Incidence and burden of injury at the Tokyo 2020 Paralympic Games held during the COVID-19 pandemic: a prospective cohort study of 66 045 athlete days

Wayne Derman ,[1,2] Phoebe Runciman ,[1] Maaike Eken ,[1] Pieter-Henk Boer ,[3] Cheri Blauwet ,[4] Manos Bogdos ,[5] Guzel Idrisova ,[6] Esme Jordaan,[7,8] James Kissick,[9] Philipe LeVan,[10] Jan Lexell ,[11] Fariba Mohammadi ,[12] Marcelo Patricio,[13] Martin Schwellnus ,[2,14] Nick Webborn ,[15] Stuart E Willick,[16] Kazuyoshi Yagishita[17]

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bjsports-2022-106234).

For numbered affiliations see end of article.

Correspondence to
Professor Wayne Derman, Institute of Sport and Exercise Medicine, Department of Exercise, Sport and Lifestyle Medicine, Faculty of Medicine and Health Sciences, Stellenbosch University, Cape Town 7505, South Africa; ewderman@iafrica.com

This study was conducted exclusively in athletes with disability, who are classified as a marginalised group, and was inclusive of all athletes participating at the Tokyo 2020 Paralympic Games. The author team is balanced. The researchers represent different genders from both Northern and Southern hemispheres and different socioeconomic status countries. Furthermore, the research group includes individuals from marginalised groups, as well as perspectives from multiple disciplines.

Accepted 25 November 2022
Published Online First 5 December 2022

To cite: Derman W, Runciman P, Eken M, *et al*. *Br J Sports Med* 2023;**57**:63–70.

ABSTRACT

Objective To describe the epidemiology of injuries at the Tokyo 2020 Paralympic Games, including injuries sustained in the new sports of badminton and taekwondo.

Methods Injury data were obtained daily via the established web-based injury and illness surveillance system (WEB-IISS; 81 countries, 3836 athletes) and local organising committee medical facilities (81 countries, 567 athletes). Univariate unadjusted incidences (injuries per 1000 athlete days with 95% CIs), injury proportion (IP, %) and injury burden (days lost per 1000 athlete days) are reported.

Results A total of 4403 athletes (1853 women, 2550 men) from 162 countries were monitored prospectively during the 3-day pre-competition and 12-day competition periods (66 045 athlete days). 386 injuries were reported in 352 athletes (IP=8.0%) with an incidence of 5.8 per 1000 athlete days (95% CI 5.3 to 6.5). Football 5-a-side (17.2), taekwondo (16.0), judo (11.6) and badminton (9.6) had the highest incidence. There was a higher incidence of injuries in the pre-competition period than in the competition period (7.5 vs 5.4; p=0.0053). Acute (sudden onset) injuries and injuries to the shoulder (0.7) and hand/fingers (0.6) were most common. Injury burden was 10.9 (8.6–13.8), with 35% of injuries resulting in time loss from training and competition.

Conclusion Compared with previous Paralympic Games, there was a reduction in injury incidence but higher injury burden at the Tokyo 2020 Paralympic Games. The new sports of taekwondo and badminton had a high injury incidence, with the highest injury burden in taekwondo, compared with other sports. These findings provide epidemiological data to inform injury prevention measures for high-risk sports.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ During the Paralympic Games the incidence of injury has been shown to be high in sports of football 5-a-side, judo and athletics.
⇒ Most common injuries are reported to be acute (sudden onset) in nature, occurring in the shoulder, lower leg, hand and fingers as well as head/face.
⇒ The incidences of injury in the sports of taekwondo and badminton, which were introduced as new sports to the Tokyo 2020 Paralympic Games, have not been reported in previous research.

WHAT THIS STUDY ADDS

⇒ This is the third significant dataset to document injuries in a summer Paralympic Games setting, as well as the first to document injuries sustained during the COVID-19 pandemic.
⇒ There was a lower incidence of injury at the Tokyo Paralympic Games compared with previous Paralympic Games.
⇒ The sports of football 5-a-side, taekwondo, judo and badminton had the highest incidence of injury.
⇒ The new sports of taekwondo and badminton were highlighted as high risk for injury. This was particularly true for taekwondo, where athletes sustained concussions and serious injuries.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY?

⇒ High-risk sports require intervention to reduce injuries to athletes. Prevention practices (eg, rule changes, better preparation for competition, scheduling, recovery practices) and programmes (to address intrinsic risks) are urgently needed.
⇒ These data can help to develop these interventions and measure efficacy.

INTRODUCTION

Injury surveillance studies at the Paralympic Games have been in effect since the Salt Lake City 2002 Paralympic Winter Games.[1] From the London 2012 Games onwards, the Paralympic Injury and Illness Surveillance Study has been used to report the epidemiology of injuries in both Summer and Winter Games settings.[2–6] These studies have shown that the injuries are mostly acute (sudden onset) in nature and most common in high velocity or direct

contact sports, including football 5-a-side, judo and athletics.[7 8] A higher incidence of injury has been reported during the 3 days prior to the opening of the Paralympic Games (pre-competition period) compared with the competition period of the Games. Furthermore, the shoulder, lower leg, hand and fingers, as well as head/neck are most at risk for injury. However, most injuries reported were estimated to require no or minimal time loss from training or competition. Longitudinal prospective monitoring studies have also provided much-needed information regarding injuries that occur outside of competition, such as the occurrence of more repetitive (gradual onset) injuries.[8–10] These studies inform injury prevention interventions, which have been shown to reduce injury incidence, especially in sports that have been identified as high risk.[11] Ongoing Games-time injury surveillance is crucial for continued protection of the health of athletes in environments with multiple sports and teams.

Unlike previous iterations of the Paralympic Games, the Tokyo 2020 Paralympic Games were held under unprecedented circumstances. These Games were hosted in a 'safety-first' environment that has been described in The Playbook, which was a set of countermeasures developed prior to the Tokyo Olympic and Paralympic Games held during the COVID-19 pandemic.[12 13] There were also fewer opportunities for training and meaningful competition during the pandemic months prior to the Games which, in combination with the countermeasures at the Games, may have impacted on sport performance and perhaps injury risk in participating athletes. This study aimed to describe the epidemiology of injury at the Tokyo 2020 Paralympic Games during the global COVID-19 pandemic, and also provides the first epidemiological description of injuries sustained in the new sports of badminton and taekwondo. The findings of this study will contribute to the growing understanding of the epidemiology of injuries in Paralympic sport.

METHODS

This is a prospective cohort study of injuries reported during the 15 days of the Tokyo 2020 Paralympic Games pre-competition (3 days) and competition (12 days) periods in 23 sports, and forms part of an ongoing epidemiological study at the Paralympic Games.[3–6]

Participants

Members of the International Paralympic Committee (IPC) Medical Committee conducted this study at the Tokyo 2020 Paralympic Games. During the registration process for the Paralympic Games, all athletes consented for the use of medical data gathered during the Games to be used for the current study in a deidentified manner.

Data collection

Information about the study was distributed to all National Paralympic Committee (NPC) Chefs de Missions, as well as to chief medical officers and medical staff of teams prior to the Games. Detailed information about the study was provided at a medical briefing held during the pre-competition period.

The three sources of data for this study were: (1) the IPC master list of competitors at the Games used for athlete information (age groups: 12–25 years, 26–34 years and 35–75 years), sex (female, male), and sport (archery, athletics, badminton, boccia, canoe, cycling (combining track and road), equestrian, football 5-a-side, goalball, judo, powerlifting, rowing, shooting, sitting volleyball, swimming, table tennis, taekwondo, triathlon, wheelchair basketball, wheelchair fencing, wheelchair rugby, wheelchair tennis); (2) the established Web-Based Injury and Illness Surveillance System (WEB-IISS) used by team medical staff to report injuries sustained by athletes in their team; and (3) data obtained from the local organising medical services (polyclinic and sport venue) facilities, primarily used by teams without their own medical support. The polyclinic was also used for specialist medical encounters by teams with medical care. These included clinical visits for radiology services, hospital, specialist medical services, physiotherapy, rehabilitation services and pharmacy encounters.[14] In instances where the same injury was reported through both the polyclinic and the WEB-IISS dataset (identified by accreditation number), each injury was counted only once and was based on the best clinical description in each injury report.

After closure of the Games, both WEB-IISS and polyclinic data were cleaned to remove non-applicable data (non-athletes, duplicate entries). Data related to physiotherapy visits, radiology requests, routine dental treatments, non-ophthalmological eye examinations (optometry), pharmacy visits and bracing requests were excluded. The WEB-IISS and polyclinic data were then de-identified and integrated for analysis, and duplicates between the two systems removed, prior to being merged via accreditation number with the IPC master list for statistical analysis. Thus, the present study comprises all injuries reported by team medical staff and the polyclinic staff during the Tokyo 2020 Paralympic Games.

Definition of injury

The definitions for injuries requiring medical attention were in accordance with the International Olympic Committee (IOC) consensus statement, as well as the Para sport translation of the consensus, regarding injury and illness reporting in sport and are presented in online supplemental file 1.[15 16] The age, sex, sport, impairment (WEB-IISS entries only) and competition period in which the athlete was injured, as well as the onset (chronicity), anatomical area and estimated time loss of the injury were reported.

Calculation of athlete days

Team sizes were determined by using the master list of participating athletes in each team published by the IPC immediately prior to the Games. An estimate of athlete days was calculated by multiplying the number of athletes in each team by the total participation days (15 days) and for two distinct time periods during the Games: a 3-day pre-competition period and a 12-day competition period. These data comprised denominator data for the calculation of injury incidence (per 1000 athlete days). This is consistent with the previous methodology of these studies.

Calculation of the injury proportion and incidence and incidence ratio

Injury proportion (IP) was calculated as the percentage of athletes who sustained one or more injuries during the Games. The percentage of athletes was calculated as the number of athletes with an injury divided by the total number of athletes competing in the relevant subgroup, multiplied by 100. The estimated number of athlete days was calculated for each sport, age category, sex, competition periods, onset and anatomical areas. The injury incidence was calculated as the number of athletes with an injury relative to the total athletes competing in each category and reported as injuries per 1000 athlete days. Incidence was reported for all

injuries as well as injuries sustained in each of the 23 sports, by sex and age category, by pre-competition and competition period, by onset of injury, and by anatomical area. The incidence ratio (IR) was calculated to show the relative difference between incidences.

Calculation of time loss and burden

Injuries resulting in time loss from training and competition were reported by team medical staff as well as polyclinic staff, with time loss from the injury (days) estimated at the time of injury. The injury burden (IB) was expressed as days lost per 1000 athlete days (95% CI) overall or for the relevant subgroup.

Statistical analysis of the data

All data were analysed using SAS statistical software Version 9.4 (Cary, North Carolina, USA) via counts (the number of injuries each doctor reported). Impairment data were only reported as the total number of injuries and percentage of all injuries, because impairment information of all uninjured athletes was not available. Athletes who participated in multiple sports were included under their primary sport. Where athletes sustained more than one injury during the Games, each injury was reported as a separate encounter. Descriptive statistical analyses were reported, including number of athletes participating in 23 sports, by age, sex, pre- and competition periods, chronicity, anatomical area, impairment, number of reported injuries and number and percentage of athletes with an injury. The Poisson distribution with the PROC GENMOD statement and an associated log link option were used for analysis. All results reported were from univariate Poisson models and included a scale parameter, due to some modest overdispersion in the Poisson models. Univariate unadjusted incidences (with 95% CIs) were reported for injury overall, injury by sport, sex and age, by onset, by period and by anatomical area. To determine IR, the ratio between incidences was calculated for significantly different variables. The IB was expressed as days lost per 1000 athlete days (95% CI).

RESULTS

Participants

During this study a total of 4403 athletes (1853 women, 2550 men) from 162 countries were monitored for 15 days (66 045 athlete days; table 1). There were 3836 athletes (87% of all athletes) from 81 countries (50% of all countries) that were monitored by team medical staff using the WEB-IISS, as well as 567 athletes from 81 countries that used the local polyclinic medical services. The number of athletes by sex and age category participating in 23 sports (cycling track and road combined) at the Games is shown in table 1.

Overall incidence of injury

A total of 386 injuries (306 WEB-IISS, 80 polyclinic) were reported in 352 athletes (301 WEB-IISS, 51 polyclinic) at the Tokyo Paralympic Games. The IP (%) of all athletes who sustained an injury during the Games was 8%, with an overall incidence of 5.8 injuries per 1000 athlete days (95% CI 5.3 to 6.5). There were more new injuries reported (n=313; 4.7 (95% CI 4.2 to 5.3)) compared with recurrent and subsequent injuries (n=73; 1.1 (95% CI 0.9 to 1.4); IR=4.3 (95% CI 3.3 to 5.6); p<0.0001). There were 342 sport-related injuries in 316 athletes (5.2 (95% CI 4.6 to 5.8)) and 44 non-sport-related injuries in 41 athletes (0.62 (95% CI 0.43 to 0.81); IR=7.8 (95% CI 5.6 to 10.8); p<0.0001). All tables show both sport-related and non-sport-related injuries, except table 6 (anatomical area) which shows only sport-related injuries.

Table 1 Number of athletes participating in each of the 23 sports at the Tokyo 2020 Paralympic Games

Sport	All athletes	Women	Men	Age 12–25	Age 26–34	Age 35–75
All	4403	1853	2550	1 244	1 651	1508
Archery	139	60	79	16	41	82
Athletics	1144	491	653	392	451	301
Badminton	90	44	46	25	32	33
Boccia	114	41	73	23	45	46
Canoe	88	40	48	12	33	43
Cycling (track and road)	228	79	149	27	68	133
Equestrian	78	55	23	16	20	42
Football 5-a-side	62	0	62	14	32	16
Goalball	118	58	60	43	55	20
Judo	138	58	80	34	66	38
Powerlifting	178	88	90	17	64	97
Rowing	96	48	48	20	34	42
Shooting	154	54	100	16	33	105
Sitting volleyball	188	92	96	26	70	92
Swimming	606	264	342	366	185	55
Table tennis	278	105	173	58	96	124
Taekwondo	71	34	37	24	35	12
Triathlon	78	39	39	10	30	38
Wheelchair basketball	263	119	144	66	127	70
Wheelchair fencing	96	48	48	11	45	40
Wheelchair rugby	92	4	88	6	45	41
Wheelchair tennis	104	32	72	22	44	38

Table 2 Incidence of injury by sport for athletes competing at the Tokyo 2020 Paralympic games, in descending order of injury incidence

Sport	Total no of injuries (% total no of injuries)	No of athletes with an injury	Total no of athletes competing	Total no of athlete days	Proportion of athletes with an injury (%)	Injury incidence: no of injuries/1000 athlete days (95% CI)
All	386 (100)	352	4403	66 045	8.0	5.8 (5.3 to 6.5)
Football 5-a-side	16 (4.1)	14	62	930	22.6	17.2 (10.6 to 28.0)*
Taekwondo	17 (4.4)	15	71	1065	21.1	16.0 (9.9 to 25.7)*
Judo	24 (6.2)	21	138	2070	15.2	11.6 (7.7 to 17.6)*
Badminton	13 (3.4)	12	90	1350	13.3	9.6 (5.6 to 16.6)
Goalball	15 (4.0)	13	118	1770	11.0	8.5 (4.9 to 14.6)
Wheelchair tennis	13 (3.4)	11	104	1560	10.6	8.3 (4.4 to 15.6)
Athletics	134 (34.7)	123	1144	17 160	10.8	7.8 (6.6 to 9.3)
Cycling (track and road)	20 (5.2)	18	228	3420	7.9	5.8 (3.7 to 9.3)
Rowing	8 (2.1)	7	96	1440	7.3	5.6 (2.6 to 11.7)
Wheelchair rugby	7 (1.8)	7	92	1380	7.6	5.1 (2.5 to 10.3)
Wheelchair basketball	20 (5.2)	18	263	3945	6.8	5.1 (3.2 to 8.1)
Sitting volleyball	14 (3.6)	14	188	2820	7.4	5.0 (3.0 to 8.2)
Table tennis	21 (5.4)	19	278	4170	6.8	5.0 (3.2 to 7.9)
Canoe	6 (1.5)	6	88	1320	6.8	4.5 (2.1 to 9.8)
Triathlon	5 (1.3)	5	78	1170	6.4	4.3 (1.8 to 10.0)
Wheelchair fencing	6 (1.5)	5	96	1440	5.2	4.2 (1.7 to 10.3)
Equestrian	4 (1.0)	4	78	1170	5.1	3.4 (1.3 to 8.9)
Swimming	28 (7.3)	25	606	9090	4.1	3.1 (2.0 to 4.7)
Powerlifting	6 (1.5)	6	178	2670	3.4	2.2 (1.0 to 4.9)
Boccia	3 (0.8)	3	114	1710	2.6	1.8 (0.6 to 5.4)
Archery	3 (0.8)	3	139	2085	2.2	1.4 (0.5 to 4.4)
Shooting	3 (0.8)	3	154	2310	1.9	1.3 (0.4 to 4.0)

*Significantly higher incidence than the combination of all other sports (p<0.05).

Incidence of injury by sport

The incidence of all injuries by sport is shown in table 2. The incidence of injury was highest in football 5-a-side (17.2 (95% CI 10.6 to 28.0); IR=3.3 (95% CI 2.0 to 5.5); p<0.0001), taekwondo (16.0 (95% CI 9.9 to 25.7); IR=3.1 (95% CI 1.9 to 5.0); p<0.0001), judo (11.6 (95% CI 7.7 to 17.6); IR=2.2 (95% CI 1.4 to 3.4); p=0.0003) and badminton (9.6 (95% CI 5.6 to 16.6); IR=1.8 (95% CI 1.1 to 3.2); p=0.0311) compared with the incidence of all other injuries .

Incidence of injury by sex and age group

The incidence of injury by sex and age group is shown in table 3. The incidences for men and women are similar. The incidence of injury in athletes aged 26–34 years (6.9 (95% CI 5.9 to 8.1)) was significantly higher than for athletes aged 12–25 years (4.4 (95% CI 3.6 to 5.6); IR=1.6 (95% CI 1.2 to 2.1); p=0.0014).

Incidence of injury in the 3-day pre-competition and 12-day competition periods

The incidence of injury in the pre-competition and competition periods is shown in table 4. There was a significantly higher incidence of injury during the pre-competition period (99 injuries reported in 95 athletes; 7.5 (95% CI 6.1 to 9.1)) compared with the competition period (287 injuries reported in 269 athletes; 5.4 (95% CI 4.8 to 6.1); IR=1.4 (95% CI 1.1 to 1.7); p=0.0053).

Incidence of injury by onset

The number and incidence of injury by onset is shown in table 5. There was a significantly higher incidence of acute (sudden onset) injuries (3.9 (95% CI 3.4 to 4.4)) compared with repetitive (sudden onset) injuries (1.3 (95% CI 1.0 to 1.6); IR=3.0 (95% CI 2.3 to 3.9); p<0.0001) and repetitive (gradual onset) injuries (0.7 (95% CI 0.5 to 0.9); IR=5.7 (95% CI 4.2 to 7.8); p<0.0001).

Incidence of injury by anatomical area

The anatomical areas affected by sport-related injuries (n=342; 7.7% of all athletes; 6.3 (95% CI 5.6 to 7.0)) are shown in table 6. A total of 44 non-sport-related injuries are not included in this table. For sport-related injuries, the shoulder (n=46; 0.7 (95% CI 0.5 to 0.9)) was the area most affected by injury,

Table 3 Incidence of injury by sex and age group for athletes competing at the Tokyo 2020 Paralympic Games

Sex/age group	Total no of injuries (% total no of injuries)	No of athletes with an injury	Total no of athletes competing	Total no of athlete days	Proportion of athletes with an injury (%)	Injury incidence: injuries/1000 athlete days (95% CI)
All	386 (100)	352	4403	66 045	8.0	5.8 (5.3 to 6.5)
Women	228 (59.1)	210	2550	38 250	8.2	5.6 (4.8 to 6.7)
Men	158 (40.9)	142	1853	27 795	7.7	6.0 (5.2 to 6.8)
Age 12–25 years	83 (21.5)	77	1244	18 660	6.2	4.4 (3.6 to 5.6)
Age 26–34 years	172 (44.5)	154	1651	24 765	9.3	6.9 (5.9 to 8.1)*
Age 35–75 years	131 (34.0)	121	1508	22 620	8.0	5.8 (4.9 to 6.9)

*Significantly higher incidence than 12–25 years category (p=0.0014).

Table 4 Incidence of injury in the pre-competition and competition periods for athletes competing at the Tokyo 2020 Paralympic Games

Period	Total no of injuries (% total no of injuries)	No of athletes with an injury	Total no of athletes competing	Total no of athlete days	Proportion of athletes with an injury (%)	Injury incidence: injuries/1000 athlete days (95% CI)
All	386 (100)	352	4403	66 045	8.0	5.8 (5.3 to 6.5)
Pre-competition	99 (25.6)	95	4403	13 209	2.2	7.5 (6.1 to 9.1)*
Competition	287 (74.4)	269	4403	52 836	6.1	5.4 (4.8 to 6.1)

Some athletes (n=12) sustained more than one injury in the pre-competition and/or competition periods, resulting in total numbers of athletes injured not equalling the total listed for the entire Games period.
*Significantly higher incidence than competition period (p=0.0053).

followed by hand and fingers (n=40; 0.6 (95% CI 0.4 to 0.8)), knee (n=31; 0.5 (95% CI 0.3 to 0.7)) and lower leg (n=30; 0.5 (95% CI 0.3 to 0.6)). The details of the nine concussions relating to head/face and neck injuries that were reported at the Tokyo Paralympic Games are shown in online supplemental file 2.

Injury proportion by impairment

The impairment types of 275 athletes with injuries (n=301) whose data were captured on the WEB-IISS are shown in table 7 (polyclinic records did not include impairment information). Of the injured athletes, there were 62 athletes with visual impairment (IP=22.5), 58 athletes with limb deficiency (IP=21.1) and 56 athletes with spinal cord-related disorders (IP=20.4).

Severity of injuries (time loss and injury burden (IB))

Of all injuries reported at the Tokyo Paralympic Games (386 injuries), 133 injuries (34.5%) prevented athletes from training or competition for an estimated period of >1 day (time loss injury) and 253 injuries (65.5%) did not result in time loss. Of the time loss injuries, 87 (65.4%) required two or more days exclusion from training or competition. There were 21 (15.8%) injuries that were classified as moderately serious (8–28 days lost) and 10 (7.5%) injuries that were classified as serious (28 days–3 months lost). Half of these injuries required 1 month away from training and half required 6–12 weeks away from training.[15 16] Two serious injuries each were recorded for the sports of taekwondo, cycling and sitting volleyball. The most serious injuries included bone fractures, retinal detachment, pneumothorax and knee anterior cruciate ligament rupture.

The overall IB was 10.9 days lost per 1000 athlete days (95% CI 8.6 to 13.8). Although the highest number of total days lost occurred with athletics (195 days lost; IB 11.4 (95% CI 9.8 to 13.1)), the highest number of days lost per 1000 athletes was for taekwondo (IB 78.9 (95% CI 52.1 to 84.1)) followed by football 5-a-side (IB 49.5 (95% CI 36.2 to 66.0)), judo (IB 33.3 (95% CI 25.9 to 42.2)), badminton (IB 21.5 (95% CI 14.4 to 30.9)) and goalball (IB 13.6 (95% CI 8.7 to 20.2)). Athletes in the age group 26–34 years (IB 14.5 (95% CI 10.3 to 20.5)) had a significantly higher IB compared with athletes in the age group of 12–25 years (IB 6.2 (95% CI 3.6 to 10.5); p=0.0081), but not compared with the age group of 35–75 years (IB 10.8 (95% CI 7.1 to 16.4)). There were no significant differences in IB regarding the sex of the athlete (women: IB 11.0 (95% CI 7.7 to 15.7); men: IB 10.9 (95% CI 7.9 to 14.9)).

DISCUSSION

The current study comprises the third iteration of the Paralympic Injury and Illness Surveillance Study in the summer setting, following the London and Rio Paralympic Games, and aimed to describe the epidemiology of injuries at the Tokyo 2020 Paralympic Games. The main findings of this study are that: (1) there was a lower incidence of injury compared with previous summer Paralympic Games; (2) the newly introduced Paralympic sports of taekwondo and badminton have a high incidence of injury; (3) there was an increase in severity (IB) of injury compared with previous summer Paralympic Games.

The findings of the current study also support previous findings regarding the incidence and nature of injuries in athletes with disability. Football 5-a-side remains the sport with the highest incidence of injury across three successive Paralympic Games, with judo also highlighted as high risk for injury. Injuries incurred during the Paralympic Games are mostly acute (sudden onset) in nature and occur at a higher incidence in the pre-competition period. Furthermore, the anatomical areas of the shoulder, head/face, hand and fingers as well as certain areas of the lower limb are at risk for injury.

Lower incidence of injury at the Tokyo 2020 Paralympic Games

The first important finding of this study was that the incidence of injury at the Tokyo Paralympic Games (incidence 5.8; IP=8%) was considerably lower than previously recorded at the London Games (incidence 12.7; IP=11.6%) and Rio Games (incidence 10.0; IP=12.1%).[2 6] Indeed, there was a reduction in injury incidence in nearly all sports, with the exception of goalball, athletics, cycling and rowing. While a lower incidence of illness may have been expected with the COVID-19 countermeasures implemented at these Games, the reasons for the lower incidence of injury are not directly apparent. Over the past decade there have been significant developments in the education and practice of sports physicians which could perhaps translate to

Table 5 Incidence of injury by onset (chronicity) for 4403 athletes competing at the Tokyo 2020 Paralympic Games (66 045 athlete days)

Type of injury	Total no of injuries (% total no of injuries)	No of athletes with an injury	Proportion of athletes with an injury (%)	Injury incidence: injuries/1000 athlete days (95% CI)
All	386 (100)	352	8.0	5.8 (5.3 to 6.5)
Acute (sudden onset)	256 (66.3)	228	5.4	3.9 (3.4 to 4.4)*
Repetitive (sudden onset)	85 (22.0)	83	1.9	1.3 (1.0 to 1.6)†
Repetitive (gradual onset)	45 (11.7)	45	1.0	0.7 (0.5 to 0.9)

*Significantly higher incidence than repetitive (sudden onset) and repetitive (gradual onset) injuries (p<0.0001).
†Significantly higher incidence than repetitive (gradual onset) injuries (p=0.0005).

Table 6 Incidence of 342 sport-related injuries in each anatomical area for athletes competing at the Tokyo 2020 Paralympic games, in descending order of injury incidence

Anatomical area	Total no of injuries (% total no of sport-related injuries)	No of athletes with an injury	Proportion of athletes with a sport-related injury (%)	Injury incidence: no of injuries/1000 athlete days (95% CI)
All	342 (100)	338	7.7	6.3 (5.6 to 7.0)
Shoulder	46 (13.5)	46	1.0	0.7 (0.5 to 0.9)
Hand and fingers	40 (11.7)	38	0.9	0.6 (0.4 to 0.8)
Knee	31 (9.1)	31	0.7	0.5 (0.3 to 0.7)
Lower leg	30 (8.8)	30	0.7	0.5 (0.3 to 0.6)
Lumbosacral spine	26 (7.6)	26	0.6	0.4 (0.3 to 0.6)
Hip and groin	23 (6.7)	23	0.5	0.3 (0.2 to 0.5)
Thigh	22 (6.4)	22	0.5	0.3 (0.2 to 0.5)
Elbow	21 (6.1)	21	0.5	0.3 (0.2 to 0.5)
Ankle	21 (6.1)	21	0.5	0.3 (0.2 to 0.5)
Foot	16 (4.7)	15	0.3	0.2 (0.1 to 0.4)
Head and face*	14 (4.1)	14	0.3	0.2 (0.1 to 0.4)
Wrist	14 (4.1)	13	0.3	0.2 (0.1 to 0.4)
Forearm	11 3.2)	11	0.2	0.2 (0.1 to 0.3)
Neck†	9 (2.6)	9	0.2	0.1 (0.1 to 0.3)
Upper arm	8 (2.3)	8	0.2	0.1 (0.1 to 0.2)
Chest	4 (1.2)	4	0.1	–
Thoracic spine	3 (0.9)	3	0.1	–
Abdominal	1 (0.3)	1	0.0	–
Non-specific /other	2 (0.6)	2	0.0	–

There were 342 sport-related injuries in 316 athletes and 44 non-sport-related injuries in 41 athletes reported. The non-sport-related injuries are not included in this table.
*Six head/face injuries (including non-sport-related injuries) were recorded together with concussions, as reported by medical staff. These included two in road cycling, and one each in judo, taekwondo and swimming (see online supplemental file 2).
†Three neck injuries (including non-sport-related injuries) were recorded together with concussions, as reported by medical staff. These included two in judo and one in taekwondo (see online supplemental file 2).

improved medical management and injury prevention strategies over time.[17] However, it is unknown whether these improvements alone account for the large reduction in injuries seen in one Games cycle, as observed at the Tokyo Paralympic Games.

The alteration of training and competition opportunities prior to the Games, as well as curtailment of social interactions within venues and in external environments at the Games, may have resulted in less exposure to physical stress experienced by the athletes before and during the Games period—that is, with less total exposure to circumstances that may result in an injury, the risk for injury is reduced.[18] The lack of spectators may have also influenced the psychological load on athletes performing at the Games, perhaps reducing performance anxiety. Whereas exposure to physical load is understood to be an underpinning principle of injury risk,[18 19] the psychological load placed on athletes during competition by spectators is relatively under-investigated.[20]

It may be interesting to speculate on immune function linking illness and increased injury risk.[21 22] There is a well-established understanding that injury—specifically traumatic injury—has a negative impact on the functioning of an individual's immune system.[19] However, little is known about the effect of illness on

Table 7 Description of the impairment of the 275 athletes with an injury on the WEB-IISS at the Tokyo 2020 Paralympic Games

Impairment type	Total no of injuries (% total no of injuries on WEB-IISS)	No of athletes with an injury	Proportion of athletes with an injury on WEB-IISS (%)
All	301 (100)	275	100
Visual impairment	67 (22.2)	62	22.5
Limb deficiency (amputation, dysmelia)	65 (21.6)	58	21.1
Spinal cord-related disorders (eg, paraplegia, tetraplegia)	62 (20.6)	56	20.4
Brain disorders (eg, cerebral palsy, traumatic brain injury, stroke, multiple sclerosis)	37 (12.3)	35	12.7
Neuromuscular disorders – stable (eg, post polio syndrome, peripheral nerve injury)	18 (6.0)	18	6.5
Leg length difference	13 (4.3)	12	4.4
Intellectual impairment	11 (3.7)	10	3.6
Neuromuscular disorders – progressive (eg, neuromuscular disease, myopathy; muscular dystrophy)	9 (3.0)	6	2.2
Short stature	8 (2.6)	7	2.6
Impaired passive range of motion (eg, arthrogryposis, clubfoot)	6 (2.0)	6	2.2
Other / unknown	5 (1.7)	5	1.8

cellular function that may disrupt homeostasis and predispose that individual to injury. There was also a considerable reduction in illness observed at the Tokyo Paralympic Games (see the companion paper on the epidemiology of illness at the Tokyo Paralympic Games) which, along with the reduction in injury reported here, indicates a possible complex link between the two.[19 21 22] However, further in-depth studies are required to provide mechanisms by which this phenomenon could occur.

New sports of taekwondo and badminton have a high incidence of injury

The second important finding of this study was that the incidence of injury in the newly introduced sports of taekwondo (incidence 16.0; IP 21.1%) and badminton (incidence 9.6; IP 13.3%) ranked second and fourth highest, respectively, with football 5-a-side (incidence 17.2; IP 22.6%) ranked first and judo (incidence 11.0; IP 15.2%) ranked third. There were also two concussions and two serious injuries sustained during taekwondo (see online supplemental file 2). Taekwondo has been shown to be high risk for acute (sudden onset) injury in able-bodied participants, given the nature of the sport with explosive contact between athletes, with a similar proportion of injured taekwondo athletes at the Olympic and Paralympic Games (24–39% Olympic vs 21% Paralympic).[23 24] This is the first report of injuries sustained by athletes competing in taekwondo and badminton at the Paralympic Games and studies further investigating risks and mitigation strategies are warranted.

Increased severity of injury at the Tokyo 2020 Paralympic Games

It is important to note that, while the injury incidence was reduced at the Tokyo Paralympic Games, it appears that injuries sustained were more severe. The frequency of time loss injuries was higher when compared with previous Games (35% for Tokyo vs 25% for Rio).[25] Furthermore, there were 10 injuries associated with time loss of more than a month away from training or competition. These injuries were mostly observed in cycling, taekwondo and sitting volleyball and included mostly bone fractures. Within sports, taekwondo was ranked first in IB (IB 78.9) followed by football 5-a-side (IB 49.5) and judo (IB 33.3). Taekwondo thus presented with both a high incidence as well as a high IB in the sport's first Paralympic Games and influenced the overall higher burden observed at these Games. This finding indicates that prevention practices (eg, rule changes, better preparation for competition, scheduling, recovery practices) and programmes (to address intrinsic risks) are urgently needed. It is important to reduce both minor and major injuries in the Paralympic Games setting, and understanding characteristics of major injuries may help medical staff to reduce the likelihood of their occurrence.

Study limitations

This study comprises a significant contribution to the literature. However, the study was potentially limited by the use of team sizes from the IPC master list, where the total team size used may not have represented the true nature of the team size, given the staggered nature of arrival/departure that occurred at the Tokyo Paralympic Games. Determining true team sizes would require each individual athlete to be tracked as they arrived at and left the Village, which was not possible. Thus, using crude team sizes overestimated the true number of athletes in the village at any one time, which affected the calculation of true athlete day exposure denominator data and consequently underestimated the incidence of injury. This difference is represented by approximately 18% more athlete days (10 000) and fewer injuries (1.0) per 1000 athlete days. IPs can be used to directly compare with previous Games, as these did not include athlete day exposure data. In addition, the analyses performed in these studies are univariate, which do not allow for the description of risk factors. A further limitation was the lack of impairment data for all athletes at the Games, limiting the incidence reporting per impairment type (not available for the polyclinic system). Finally, it is important to note that this study reports Games-time injury incidences, which do not reflect injuries sustained outside of competition time.

CONCLUSION

This study is the third report of injuries sustained during the summer Paralympic Games, as well as the first description of injuries sustained by athletes at a Paralympic Games held in an environment in which novel countermeasures were in place to protect the health and safety of athletes. There was a marked reduction in the overall incidence but not in the severity of injuries observed at the Tokyo Paralympic Games compared with previous Games. The lower incidence may have been the result of one or more of the measures related to the COVID-19 pandemic. The high incidence of injury in the new sports of taekwondo and badminton is of concern and warrants development and implementation of prevention strategies in these sports. The findings included in this study contribute to baseline epidemiological data as well as inform injury prevention measures in high-risk sports.

Author affiliations
[1]Institute of Sport and Exercise Medicine, Department of Exercise, Sport and Lifestyle Medicine, Faculty of Medicine and Health Sciences, Stellenbosch University, Cape Town, South Africa
[2]IOC Research Center, Pretoria, South Africa
[3]Department of Human Movement Science, Cape Peninsula University of Technology, Cape Town, South Africa
[4]Department of Physical Medicine and Rehabilitation, Spaulding Rehabilitation Hospital and Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts, USA
[5]Alzheimer's Disease Center, Nestor Psychogeriatric Society, Athens, Greece
[6]Sport and Health, Lesgaft National State University of Physical Education, St. Petersburg, Russian Federation
[7]Biostatistics Unit, South African Medical Research Council, Cape Town, South Africa
[8]Statistics and Population Studies Department, University of the Western Cape, Cape Town, South Africa
[9]Department of Family Medicine, University of Ottawa, Ottawa, Ontario, Canada
[10]Pôle Médical, Institut National des Sports de l'Expertise et de la Performance, Paris, France
[11]Rehabilitation Medicine Research Group, Department of Health Sciences, Lund University, Lund, Sweden
[12]Department of Sport Medicine, Sport Sciences Research Institute, Tehran, Iran (the Islamic Republic of)
[13]Trauma Observatory, National Institute of Traumatology and Orthopedics, Rio de Janeiro, Brazil
[14]Sport, Exercise Medicine and Lifestyle Institute, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa
[15]School of Sport and Health Sciences, Loughborough University, Loughborough, UK
[16]Physical Medicine and Rehabilitation, University of Utah Orthopaedic Center, Salt Lake City, Utah, USA
[17]Clinical Center for Sports Medicine and Sports Dentistry, Tokyo Medical and Dental University, Bunkyo-ku, Japan

Twitter Wayne Derman @wderman, Phoebe Runciman @ISEM_SU, Cheri Blauwet @CheriBlauwetMD, Guzel Idrisova @drguzelidrisova, Jan Lexell @jan.lexell and Nick Webborn @SportswiseUK

Acknowledgements This study was approved and supported by the International Paralympic Committee (IPC). The authors would like to thank the Tokyo Organisation Committee of the Olympic and Paralympic Games (TOCOG) staff, as well as the

National Paralympic Committee (NPC) medical staff, whose input was pivotal to the success of this study.

Contributors All authors have contributed to the development, application and write-up of the study.WD stands as guarantor.

Funding Funding for this study was provided by the IOC Research Centre South Africa grant and International Paralympic Committee research support.

Competing interests All authors have completed and submitted COI forms. WD is an associate editor of BJSM IPHP editions.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval All athletes provided consent for the use of medical data collected during the Paralympic Games to be reported in a de-identified format. Prior to research activities, ethical approval was granted by the Research Ethics Committees of the University of Brighton (FREGS/ES/12/11) and Stellenbosch University (N16/05/067). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available.

ORCID iDs
Wayne Derman http://orcid.org/0000-0002-8879-177X
Phoebe Runciman http://orcid.org/0000-0001-8220-7694
Maaike Eken http://orcid.org/0000-0002-0623-2908
Pieter-Henk Boer http://orcid.org/0000-0003-3622-2599
Cheri Blauwet http://orcid.org/0000-0001-8568-1009
Manos Bogdos http://orcid.org/0000-0003-4769-5260
Guzel Idrisova http://orcid.org/0000-0001-6219-8268
Jan Lexell http://orcid.org/0000-0001-5294-3332
Fariba Mohammadi http://orcid.org/0000-0002-9114-3319
Martin Schwellnus http://orcid.org/0000-0003-3647-0429
Nick Webborn http://orcid.org/0000-0003-3636-5557

REFERENCES

1 Webborn N, Willick S, Reeser JC. Injuries among disabled athletes during the 2002 Winter Paralympic Games. *Med Sci Sports Exerc* 2006;38:811–5.
2 Derman W, Schwellnus M, Jordaan E, *et al*. Illness and injury in athletes during the competition period at the London 2012 Paralympic Games: development and implementation of a web-based surveillance system (WEB-IISS) for team medical staff. *Br J Sports Med* 2013;47:420–5.
3 Derman W, Schwellnus MP, Jordaan E, *et al*. High incidence of injury at the Sochi 2014 Winter Paralympic Games: a prospective cohort study of 6564 athlete days. *Br J Sports Med* 2016;50:1069–74.
4 Derman W, Runciman P, Schwellnus M, *et al*. High precompetition injury rate dominates the injury profile at the Rio 2016 Summer Paralympic Games: a prospective cohort study of 51 198 athlete days. *Br J Sports Med* 2018;52:24–31.
5 Derman W, Runciman P, Jordaan E, *et al*. High incidence of injuries at the Pyeongchang 2018 Paralympic Winter Games: a prospective cohort study of 6804 athlete days. *Br J Sports Med* 2020;54:38–43.
6 Willick SE, Webborn N, Emery C, *et al*. The epidemiology of injuries at the London 2012 Paralympic Games. *Br J Sports Med* 2013;47:426–32.
7 Blauwet CA, Cushman D, Emery C, *et al*. Risk of injuries in paralympic track and field differs by impairment and event discipline: a prospective cohort study at the London 2012 Paralympic Games. *Am J Sports Med* 2016;44:1455–62.
8 Steffen K, Clarsen B, Gjelsvik H, *et al*. Illness and injury among Norwegian para athletes over five consecutive Paralympic Summer and Winter Games cycles: prevailing high illness burden on the road from 2012 to 2020. *Br J Sports Med* 2022;56:204–12.
9 Fagher K, Dahlström Ö, Jacobsson J, *et al*. Injuries and illnesses in Swedish Paralympic athletes: a 52-week prospective study of incidence and risk factors. *Scand J Med Sci Sports* 2020;30:1457–70.
10 Busch A, Kubosch EJ, Meidl V, *et al*. Health problems in German Paralympic athletes preparing for the 2020 Tokyo Paralympic Games. *Dtsch Z Sportmed* 2021;72:212–8.
11 Derman W, Blauwet C, Webborn N, *et al*. Mitigating risk of injury in alpine skiing in the Pyeongchang 2018 Paralympic Winter Games: the time is now! *Br J Sports Med* 2018;52:419–20.
12 Massey A, Lindsay S, Seow D, *et al*. Bubble concept for sporting tournaments during the COVID-19 pandemic: Football Club World Cup. *BMJ Open Sport Exerc Med* 2021;7:e001126.
13 IOC IPC. First Playbook published outlining measures to deliver safe and successful games, 2020. Available: https://www.paralympic.org/tokyo-2020/playbooks
14 Jarraya M, Blauwet CA, Crema MD, *et al*. Sports injuries at the Rio de Janeiro 2016 Summer Paralympic Games: use of diagnostic imaging services. *Eur Radiol* 2021;31:6768–79.
15 Bahr R, Clarsen B, Derman W, *et al*. International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (including STROBE extension for sport injury and illness surveillance (STROBE-SIIS)). *Br J Sports Med* 2020;54:372–89.
16 Derman W, Badenhorst M, Blauwet C, *et al*. Para sport translation of the IOC consensus on recording and reporting of data for injury and illness in sport. *Br J Sports Med* 2021;55:1068–76.
17 Yoshii I, Sayegh R, Lotfipour S, *et al*. Need for injury-prevention education in medical school curriculum. *West J Emerg Med* 2010;11:40–3.
18 Soligard T, Schwellnus M, Alonso J-M, *et al*. How much is too much? (Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. *Br J Sports Med* 2016;50:1030–41.
19 Schwellnus M, Soligard T, Alonso J-M, *et al*. How much is too much? (Part 2) International Olympic Committee consensus statement on load in sport and risk of illness. *Br J Sports Med* 2016;50:1043–52.
20 Strauss B, Staufenbiel K, van Meurs E. Social influence of sport spectators; 2021.
21 McKenna HT, Reiss IK, Martin DS. The significance of circadian rhythms and dysrhythmias in critical illness. *J Intensive Care Soc* 2017;18:121–9.
22 Adams J, Kirkby R, Dependence E. Exercise dependence and overtraining: the physiological and psychological consequences of excessive exercise. *Sports Medicine, Training and Rehabilitation* 2001;10:199–222.
23 Engebretsen L, Soligard T, Steffen K, *et al*. Sports injuries and illnesses during the London Summer Olympic Games 2012. *Br J Sports Med* 2013;47:407–14.
24 Soligard T, Steffen K, Palmer D, *et al*. Sports injury and illness incidence in the Rio de Janeiro 2016 Olympic Summer Games: a prospective study of 11274 athletes from 207 countries. *Br J Sports Med* 2017;51:1265–71.
25 Bahr R, Clarsen B, Ekstrand J. Why we should focus on the burden of injuries and illnesses, not just their incidence. *Br J Sports Med* 2018;52:1018–21.