

## **HIGH INCIDENCE OF INJURIES AT THE PYEONGCHANG 2018 PARALYMPIC WINTER GAMES: A PROSPECTIVE COHORT STUDY OF 6804 ATHLETE DAYS**

**Derman, W. (Prof)** Institute of Sport and Exercise Medicine, Department of Surgical Sciences, Stellenbosch University, International Olympic Committee (IOC) Research Centre, South Africa. [ewderman@iafrica.com](mailto:ewderman@iafrica.com)

**Runciman, P. (Dr)**. Institute of Sport and Exercise Medicine, Department of Surgical Sciences, Stellenbosch University; International Olympic Committee (IOC) Research Centre, South Africa [phoebe.runciman@gmail.com](mailto:phoebe.runciman@gmail.com)

**Jordaan, E.** Biostatistics Unit, Medical Research Council of South Africa, Statistics and Population Studies Department, University of the Western Cape. [esme.jordaan@mrc.ac.za](mailto:esme.jordaan@mrc.ac.za)

**Schwellnus, M. P. (Prof)**. Sport, Exercise Medicine and Lifestyle Institute (SEMLI) and Section Sports Medicine, Faculty of Health Sciences, University of Pretoria; International Olympic Committee (IOC) Research Centre, South Africa. [mschwell@iafrica.com](mailto:mschwell@iafrica.com)

**Blauwet, C. (Dr)**. Department of Physical Medicine and Rehabilitation, Spaulding Rehabilitation Hospital and Brigham and Women's Hospital, Harvard Medical School, Boston, USA. [cblauwet@gmail.com](mailto:cblauwet@gmail.com)

**Webborn, N. (Prof)**. Centre for Sport and Exercise Science and Medicine (SESAME), University of Brighton, UK. [nickwebborn@sportswise.org.uk](mailto:nickwebborn@sportswise.org.uk)

**Lexell, J. (Prof)**. Department of Neuroscience, Rehabilitation Medicine, Uppsala University, Uppsala, Sweden; [jan.lexell@neuro.uu.se](mailto:jan.lexell@neuro.uu.se)

**Van de Vliet, P. (Dr)**. Medical & Scientific Department, International Paralympic Committee, Bonn, Germany. [peter.vandevliet@paralympic.org](mailto:peter.vandevliet@paralympic.org)

**Kissick, J. (Dr)**. Carleton University Sport Medicine Clinic; University of Ottawa, Department of Family Medicine. [jameskissick@me.com](mailto:jameskissick@me.com)

**Stomphorst, J. (Dr).** Department of Sport Medicine. Isala Klinieken, Zwolle, Netherlands.  
[jstomphorst@hotmail.com](mailto:jstomphorst@hotmail.com)

**Lee, Y. H. (Prof).** Department of Rehabilitation Medicine, Wonju Severance Christian Hospital, Yonsei University Wonju College of Medicine, Wonju, Republic of Korea.  
[lee02@yonsei.ac.kr](mailto:lee02@yonsei.ac.kr)

**Kim, K. S. (Dr).** Yonsei Institute of Sports Science and Exercise Medicine, Yonsei University, Seoul/Wonju, Republic of Korea. [keunsuhkim@gmail.com](mailto:keunsuhkim@gmail.com)

### **Address for correspondence**

Professor Wayne Derman  
Institute of Sport and Exercise Medicine  
Division of Orthopaedic Surgery  
Faculty of Medicine and Health Science  
Room 4019, 4<sup>th</sup> Floor, Clinical Building  
Tygerberg Medical Campus  
Francie van Zijl Drive, Bellville, Cape Town, 7505  
[ewderman@iafrica.com](mailto:ewderman@iafrica.com)

### **Keywords**

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### **What are the new findings?**

- The new sport of Para snowboard had a higher IR of injury than all other sports, indicating the need for injury intervention and prevention programs in the sport.
- The shoulder joint was the most commonly affected anatomical area—in sports where the arms were used for power and stability during high-speed propulsion.
- There were fewer injuries at the Pyeongchang 2018 Games than the Sochi 2014 Games in the sport of Para alpine skiing. We feel injuries were fewer because of favourable environmental conditions and the injury prevention program implemented by the International Paralympic Committee and World Para Alpine Skiing.

### **How might this impact on clinical practice in the near future?**

- Sporting organisations, coaches and athletes can use these data to identify the anatomical areas and sports with high risk for injury in a Winter Games setting for athletes with impairment.
- Our methods for the capturing and analysing the incidence of injury in athletes with impairment in a Winter Paralympic Games setting, provides a basis for future studies at upcoming Paralympic Games.

### **ABSTRACT**

**Objective:** To describe the epidemiology of sports injury at the Pyeongchang 2018 Paralympic Winter Games.

**Methods:** 567 athletes from 49 countries were monitored daily for 12 days over the Pyeongchang 2018 Paralympic Winter Games (6804 athlete days). Injury data were obtained daily from teams with their own medical support (41 teams, 557 athletes) and teams without their own medical support (8 teams, 10 athletes) through two electronic data capturing systems.

#### **Results:**

112 of 567 athletes (19.8%) reported a total of 142 injuries, with an injury incidence rate (IR) of 20.9 per 1000 athlete days (95% CI 17.4 - 25.0). The highest IR was reported for Para snowboard (IR of 40.5 per 1000 athlete days (95% CI 28.5 - 57.5);  $p < 0.02$ ), particularly in the lower limb and head/face/neck anatomical areas. Across all sports at the Games, acute traumatic injuries (IR of 16.2 per 1000 athlete days (95% CI 13.2 - 19.8)) and injuries to the shoulder/arm/elbow complex (IR of 5.7 per 1000 athlete days (95% CI 4.2 - 7.8)) were most common. However, most injuries (78.9%) did not require time loss.

**Conclusion:** The new Paralympic Winter Games sport of Para snowboard requires attention to implement actions that will reduce injury risk. The shoulder was the most injured single joint—a consistent finding in elite Para sport.

## INTRODUCTION

Given the increase in health surveillance research in the sporting arena, the International Paralympic Committee (IPC) seeks to preserve the health of the Para athlete in several ways including high-quality epidemiological research on injury and illness in the Paralympic Games.[1–5] Web-based studies began at the London 2012 Summer Paralympic Games[1] and have continued at Rio 2016[5] Summer Games and at Paralympic Winter Games at the Sochi 2014[4] and Pyeongchang 2018 Games. These studies are the first epidemiological descriptions of the incidence of injury per 1000 athlete days in Para athletes in a Winter setting, and build on previous work initiated from the Salt Lake 2002 Paralympic Winter Games.[6,7]

The injury incidence rate (IR) reported in the web-based studies represents training and competition related injuries recorded in a cohort of athletes during the pre-competition and competition period of a Paralympic Games and expressed per 1000 athlete days. The overall IR of the 12-day Sochi 2014 Paralympic Winter Games was 26.5 injuries per 1000 athlete days (95% CI 22.7 to 30.8).[4] The combined sports of Para alpine skiing and Para snowboard (a sub-discipline of Para alpine skiing at the Sochi Games) had a higher rate of injury (IR of 41.1 (95% CI 33.7 to 49.6),  $p = 0.0001$ ) compared with all other sport categories. Subsequent analysis indicates an individual IR of 43.8 (95% CI 35.0 to 54.9) for Para alpine skiing and an IR of 30.3 (95% CI 17.7 to 52.0) for Para snowboard). At the Sochi Games, although injuries to the upper body (IR of 8.5 (95% CI 6.4 to 11.1)) and lower body (IR of 8.4 (95% CI 6.3 to 10.9)) were similar, injuries in the shoulder region were most common (IR of 6.4 (95% CI 4.6 to 8.6)). Additionally, the IR of acute traumatic injuries (IR of 17.8 (95% CI 14.7 to 21.4)) was higher than acute on chronic injuries (IR of 3.8 (95% CI 2.5 to 5.6)) and chronic overuse injuries (IR of 4.9 (95% CI 3.3 to 6.9)).[4]

It is important that longitudinal investigations remain ongoing with repeated measures at multiple Games to identify which areas of Para athlete health require attention, intervention and further monitoring.[8] Thus, subsequent studies are required in order to further elucidate the patterns of injury observed in the Paralympic Games setting.

The objective of the present study was to document the incidence of injuries sustained at the Pyeongchang 2018 Paralympic Winter Games. This study aimed to report overall injury incidence rate, injury incidence rate per sport (specifically to determine the baseline injury

incidence rate in the new sport of Para snowboard), type of injury and anatomical areas affected by the injury in both the pre-competition and competition period of the Games. These data will help identify risk factors for injuries in the Winter Games setting, and help guide injury education and prevention programs.

## **METHODS**

This descriptive study was a component of a larger ongoing prospective epidemiological study of injury in both Summer and Winter Paralympic Games, and was conducted during the three-day pre-competition period and nine-day competition period of the Pyeongchang 2018 Paralympic Winter Games. Athletes participated in five categories of sports: Para alpine skiing, Para snowboard, Para Nordic skiing (combining Para cross country skiing and Para biathlon), Para ice hockey and wheelchair curling.

### **Participants**

The current study was conducted by members of the IPC's Medical Committee. Ethics board approval for this study was granted by the Research Ethics Committees of the University of Brighton (FREGS/ES/12/11) and Stellenbosch University (N16/05/067). Consent was provided by all athletes for the use of de-identified medical data gathered during the Games.

The web-based injury and injury surveillance system (WEB-IISS) was utilised to record injuries by physicians of teams who had their own medical support at the Games. This system has been utilised successfully at the London 2012, Sochi 2014 and Rio 2016 Paralympic Games.[1,4,5] A more detailed description of the WEB-IISS can be found in the previous literature.[4] Daily use of the WEB-IISS was enhanced by education provided to teams participating at the Games. Introductory information about the study was provided prior to the Games via email to all National Paralympic Committees' (NPCs) chefs de mission (n=49). Further communication was sent to all teams who had their own medical support at the Games (n=41). A medical briefing was held during the pre-competition period where team physicians were provided with detailed information about the study and individualised training sessions on using the WEB-IISS. Daily data entry compliance was also incentivised by the provision of a basic tablet computer (Samsung, Seoul, Korea) to each participating country that had medical support at the Games, which team physicians could use for data entry. Countries with accompanying medical staff who had less than five athletes in their team reported their data

through the same secure, password-protected portal via either personal computers or computers available in the athlete village.

The Pyeongchang Local Organising Committee of the Games (POCOG) customised surveillance system in the medical polyclinic venues was utilised by teams who did not have accompanying medical staff (n = 8). This system was used to capture all admissions to peripheral hospitals, radiology services and all medical and pharmacy encounters. It was also used to record specialist services at both the central polyclinic and medical support at the venues at the Games. After the close of the Games, these data were de-linked and processed to remove duplicate entries and data from non-athletes. We excluded radiology, physiotherapy, non-ophthalmological eye examinations (optometry) or orthopaedic bracing visits to the polyclinic during this time. The remaining data were then integrated into the WEB-IISS injury master spreadsheet for analysis. Thus, the present study constitutes all injuries presented to team physicians and local polyclinic staff during the 12-day Games period of the Pyeongchang 2018 Paralympic Winter Games.

### **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’. An injury was 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 Pyeongchang 2018 Paralympic Winter 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’.[4]

### **Calculation of athlete days**

Team size was determined using the list of all accredited athletes participating at the Games published by the IPC prior to the Games. This was to ensure that all team sizes (both WEB-IISS and polyclinic monitored athletes) came from the same source and were seen to be reliable data. Athlete days were calculated by multiplying the total term days (three-day pre-

competition and nine-day competition period) multiplied by team size as published by the IPC. These data constituted denominator data for the calculation of injury incidence rate (IR). The provision of accurate denominator data is critical to correct analysis and reporting of the epidemiology of injury in this international multi-sport setting, with multiple teams.

### **Calculation of the injury proportion and incidence rate**

Injury proportion was calculated as the percentage of athletes who sustained one or more injuries during the Games period. The injury IR was calculated as injuries per 1000 athlete days. The number of athlete days was reported separately by sport, age group and sex. The IR per 1000 athlete days was reported for all injuries as well as injuries in different sports and anatomical areas. The percentage of athletes reporting an injury 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. Where athletes incurred multiple injuries during the total Games period, each of these were reported as distinct injuries.

### **Calculation of time loss**

Time loss as a result of injury was estimated by the team physician at the time of reporting the injury. They were then able to log into the system at a later stage and modify the entry to represent the actual days lost by the athlete.

Time loss data were only available for injuries logged on the WEB-IISS. Thus, the time loss data represented 557 athletes (98.2%) who had their own medical support (6684 athlete days).

### **Statistical analysis of the data**

All data (WEB-IISS and polyclinic datasets) were in the form of counts (i.e. the number of injuries each athlete reported). Results for impairment data were reported via total number of injuries (%) only since the impairment data of all the athletes participating at the Games was not available. Some athletes participated in more than one sport and/or more than one event; the primary sport of the athlete was used in the analysis. Where some athletes incurred multiple injuries during the total Games period, each of these were reported as distinct injuries. Further, if an athlete sustained a two-part injury, the injuries were classified as distinct injuries. Descriptive statistical analyses were reported, including number of athletes participating in five categories of sport (Para alpine skiing, Para snowboard, Para Nordic skiing (combining Para cross country skiing and Para biathlon), Para ice hockey and wheelchair curling), by age (12-

25 years, 26-34 years and 35-75 years) and sex (male or female), number of reported injuries and number and percentage of athletes with an injury. Generalized linear Poisson regression modelling (SAS 9.4) was used to model the number of reported injuries overall, as well as the number of injuries for anatomical areas affected by the injury and were corrected for overdispersion and included the independent variables of interest. Unadjusted injury incidence rates were reported per 1000 athlete days (including 95% confidence intervals). Incidence of injury was reported by sex, age group, type of sport and anatomical area affected by the injury.

## RESULTS

### Participants

A total of 567 athletes (433 male and 134 female), represented 49 countries at the Games (6804 athletes days). 557 athletes from 41 countries (98.2% of all athletes, 6684 athlete days) had their own medical support, and 10 athletes from 8 countries (120 athlete days) utilised the local polyclinic medical facilities. Some athletes were monitored on the WEB-IISS and also chose to utilised polyclinic services, however, in instances where the same injury was reported, only WEB-IISS encounters were included given that they offered greater detail regarding the clinical characteristics of each injury.

The mean ( $\pm$  SD) age of all athletes in this study was  $32.1 \pm 10.3$  years (range 15 – 67 years). Table 1 presents the total numbers of athletes, sex and age distribution in five categories of sports, namely Para alpine skiing, Para snowboard, Para Nordic skiing (combining Para cross country skiing and Para biathlon), Para ice hockey and wheelchair curling.

**Table 1: Number of athletes participating in each sport at the Pyeongchang 2018 Paralympic Winter Games**

<b>Sport</b>	<b>All athletes</b>	<b>Males</b>	<b>Females</b>	<b>Age 13-25</b>	<b>Age 26-35</b>	<b>Age 36-75</b>
All	567	433	134	161	216	190
Para alpine skiing	141	101	40	59	53	29
Para snowboard	72	58	14	20	30	22
Para Nordic skiing	159	100	59	52	73	34
Para ice hockey	135	134	1	29	52	54
Wheelchair curling	60	40	20	1	8	51

### Incidence of injury by sport

The total number of injuries, as well as injuries reported in five categories of sports are presented in table 2. A total of 142 injuries (114 WEB-IISS, 28 polyclinic) were recorded in 112 athletes during the 12-day Games period, thus 19.8% (injury proportion) of all athletes sustained one or more injuries at the Games. This represented an IR of 20.9 injuries per 1000 athlete days (95% CI 17.4 to 25.0)). There were more new injuries reported (n = 118; IR of 17.3 (95% CI 14.2 to 21.1)) than recurrent injuries (n = 24; IR of 3.5 (95% CI 2.4 to 5.2)). 28 athletes sustained separate injuries on different days of competition, and 1 athlete sustained a multi-location injury.

There was a higher IR of injury recorded for Para snowboard (IR of 40.5 (95% CI 28.5 to 57.5),  $p < 0.02$ ) than all other sports categories combined. The most cited mechanisms of sport related acute injury as reported by team physicians for Para snowboard athletes included 1) the athlete being out of control, 2) technique faults, 3) technical difficulties, or 4) not knowing how the injury occurred. The sport of wheelchair curling had a lower IR of injury (IR of 6.9 (95% CI 2.7 to 17.6),  $p < 0.01$ ) compared with Para alpine skiing, Para snowboard and Para ice hockey, but not Para Nordic skiing.

**Table 2: Incidence of injury by sport for athletes competing at the Pyeongchang 2018 Paralympic Winter Games**

<b>Sport</b>	<b>Total number of injuries</b>	<b>Number of athletes with an injury</b>	<b>Total number of athletes competing</b>	<b>Total number of athlete days</b>	<b>Percentage of athletes with an injury (%)</b>	<b>Injury incidence rate: injuries/1000 athlete days (95% CI)</b>
All	142	112	567	6804	19.8	20.9 (17.4 – 25.0)
Para snowboard	35	24	72	864	33.3	40.5 (28.5 – 57.5)*
Para alpine skiing	39	30	141	1692	21.3	23.1 (16.5 – 32.1)
Para ice hockey	37	29	135	1620	21.5	22.8 (16.2 – 32.1)
Para Nordic skiing	26	24	159	1908	15.1	13.6 (9.1 – 20.5)
Wheelchair curling	5	5	60	720	8.3	6.9 (2.7 – 17.6)#

\* Higher than all other sport categories ( $p < 0.02$ )

# Lower than Para snowboard, Para alpine skiing and Para ice hockey, but not Para Nordic skiing ( $p < 0.01$ )

### Incidence of injury by sex and age group

Table 3 presents the incidence of injury by sex and age group. There were no significant differences in the injury incidence rates between males and females, and between age groups.

**Table 3: Incidence of injury by sex and age group for athletes competing at the Pyeongchang 2018 Paralympic Winter Games**

<b>Sex/Age group</b>	<b>Total number of injuries</b>	<b>Number of athletes with an injury</b>	<b>Total number of athletes competing</b>	<b>Total number of athlete days</b>	<b>Percentage of athletes with an injury (%)</b>	<b>Injury incidence rate: injuries/1000 athlete days (95% CI)</b>
All	142	112	567	6804	19.8	20.9 (17.4 – 25.0)
Male	103	82	433	5196	18.9	19.8 (16.0 – 24.5)
Female	39	30	134	1608	22.4	24.3 (17.2 – 34.3)
Age 13 to 25 years	34	27	161	1932	16.8	17.6 (12.2 – 25.5)
Age 26 to 35 years	60	47	216	2592	21.8	23.2 (17.5 – 30.6)
Age 36 to 75 years	48	38	190	2280	20.0	21.2 (15.4 – 28.8)

### Incidence of injury in the pre-competition (3 days) and competition period (9 days)

There were 33 injuries recorded in 31 athletes (IR of 19.4 (95% CI 13.6 to 27.6)) during the pre-competition period, and 109 injuries recorded in 95 athletes (IR of 21.4 (95% CI 17.4 to 26.3)) during the competition period of the Pyeongchang 2018 Paralympic Winter Games (table 4). There was no significant difference in the injury incidence rate between these two periods.

**Table 4: Incidence of injury in the pre-competition and competition periods for athletes competing at the Pyeongchang 2018 Paralympic Winter Games**

<b>Period</b>	<b>Total number of injuries</b>	<b>Number of athletes with an injury</b>	<b>Total number of athletes competing</b>	<b>Total number of athlete days</b>	<b>Percentage of athletes with an injury (%)</b>	<b>Injury incidence rate: injuries/1000 athlete days (95% CI)</b>
All	142	112	567	6804	19.8	20.9 (17.4 – 25.0)
Pre-competition	33	31	567	1701	5.5	19.4 (13.6 – 27.6)
Competition	109	95	567	5103	16.8	21.4 (17.4 – 26.3)

### Incidence of injury by anatomical area

The anatomical areas affected by injury are presented in Table 5. The upper limb (IR of 7.9 (95% CI 6.1 to 10.3)) and lower limb (IR of 7.1 (95% CI 5.2 to 9.54)) had a similar IR of injury. The shoulder/upper arm/elbow complex had the highest IR of injury (IR of 5.7 (95% CI 4.2 to 7.8)), followed by the head/neck/face complex (IR of 4.3 (95% CI 2.9 to 6.2)) and the wrist/hand/finger complex (IR of 2.2 (95% CI 1.3 to 3.6)).

Injuries to the shoulder/upper arm/elbow complex were highest in the following sports: Para ice hockey (n = 21; 56% of all injuries), Para Nordic skiing (n = 13; 50% of all injuries) and Para alpine skiing (n = 13; 30% of all injuries).

**Table 5: Incidence of injury in each anatomical area for athletes competing at the Pyeongchang 2018 Paralympic Winter Games**

Anatomical area	Total number of injuries	Number of athletes with an injury	Percentage of athletes with an injury (%)	Injury incidence rate: injuries/1000 athlete days (95% CI)
All	142	112	19.8	20.9 (17.4 – 25.0)
<i>Upper limb</i>	54	52	9.2	7.9 (6.1 – 10.3)
Shoulder/Arm/Elbow	39	38	6.7	5.7 (4.2 – 7.8)
Wrist/Hand/Finger	15	15	2.6	2.2 (1.3 – 3.6)
<i>Lower Limb</i> #	48	43	7.6	7.1 (5.2 – 9.5)
Knee	11	10	1.8	1.6 (0.9 – 3.1)
Ankle/Foot/Toe	13	12	2.1	1.9 (1.1 -3.4)
Lower Leg	7	7	1.2	1.0 (0.5 – 2.1)
Thigh/Stump	10	10	1.8	1.5 (0.8 – 2.7)
Hip/Groin/Pelvis	7	7	1.2	1.0 (0.4 – 2.4)
Head/Face/Neck * †	29	27	4.8	4.3 (2.9 – 6.2)
Spine	6	6	1.1	0.9 (0.4 – 2.0)
Chest/Trunk/Abdomen	5	5	0.9	0.7 (0.3 – 1.8)

# 15 of these injuries occurred in Para snowboard (p < 0.01).

\* 14 of these injuries occurred in Para snowboard (p < 0.01).

† Four of these injuries were concussions, as reported by team physicians. These included two in Para alpine skiing and two in Para ice hockey.

### Incidence of injuries by onset

Table 6 presents the number and rate of injuries by onset of injury, namely acute traumatic injury, acute on chronic injury and chronic overuse injury. There were more acute traumatic injuries (IR of 16.2 (95% CI 13.2 to 19.8);  $p < 0.05$ ) than acute on chronic (IR of 1.5 (95% CI 0.8 to 2.7)) and chronic overuse (IR of 3.2 (95% CI 2.1 to 5.0)) injuries.

**Table 6: Incidence of injury by onset (chronicity) for athletes competing at the Pyeongchang 2018 Paralympic Winter Games**

Type of injury	Total number of injuries	Number of athletes with an injury	Percentage of athletes with an injury	Injury incidence rate: injuries/1000 athlete days (95% CI)
All	142	112	19.8	20.9 (17.4 – 25.0)
Acute traumatic	110	91	16.0	16.2 (13.2 – 19.8)*
Acute on chronic	10	10	1.8	1.5 (0.8 – 2.7)
Chronic overuse	22	21	3.7	3.2 (2.1 – 5.0)

\* Higher than all other onsets ( $p < 0.05$ )

**Table 7: A description of the impairment types of the 93 athletes with an injury on the WEB-IISS at the Pyeongchang 2018 Paralympic Winter Games**

Impairment type	Number of athletes with an injury	Percentage of injured athletes in each impairment type (%)
All	93	100
Limb deficiency (amputation, dysmelia, congenital deformity)	50	53.8
Spinal cord injury	25	26.9
Visual impairment	8	8.6
Central neurologic injury (cerebral palsy, traumatic brain injury, stroke, other neurologic impairment)	6	6.5
Les autres	0	0
Unknown	4	4.3

## Injury by impairment

Table 7 depicts the impairment profiles of 93 athletes with injuries, whose data were captured on the WEB-IISS. Injuries provided by the polyclinic did not provide impairment details of the injured athletes. There were 50 injuries (53.8%) recorded in athletes with limb deficiency, followed by 25 injuries (26.9%) recorded in athletes with spinal cord injury.

## Time loss as a result of injury

Of the injuries reported utilising the WEB-IISS during the Games period, 21.1% (24 out of 114 injuries) required one or more days of exclusion from training or competition, whilst 78.9% of athletes reporting an injury on the WEB-IISS required no time loss from training or competition. There were three injuries that were classified as moderately serious (8 to 28 days lost due to injury) and three injuries classified as serious (28 days to 6 months lost), according to the consensus statement on time loss injuries in athletics (table 8).[9]

**Table 8: A description of the moderately serious (8-28 days), and serious (28 days-6 months) time loss injuries recorded on the WEB-IISS at the Pyeongchang 2018 Paralympic Winter Games**

<b>Time lost due to injury</b>	<b>Onset, anatomical area and mechanism of injury</b>	<b>Sport (event) in which the injury occurred</b>
<i>Moderately severe injury (8-28 days lost)</i>		
20 days	Acute knee anterior cruciate ligament injury, movement fault during training	Para alpine skiing (in gym training session)
21 days	Acute shoulder dislocation injury, athlete was out of control	Para snowboard (banked slalom)
21 days	Acute ankle lateral ligament sprain and head/facial fractures, athlete twisted an extremity	Para snowboard (snowboard cross)
<i>Severe injury (28 days-6 months lost)</i>		
35 days	Acute wrist and hand avulsion fracture, sledge contact with another sledge	Para ice hockey (play-off match)
60 days	Acute shoulder fractures and neck whiplash injury, pole hooked a gate/bar	Para alpine skiing (giant slalom, lower half of course)
6 months	Acute knee anterior cruciate ligament injury, athlete landed a jump poorly	Para snowboard (testing jump)

## DISCUSSION

The present study represents a significant addition to the literature regarding the incidence of injuries per 1000 athlete days in athletes competing at the Paralympic Winter Games, and documents the incidence of injury in five categories of sport during the Pyeongchang 2018 Games.

### **Para snowboard: More injuries than all other sports combined**

The first important finding was that the new Winter sport of Para snowboard had a higher rate of injury (IR of 40.5 (95% CI 28.5 to 57.5);  $p < 0.02$ ) than all other sports. Injuries to the anatomical areas of the lower limb ( $n = 15$ ; 42% of total injuries;  $p < 0.01$ ) and head/neck/face ( $n = 14$ ; 40% of total injuries;  $p < 0.01$ ) constituted more than 80% of the injuries among Para snowboard athletes monitored using the WEB-IISS. This finding extends our knowledge of injuries in able-bodied athletes participating in snowboarding, where higher rates of injury were reported following the inclusion of the discipline into existing Winter sport programs. The most common injuries reported in these studies included head and knee injuries, and indicates a similar pattern of injuries as a result of snowboarding in both able-bodied and Para athletes.[10–18]

Acute traumatic injuries were the most commonly reported injuries at these Games (IR of 16.2 (95% CI 13.2 to 19.8))[1,4,5] and also constituted the majority of injuries reported in Para snowboard athletes (82% of all snowboard injuries). The mechanisms of acute sport related acute injury on the WEB-IISS for Para snowboard athletes were: the athlete being out of control, technique faults, technical difficulties or not knowing how the injury occurred. It is interesting to note that the most severe serious injury (six months) was acquired during a Para snowboard training run, in the lower half of the course, where the athlete suffered an acute anterior cruciate knee ligament injury which required surgery (table 8). Yet, the vast majority of Para snowboard injuries were only medical attention injuries (including many lacerations and contusions) and did not lead to any time loss.

Although the incidence of injury was reported for Para snowboard at the Sochi 2014 Games, this was combined with Para alpine skiing given that in 2014, Para snowboard was organised as a sub-discipline within World Para Alpine Skiing (45 athletes; IR of 30.3 (95% CI 17.7 to 52.0)). It was however listed as an individual sport at the Pyeongchang 2018 Games. Thus, this

study is the first to fully describe injuries acquired during this sport in a Paralympic Winter Games setting. As this may reflect the relative inexperience of the competitors compared to the other well-established Winter Para sports, it is suggested that education and safety programs are considered within this sport going forward.

We believe it is important to contextualise injury as reported in this paper, especially with respect to severity. 78.9% of all injuries sustained in these Games did not require time away from training or competition, indicating that these injuries are not as clinically significant as those injuries that resulted in the athlete to be unable to compete/train in their sport. Although there was a significantly higher unadjusted IR of injury in Para snowboard in this study, further studies investigating significant time loss injuries in isolation are required.

### **Shoulder injuries remain common in Para athletes**

The second important finding was the high incidence of injury in the shoulder/arm/elbow complex (39 injuries; IR of 5.7 (95% CI 4.2 to 7.8)), with 27 of these injuries reported for the shoulder joint. The shoulder joint has been highlighted in both the Summer and Winter setting for athletes with impairment, mainly for wheelchair users, who utilise their upper body to perform both their sport and activities of daily living.[1,4,19–23] In the current study, sports in which athletes utilised their arms for power and stability during high-speed propulsion, namely Para ice hockey (n = 21; 56% of all injuries), Para Nordic skiing (n = 13; 50% of all injuries) and Para alpine skiing (n = 13; 30% of all injuries) had a higher number of reported injuries in this area.

The IPC Medical Committee is committed to investigating shoulder injuries in athletes competing in Para Athletics and Para Powerlifting events in an effort to determine the true extent of the problem facing athletes who utilise wheelchairs. It is apparent that this challenge is present in many sporting events (other than in the sports mentioned above) in which athletes with lower limb impairment compete (i.e. Para Winter sports). It is therefore indicated that all sports with a high risk for shoulder injuries require further investigation, and subsequent intervention.

### **Intervention program in Para alpine skiing**

The third important finding was the reduction in injuries reported in the sport of Para alpine skiing from the Sochi 2014 Games (IR of 43.8 (95% CI 35.0 to 54.9)) to the Pyeongchang 2018

Games (IR of 23.1 (95% CI 16.5 to 32.1)). It is hypothesized that this reduction was due, in part, to the improved environmental conditions in Pyeongchang (mean temperature: -2°) compared with Sochi (mean temperature: 9°), and also to accelerated interventions made by the IPC and World Para Alpine Skiing federation in an effort to decrease the injury load in this sport.[24,25] At the Sochi Games, modifiable risk factors for sustaining an injury in Para alpine skiing were identified, including: 1) course design, 2) number of training runs permitted on the course and 3) the command and control structure between the technical and medical staff. At the Pyeongchang Games, the Technical Committee implemented a series of changes to mitigate the risk of injury, including: 1) redesigning the course, 2) increasing the number of training runs, 3) having the ability to change event start times, and 4) the development of a snow contingency plan. Education opportunities were also made available to all NPC medical and technical staff, to increase the awareness and management of Para alpine injuries in this setting.[24] The incidence of injuries sustained during the Games' decreased from an IR of 43.8 (95% CI 35.0 to 54.9) injuries per 1000 athlete days in Sochi 2014, to 23.1 (95% CI 16.5 to 32.1) injuries per 1000 athlete days in Pyeongchang 2018.

### **Strengths and limitations of the study**

A strength of the current study was that the data collection system was upgraded prior to these Games, so that medical officers could alter the number of days lost after the initial logging of the illness or injury. This facility was kept open for alterations to the time loss data to be made by the team physicians for a period of two weeks following the conclusion of the Games.

A limitation was that two electronic sources were used for data collection (WEB-IISS and polyclinic entries). We suggest that all athletes be covered on the WEB-IISS at future editions of the Games or that the local organising committee system be expanded to include the same variables as the WEB-IISS, in particular number of days lost and mechanism of injury. There were a relatively small total number of injuries in this study, which limits our abilities to perform complex multivariate statistical analysis.

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### **Ethical approval**

Research Ethical Approval was granted by the University of Brighton (FREGS/ES/12/11) and Stellenbosch University (N16/05/067).

### **Patient involvement**

No.

### **Contributorship**

All authors have contributed to the development, application and write up of the current study. Each author has completed a Conflicts of Interest form.

### **Conflicts of interest**

All authors have declared competing interests.

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### **Data sharing statement**

No data are available.

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