


High incidence of injuries at the Pyeongchang 2018 Paralympic Winter Games: a prospective cohort study of 6804 athlete days

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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 and 557 athletes) and teams without their own medical support (8 teams and 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 to 25.0). The highest IR was reported for para snowboard (IR of 40.5 per 1000 athlete days [95% CI 28.5 to 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 to 19.8]) and injuries to the shoulder/arm/elbow complex (IR of 5.7 per 1000 athlete days [95% CI 4.2 to 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 Games¹ and have continued at the Rio 2016⁵ Summer Games and at Paralympic Winter Games at the Sochi 2014⁴ 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 precompetition 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 subdiscipline 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 IR, injury IR per sport (specifically to determine the baseline injury IR in the new sport of para snowboard), type of injury and anatomical areas affected by the injury in both the precompetition 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 programmes.

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 3-day precompetition period and 9-day competition period of the Pyeongchang 2018 Paralympic Winter Games. Athletes participated in five categories of sports: para alpine



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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. Consent was provided by all athletes for the use of deidentified medical data gathered during the Games.

The web-based injury and injury surveillance system (WEB-IISS) was used to record injuries by physicians of teams who had their own medical support at the Games. This system has been used 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 Committee's (NPC) 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 precompetition 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 customised surveillance system in the medical polyclinic venues was used by teams who did not have accompanying medical staff (n=8), as well as WEB-IISS covered athletes who chose to use polyclinic services. 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 delinked 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 (3 day precompetition and 9-day competition period) multiplied by team size as published by the IPC. These data constituted denominator data for the calculation of injury IR. The provision of accurate denominator data is critical to correct analysis and reporting of the epidemiology of injury in this international multisport setting, with multiple teams.

Calculation of the injury proportion and IR

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 sub group, 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 (ie, 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. Furthermore, 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. Generalised linear Poisson regression modelling (SAS V.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

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

| Sport | All athletes | Men | Women | Age 13–25 years | Age 26–35 years | Age 36–75 years |
|--------------------|--------------|-----|-------|-----------------|-----------------|-----------------|
| 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 |

the independent variables of interest. Unadjusted injury IRs were reported per 1000 athlete days (including 95% CIs). 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 men and 134 women), represented 49 countries at the Games (6804 athlete days). Five hundred and fifty-seven athletes from 41 countries (98.2% of all athletes, 6684 athlete days) had their own medical support, and 10 athletes from eight countries (120 athlete days) used the local polyclinic medical facilities. Some athletes were monitored on the WEB-IISS and also chose to use 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.

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 and 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]). Twenty-eight athletes sustained separate injuries on different days of competition, and one athlete sustained a multilocation 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.

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 IRs between men and women and between age groups.

Incidence of injury in the precompetition (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 precompetition 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 IR between these two periods.

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).

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

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

| Sport | Total number of injuries | Number of athletes with an injury | Total number of athletes competing | Total number of athlete days | Percentage of athletes with an injury (%) | Injury incidence rate: injuries/1000 athlete days (95% CI) |
|--------------------|--------------------------|-----------------------------------|------------------------------------|------------------------------|---|--|
| All | 142 | 112 | 567 | 6804 | 19.8 | 20.9 (17.4 to 25.0) |
| Para snowboard | 35 | 24 | 72 | 864 | 33.3 | 40.5 (28.5 to 57.5)* |
| Para alpine skiing | 39 | 30 | 141 | 1692 | 21.3 | 23.1 (16.5 to 32.1) |
| Para ice hockey | 37 | 29 | 135 | 1620 | 21.5 | 22.8 (16.2 to 32.1) |
| Para Nordic skiing | 26 | 24 | 159 | 1908 | 15.1 | 13.6 (9.1 to 20.5) |
| Wheelchair curling | 5 | 5 | 60 | 720 | 8.3 | 6.9 (2.7 to 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 ($p<0.01$).

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

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

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.

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 using 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, while 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 (8–28 days lost due to injury) and three injuries classified as serious (28 days–6 months lost), according to the consensus statement on time loss injuries in athletics (table 8).⁹

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 programmes. 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 (6 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 that required surgery (table 8). Yet, the vast majority of para snowboard injuries were only medical attention injuries (including many lacerations and contusions) that 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 subsdiscipline 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 with the other well-established winter para sports, it is suggested that education and safety programmes 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. A percentage of 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

Table 4 Incidence of injury in the precompetition and competition periods for athletes competing at the Pyeongchang 2018 Paralympic Winter Games

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

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 to 25.0) |
| Upper limb | 54 | 52 | 9.2 | 7.9 (6.1 to 10.3) |
| Shoulder/arm/elbow | 39 | 38 | 6.7 | 5.7 (4.2 to 7.8) |
| Wrist/hand/finger | 15 | 15 | 2.6 | 2.2 (1.3 to 3.6) |
| Lower limb* | 48 | 43 | 7.6 | 7.1 (5.2 to 9.5) |
| Knee | 11 | 10 | 1.8 | 1.6 (0.9 to 3.1) |
| Ankle/foot/toe | 13 | 12 | 2.1 | 1.9 (1.1 to 3.4) |
| Lower leg | 7 | 7 | 1.2 | 1.0 (0.5 to 2.1) |
| Thigh/stump | 10 | 10 | 1.8 | 1.5 (0.8 to 2.7) |
| Hip/groin/pelvis | 7 | 7 | 1.2 | 1.0 (0.4 to 2.4) |
| Head/face/neck†‡ | 29 | 27 | 4.8 | 4.3 (2.9 to 6.2) |
| Spine | 6 | 6 | 1.1 | 0.9 (0.4 to 2.0) |
| Chest/trunk/abdomen | 5 | 5 | 0.9 | 0.7 (0.3 to 1.8) |

*Fifteen of these injuries occurred in para snowboard (p<0.01).

†Fourteen 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.

joint. The shoulder joint has been highlighted in both the summer and winter setting for athletes with impairment, mainly for wheelchair users who use their upper body to perform both their sport and activities of daily living.^{1 4 5 19–22} In the current study, sports in which athletes used 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 use 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 (ie, para winter sports). It is therefore indicated that all sports with a high risk for shoulder injuries require further investigation and subsequent intervention.

Intervention programme 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 hypothesised that this reduction was due, in part, to the improved environmental conditions in Pyeongchang (mean temperature:

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 to 25.0) |
| Acute traumatic | 110 | 91 | 16.0 | 16.2 (13.2 to 19.8)* |
| Acute on chronic | 10 | 10 | 1.8 | 1.5 (0.8 to 2.7) |
| Chronic overuse | 22 | 21 | 3.7 | 3.2 (2.1 to 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 and 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 and other neurological impairments) | 6 | 6.5 |
| Les autres | 0 | 0 |
| Unknown | 4 | 4.3 |

WEB-IISS, web-based injury and injury surveillance system.

–2°C) compared with Sochi (mean temperature: 9°C) 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.^{23 24} 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.²³ 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.

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

| Time lost due to injury | Onset, anatomical area and mechanism of injury | Sport (event) in which the injury occurred |
|--|--|--|
| <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/face 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). |

WEB-IISS, web-based injury and injury surveillance system.

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 2 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.

What are the findings?

- ▶ The new sport of para snowboard had a higher incidence rate of injury than all other sports, indicating the need for injury intervention and prevention programmes in the sport.
- ▶ The shoulder joint was the most commonly affected anatomical area—specifically 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 programme implemented by the International Paralympic Committee and World Para Alpine Skiing.

How might it impact on clinical practice in the 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 provide a basis for future studies at upcoming Paralympic Games.

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