2 (0.1 to 0.3)
Thigh	32 (7.3%)	28	0.8	0.6 (0.4 to 0.9)
Stump	1 (0.2%)	1	0.0	0.0
Knee	34 (7.7%)	33	0.9	0.7 (0.5 to 0.9)
Lower leg	25 (5.7%)	25	0.7	0.5 (0.3 to 0.7)
Ankle, foot and toe	44 (10.0%)	42	1.1	0.9 (0.6 to 1.2)
Other	16 (3.7%)	16	0.4	0.3 (0.2 to 0.5)

Incidence of sport-related injury by anatomical area

Sport-related injuries were recorded in 10.4% of athletes on the WEB-IISS. The anatomical areas affected by sport-related injury are presented in table 5. Injuries to the upper limb were most prevalent with an IR of 3.4 (95% CI 3.0 to 4.0), followed by the lower limb, which had an IR of 3.0 (95% CI 2.6 to 3.5). The anatomical areas most affected by injury included the shoulder (IR of 1.8 (95% CI 1.4 to 2.2)), wrist, hand and finger complex (IR of 1.0 (95% CI 0.8 to 1.4)) followed by the ankle, foot and toe complex (IR of 0.9 (95% CI 0.6 to 1.2)).

Incidence of injury by onset

Table 6 depicts the incidence of injury by onset, namely acute traumatic injuries, acute on chronic injuries and chronic injuries. The highest overall IR recorded was for acute injury (5.2 (95% CI 4.6 to 5.8), compared with chronic injuries (p=0.0001), followed by chronic overuse injuries (IR of 3.4 (95% CI 3.0 to 4.0)) and acute on chronic injuries (IR of 1.4 (95% CI 1.1 to 1.7)).

Proportion of injured athletes by impairment type

A description of the impairment types of the athletes who sustained an injury is reported in table 7. Athletes with limb deficiency constituted the group with the highest number of injuries (154 injuries, 32.0% of all injured athletes), followed by visual impairment (112 injuries, 20.0% of all injured athletes), spinal cord injury (103 injuries, 18.4% of all injured athletes) and central neurological impairment (82 injuries, 17.0% of all injured athletes).

Estimated time loss as a result of injury

Of all injuries reported at the Rio 2016 Summer Paralympic Games (510 injuries), 382 injuries (74.9%) did not result in the athlete requiring time away from training or competition. Injuries that required athletes to be excluded from training or competition for an estimated period of 1 day or more equalled 128 injuries (25.1%). Of these, there were 90 injuries that required two or more days exclusion from training or competition. The total days lost by the 160 athletes were 396 out of the overall 51 198 athlete days (7.7 days lost per 1000 athlete days). The highest number of days lost was for football 5-a-side (32.7 days lost per 1000 athlete days), football 7-a-side (26.1 days lost per 1000 athlete days) and judo (15.5 days lost per 1000 athlete days). Athletes in the age group of 26–34 years (IR of 10.8) had a significantly higher rate of time loss due to injury than athletes in the age group of 35–75 years (IR of 5.3, p<0.05), however not when compared with the age group of 12–25 years (IR of 6.9). There were no significant differences with regard to sex of the athlete. Unfortunately, one athlete suffered a fatal head injury during competition (cycling).

Table 6 Incidence of injury by onset for athletes competing in the precompetition and competition periods of the Rio 2016 Summer Paralympic Games

Type of injury	Total number of injuries (percentage of total number of injuries)	Number of athletes with an injury	Proportion of athletes with an injury (%)	Injury incidence rate: number of injuries/1000 athlete days (95% CI)
All	510 (100%)	441	12.1	10.0 (9.1 to 10.9)
Acute traumatic injury	264 (51.8%)	241	6.6	5.2 (4.6 to 5.8)*
Acute on chronic injury	70 (13.7%)	64	1.8	1.4 (1.1 to 1.7)
Chronic overuse injury	176 (34.5%)	166	4.5	3.4 (3.0 o 4.0)

*Significantly higher than acute on chronic and chronic injuries (p<0.001).

Table 7 Proportion of injured athletes by impairment type for all injuries for athletes competing at the Rio 2016 Summer Paralympic Games

Impairment type	Total number of injuries (percentage of total number of injuries)	Number of athletes with an injury	Proportion of injured athletes in each impairment type (%)
All	510 (100%)	411	100
Limb deficiency (amputation, dysmelia, congenital deformity)	154 (30.2%)	141	32.0
Visual impairment	112 (22.0%)	88	20.0
Spinal cord injury	103 (20.2%)	81	18.4
Central neurological injury (cerebral palsy, traumatic brain injury, stroke, other neurological impairment)	82 (16.1%)	75	17.0
Other	25 (4.9%)	24	5.4
Les autres (non-spinal polio myelitis, ankylosis, leg shortening, joint movement restriction, nerve injury resulting in local paralysis)	17 (3.3%)	16	3.6
Intellectual impairment	8 (1.6%)	7	1.6
Unknown	5 (1.0%)	5	1.1
Short stature	4 (0.8%)	4	0.9

DISCUSSION

The present study represents the largest sample of athletes with impairment to be included in an epidemiological description of injuries sustained in the precompetition and competition periods of the Rio 2016 Summer Paralympic Games. This study also represents the second consecutive Games dataset to describe the incidence of injury in a Summer Games setting, with the Rio 2016 Summer Paralympic Games total athlete days comprising 1288 more athlete days than the London 2012 Summer Paralympic Games. These data provide important information to team medical staff to allow for preparation for future international multisport competitions as well as help to inform future longitudinal data collection studies and injury prevention programmes in this population.[15 16]

Lower overall incidence of reported injuries at the Rio Games compared with the London Games

The first important finding of this study was that the overall incidence of injury per 1000 athlete days in this study (IR of 10.0 (95% CI 9.1 to 10.9) was lower than that reported for the London 2012 Summer Paralympic Games (IR of 12.7 (95% CI 11.7 to 13.7), p<0.01).[6] Furthermore, the proportion of athletes with an injury at the Rio 2016 Summer Paralympic Games (12.1%) was lower than the proportion of injured athletes at the London 2012 Summer Paralympic Games (15.0%). As no specific intervention strategies on behalf of the IPC or (to the best of our knowledge) efforts by sporting federations to reduce rates of injury were employed in the Games setting, the reason for this finding is not directly apparent but might reflect a general increase in awareness of injury prevention by team medical staff in the 4-year period between Games. It must be kept in mind however that rates of injury may be influenced by other variables, including environmental conditions, facilities, selection criteria, scheduling of events and so on. As polyclinic data for injury were not available for this study due to challenges identified previously and the possibility that athletes from smaller and perhaps under-resourced countries might have a higher injury rate, it might be argued that injury rates may have been higher if polyclinic data of the 247 athletes from the smaller NPC delegations who were not recorded on the WEB-IISS were included in the analysis. Although this is a point of interest, it is unlikely that the influence of such a small percentage (5.6%) of the total athlete cohort would significantly alter the finding that the incidence of injury was lower at Rio compared with London.

Higher incidence of precompetition injuries

Another important finding of this study was that there was a significantly higher incidence of injury in the precompetition period (IR of 12.9 (95% CI 10.9 to 15.2), p<0.003) compared with the competition period (IR of 9.2 (95% CI 8.3 to 10.2)). A possible reason to explain these findings is that there was a unique situation at the Rio Games whereby the IPC redistributed the 267 athlete slots, following the decision of the IPC to suspend the Russian NPC from the Games. As a result, 267 athletes from other countries were recruited to the Rio Games between 23 August and 7 September 2016, who may not have targeted participation at Rio after previously being informed that they had not been selected to compete.[17] Thus, this may reflect a larger group of athletes who may have been predisposed to injury. It is also possible that increased competition for a relatively lower total number of Paralympic slots available to athletes (in comparison with the London Games) might have led to an increased injury rate in this period.[18] A detailed in-depth analysis of the current findings is planned by this group of researchers to identify possible factors related to the difference between precompetition and competition IRs.

Sports with an increased risk of injury

Findings of this study noted that the four highest risk sports at the Games represented 10% of all the athletes on WEB-IISS and include the sports football 5-a-side, judo and football 7-a-side and wheelchair fencing (combined IR of 16.8 (95% CI 13.7 to 20.8), p<0.0001). Although there were sports that had either a higher IR (wheelchair fencing (marginally significant, p=0.05)) or lower IR (goalball, shooting Para sport, equestrian and cycling), significance was not reached, likely due to the relatively lower number of athletes competing in these sports and thus low statistical power. Although there were some differences compared with the sports with the highest incidence of injury at the London 2012 Summer Paralympic Games (football 5-a-side, goalball, Para powerlifting and wheelchair fencing), the sport of football 5-a-side has repeatedly been identified as high risk for musculoskeletal injury.[11] This finding indicates that these are the sports where injury prevention programmes should be prepared for as soon as possible with specific aims, methods and detailed outcomes to determine if the rates of injury can be reduced by as early as Tokyo 2020 Summer Paralympic Games. The additional sports identified as being high risk (judo and football

7-a-side) should also be investigated further to identify possible factors compounding the risk of injury to athletes participating in these sports.

Upper limb injuries most common

A further finding of the present study was that the upper limb (IR of 3.4 (95% CI 3.0 to 4.0)) showed a slightly higher IR than that of the lower limb (IR of 3.0 (95% CI 2.6 to 3.5)), in accordance with the data reported for the London Games. Furthermore, the most injured anatomical area was the shoulder (IR of 1.8 (95% CI 1.4 to 2.2), which is also in accordance with both previous literature and our published IR of shoulder injuries at the London Games.[6 7 14 19 20]

Concussions may be under-reported in this population

A new aspect of this study was the inclusion of specific questions regarding concussion, which were posed to the physician if they reported a head, face or neck injury. Despite several incidents where athletes were observed to suffer a blow to the head followed by unsteady gait and survey reports of more significant injuries to the head and face, no concussions were reported. This indicates a need for clinician education regarding concussion recognition, assessment and management in this population.

Unfortunately, the Rio 2016 Summer Paralympic Games saw the first death of an athlete in a Games setting, through head injury during competition (cycling). This was clearly a catastrophic event and highlights the importance of ongoing efforts toward planning for trauma and acute catastrophic events at major international multisport competitions.

Impairments that may predispose athletes to injury

Finally, this study showed that athletes with the impairment of limb deficiency (32.0%), visual impairment (20.0%) and spinal cord injury (18.4%) had the highest proportion of injury. The investigation of the specific factors contributing to injury in these cohorts is important, as different impairment types affect the risk for injury and the characteristics of specific injuries.[21–23] For example, whether the athletes with limb deficiency who sustained injuries were prosthesis users or not would allow us to determine whether the use of a prosthesis is associated with injury risk. This description requires further in-depth analysis, which will be provided through the combination of Games datasets as baseline data in the future.

Strengths and limitations of the study

This study constituted the largest study of its kind to investigate incidence of injury at a major international Paralympic competition. There was high compliance from team physicians involved in the study as well as a large proportion of team physicians who have worked with the WEB-IISS on more than one occasion in previous editions of the Games, which helped to enhance data collection. Compliance was further encouraged by the provision of a tablet computer to every team physician monitoring a team of five athletes or more as well as the awarding of daily prizes for completing data entry on the previous day. Another strength of this study was that the WEB-IISS allowed for online registration of injuries over a wireless connection at the team's base or at venues during the Games. Additionally, enhancements to the WEB-IISS system were carried out prior to the Games, in order to provide a better platform for data entry. An important enhancement was the collection of impairment data from every athlete who was injured during the Games at the time of injury. This is the first system to capture impairment data, which is crucial for the implementation and tailoring of prevention programmes in the future. This study w also the first to document the incidence of injury in the new Paralympic sports of triathlon (IR of 9.9 (95% CI 4.9 to 19.7)) and canoe (IR of 9.6 (95% CI 4.6 to 20.2)).

A limitation of the present study was that data from the polyclinic and venue medical stations were not available for analysis. Therefore, the data regarding injury from the 247 athletes who did not have their own medical support and the 474 athletes from the three countries who chose not to participate have not been captured. A further consideration is that it is possible that athletes might have reported an injury to the polyclinic which was not reported to their own doctor. However, we believe that this might have occurred in a negligible number of cases, as we verified significant injuries against imaging records of the polyclinic. Furthermore, further analysis comparing the London and Rio Games in only the group of athletes monitored on the WEB-IISS, with additional statistical modelling, is planned for the future by this group of researchers. A further limitation of the study was that doctors were asked to anticipate the number of days lost due to injury and were unable to validate their estimate once the athlete had recovered. Updates to the WEB-IISS are planned in the future to allow the doctors to amend their records with regard to time loss data. Furthermore, the total number of participating athletes in each impairment types was not available for analysis in this study. Finally, a detailed analysis is required to assess the factors related to the lower overall IR of injury at the Rio Games compared with the London Games.

CONCLUSION

This study completed at the Rio 2016 Summer Paralympic Games was the largest study of its kind to successfully document the incidence of injury per 1000 athlete days in athletes with impairment. A lower incidence of injury was found at Rio 2016, as compared with the London 2012 Summer Paralympic Games. The sports with the highest incidence of injury included football 5-a-side, judo and football 7-a-side. Injuries in the precompetition period had a significantly higher IR than injuries sustained in the competition period. It was found that the upper limb had more injuries compared with the lower limb, with the shoulder joint representing the single most injured area. Acute injuries were the most common type of injury with regard to onset. This study stands to represent baseline data for the development and implementation of injury prevention programmes for athletes with impairment at future competitions.

What are the new findings?

- This is the second significant dataset to document the incidence of injury in a Summer Paralympic Games setting.
- Precompetition injury rates were significantly higher than competition injury rates.
- The sports of football 5-a-side, judo and football 7-a-side had a significantly higher incidence of injury, compared with all other sports, while boccia and Para swimming had a significantly lower injury rate.
- The shoulder joint was the most commonly injured anatomical area.
- Acute injuries constituted the highest injury rate at the Games.

How might it impact on clinical practice in the future?

- The data presented in this study allow for the further establishment of a baseline injury dataset in Paralympic athletes, to be used as a comparison for data gathered at future Paralympic Games and to inform practice for clinicians providing medical support at the Games.
- These data, in conjunction with the data from the London 2012 Summer Paralympic Games, provide the basis for evidence-based injury prevention programmes to be implemented in the future.
- These future prevention programmes should be prepared for athletes from high-risk sports. Further studies are needed to determine the cause of higher rates of injury during the precompetition period.

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Acknowledgements The authors wish to extend their sincerest thanks to all National Paralympic Committee medical personnel who participated in data collection as well as to the International Paralympic Committee for their support, in particular Anne Sargent, Katharina Grimm and Guzel Idrisova. They also wish to thank Samsung for the provision of tablet computers used as both tools for data collection as well as study incentives. Thanks are also extended to the Rio Organizing Committee for their support throughout the period of the Rio 2016 Summer Paralympic Games, particularly Joao Grangeiro and Emma Painter.

Funding This study was approved and supported by the International Paralympic Committee. Funding for the study was provided by the International Olympic Committee (IOC) Research Centre (South Africa) Grant.

Competing interests None declared.

Ethics approval Brighton University (FREGS/ES/12/11), Stellenbosch University (N16/05/067)

Provenance and peer review Not commissioned; externally peer reviewed.

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