Department of Health Sciences
Division of Physiotherapy

Physiotherapy programme
180 ECTS

Bachelor Thesis 15 ECTS

Spring 2024

The mechanisms behind sports injuries in Para Alpine Skiing during the Paralympic Games, Sochi 2014, Pyeongchang 2018 and Beijing 2022

Author
Klara Dahlin
Physiotherapy programme
Lund University
kl8384da-s@student.lu.se

Author
Maja Johansson
Physiotherapy programme
Lund University
ma8851jo-s@student.lu.se

Supervisor
Kristina Fagher, PhD
Specialist in Sports Medicine
Lund University,
Sölvegatan 19, 221 85 Lund
Kristina.fagher@med.lu.s

Co-supervisor
Dr. Phoebe Runciman
ISEM, Stellenbosch University
para@sun.ac.za

Examiner
Jenny Älmqvist Nae
Dr. of Medical Science
Lund University,
Sölvegatan 19, 221 85 Lund
Jenny.almqvist_nae@med.lu.se

Abstract

Introduction: Para sport has during the last decades increased and one of the largest sports during the Paralympic Winter Games is Para Alpine Skiing. Injuries are common among both Alpine skiers with and without disability and to be able to develop preventive measures there is a need to further understand the epidemiology behind injuries in Para Alpine Skiing.

Aim: The overall aim of this thesis is to describe the types of sports injuries (injury onset, mechanisms and anatomical area) in Para Alpine Skiing during the Winter Paralympic Games from 2014 to 2022. A second aim is to describe the incidence and injury type in the subgroups impairment, sex and age group during the Paralympic Games in Beijing 2022.

Study design: This study is a prospective study based on epidemiological data from Paralympic Games in Sochi 2014, PyeongChang 2018 and Beijing 2022.

Method: Data was collected from each injured Para Alpine athlete during the Paralympic Winter Games 2014, 2018 and 2022. To report an injury, each national medical team or the local medical support facility used a web-based electronic injury and illness surveillance system. The data was analysed with both descriptive and analytical statistical methods.

Result: Athletes participating in the Sochi Paralympic Games reported the highest incidence proportion (55%), compared with Pyeongchang (33%) and Beijing (25%). In total, acute sudden onset injuries were most common (70%), and the most frequent body location was the knee (19%). It was statistically significant that more acute injuries were reported during the Beijing Paralympic Games compared to the other games (p=0.02) and that women reported more acute injuries than men during the Beijing Game (p=0.048).

Conclusion: Results from this project show that the incidence proportion of injuries in Para Alpine Skiing has decreased from 2014 to 2022. However, a concern is that a high proportion of acute injuries still are being reported and that females report a high proportion of acute injuries. To protect athlete health further research is needed to develop preventive measures within Para Alpine Skiing targeting athletes with various impairments and sexes.

Keywords: *Para sport, sport injuries, Para Alpine Skiing, epidemiology, injury prevention*

Sammanfattning

Bakgrund: Intresset för parasport har under de senaste åren ökat och en stor idrott inom paralympiska vinterspelen är para-alpinsk skidåkning. Skador är vanligt förekommande inom alpin skidåkning oavsett funktionsnedsättning eller inte. För att kunna utveckla preventiva åtgärder finns det behov för en djupare förståelse kring epidemiologin om skador inom para-alpinsk skidåkning.

Syfte: Det övergripande syftet med studien är att beskriva olika typer av idrottsskador (skadedebut, mekanismer och anatomiskt område) i para-alpinsk skidåkning under de paralympiska vinterspelen från 2014 till 2022. Ett andra syfte är att beskriva incidensen och skadetypen i undergrupperna: funktionsnedsättning, kön och åldersgrupp under paralympiska vinterspelen i Beijing 2022.

Studiedesign: Studien är en prospektiv studie byggd på epidemiologisk data från paralympiska vinterspelen i Sotji 2014, PyeongChang 2018 och Beijing 2022.

Metod: Datan samlades in från varje skadad para-atlet under paralympiska vinterspelen 2014, 2018 och 2022. Varje landslag alternativt den lokala sjukvården rapporterade in aktuella skador via ett webb-baserat elektroniskt system för skador och sjukdom. Datan analyserades sedan med hjälp av deskriptiv och analytisk statistik.

Resultat: Deltagarna i paralympiska vinterspelen i Sotji rapporterade den högsta andelen skador (55%), i jämförelse med PyeongChang (33%) och Beijing (25%). Totalt inom alla spelen var akuta skador vanligast (70%) och den mest drabbade kroppsdelen var knät (19%). Det var statistiskt signifikant att det rapporterades fler akuta skador i paralympiska vinterspelen i Beijing i jämförelse med de andra spelen ($p=0.02$) och att kvinnor rapporterade fler akuta skador än män i Beijing ($p=0.048$).

Konklusion: Resultatet av studien visar att andelen skador i para-alpin skidåkning har minskat från 2014-2022. Ett problem är att det fortsatt rapporteras en hög andel akuta skador och att främst kvinnor drabbas av dessa. För att förebygga atleternas hälsa, krävs vidare forskning av preventiva åtgärder som tar hänsyn till atleternas biologiska kön och funktionsnedsättningar.

Nyckelord: *Parasport, idrottsskador, para-aplinsk skidåkning, epidemiologi, skadeförebyggande träning.*

Content

1. Introduction

Sport is today a popular activity for many people. Involvement in sports has both physical and physiological benefits, and it can therefore play a significant role in most people's lives. For example, participation in sports reduces risks of several medical conditions, such as cardiometabolic diseases, dementia, cancer and mental illness (1). In the last few decades, the interests of sport and its association with well-being have especially grown among people with an impairment (2).

1.1 Para sport

Para sport refers to individuals with an impairment that are doing sports at any level. Athletes participating in Para sport are named Para athletes. The term Paralympic sport indicates that the athletes, known as Paralympic athletes, are on elite level and are able to compete in the Paralympic Games (3).

In 1960, at the same time as the Olympic Games, the first official Summer Paralympic Games were held in Rome. Sixteen years later, in 1976, the first Winter Paralympics were held in Sweden, and in 1989 the International Paralympic Committee (IPC) was established (2). The Paralympics had its big breakthrough in 2012, in London. The attitude towards Para sport has since then been more open, inclusive and respectful, and the athletes´ performances continue to increase for each Paralympic Games. The Paralympic Games have now grown to one of the largest sport events in the world (4).

To determine which athletes that are eligible to compete in Para sport, IPC has created a classification system, based on the International Classification of Functioning, Disability and Health (ICF). To be eligible to compete in a Para sport, one out of ten different impairment categories must be fulfilled, for instance impaired muscle power, limb deficiency or ataxia (5, 6). The aim with the classification system is to minimise the impact of the impairment on athletes´ performance so that the sporting excellence determines which athlete that is best (6, 7). Since there are several classes for each sport and impairment, it was in 2021 suggested in the “Para sport translation of the IOC consensus on recording of data for injury and illness in sport” to use the main categories visual impairment, intellectual impairment, neurological

impairment and musculoskeletal impairment (with under categories if possible) when conducted epidemiological research (6).

Most sports included in the Paralympic Games are based on able-bodied sports, with some modifications to Para athletes, their impairments and equipment. For example, in tennis the athletes use a wheelchair (8). Altogether there are 28 sports represented in the Paralympic Games, 22 summer sports and six winter sports. Boccia, Cycling, Football 5-a-side, Table Tennis, Wheelchair basketball and Triathlon are some examples of sports being part of the Summer Paralympics. In the Winter Paralympics the following sports are included; Para Ice Hockey, Para Snowboard, Wheelchair Curling, Para Nordic skiing (including Cross-Country Skiing and Biathlon), and Para Alpine Skiing (8, 9, 10). This project will focus on injuries in Para Alpine Skiing during the Paralympic Games in Sochi 2014, Pyeongchang 2018 and Beijing 2022.

1.2 Para Alpine Skiing

Para Alpine Skiing is a popular outdoor sport both within rehabilitation, recreational sport and competitive sport as people with various impairments can participate. An advantage of the sport is that Para athletes often can use the same ski lift and slopes as their able-bodied peers (e.g friends, family, and other athletes), which makes it a very inclusive sport (11).

In Para Alpine Skiing, there are some equipment and rules that are specific for Para athletes. For instance, athletes with a visual impairment have the option to ski with a guide who provides verbal guidance regarding the correct direction and slope conditions. Using a single ski is an opportunity for athletes with one leg, while sit-skis are used by skiers with other physical impairments in the lower extremities, for example spinal cord injury or double leg amputation. Athletes with upper extremity impairments often ski without poles (12).

All athletes competing in Para Alpine Skiing must fulfill one of the IPC impairment categories, and depending on their specific impairment they are divided into different sport classes. These classes are set by World Para Alpine Skiing Classification Rules and Regulations. The overall categories are standing skiers, sit-skiers and skiers with vision impairment, and depending on the degree of impairment, the athletes will be divided into

different subclasses. Currently, athletes with intellectual impairment do not have an alpine class at the Paralympic Games, but they can compete at the Special Olympic Games (13).

Despite that there are several positive health effects with participation in Para sport, a concern is that research has shown that athletes participating in Para Alpine Skiing reports a high rate of sports injuries. For example, 22% of all Para Alpine Skiers participating in the Paralympic Games in Vancouver 2010 sought medical care (14). Data also show that athletes participating in Para Alpine Skiing during the Paralympic Games in Sochi 2014 and PyeongChang 2018 reported a high incidence rate of injuries compared to the other winter sports (12, 14).

Injuries in Alpine Skiing is also a problem in able-bodied skiers (15). Among all 314 Alpine Skiers competed in the Olympics in Sochi 2014, 20,7% reported at least one injury (16). Other data from previous research in able-bodied athletes have shown that it is frequent with injuries in the lower extremities, especially, anterior cruciate ligament- (ACL), and medial collateral ligament- (MCL) ruptures are common. In the upper extremity, injuries in the thumb, shoulder and head are most frequent. Data also show that men in general suffer more injuries compared to women. Concerning type of injury, men suffer more fractures than women. In contrast it is more common with ligament injuries, and especially ACL-ruptures, among women compared to men. With the development of epidemiological research, better equipment, better use of helmets and the implementation of injury training prevention programmes the overall injury incidence has decreased. Yet, the data of traumatic sports injuries remain the same in Alpine Skiing, which is a concern (15).

Data concerning incidence rate (IR) and incidence proportion (IP) during the Paralympic Games in Sochi 2014, Pyeongchang 2018 and Beijing 2022 have been reported in previous published studies (12, 17, 18). However, in Para Alpine Skiing, the knowledge about the mechanisms, risk factors and types of injuries is still scarce. Moreover, there are no data presented on incidence, mechanisms and injuries in respective subgroup of sex, age and impairment class during the Beijing Games 2022. A concern is that elite Para athletes in general report higher incidence of injuries compared to able-bodied athletes (19, 20). It could be hypothesized that Para Alpine Athletes are exposed to other risk factors compared to able-bodied alpine athletes. Examples of such risk factors are lack of vision, poor balance,

less muscle strength, neurological impairment and use of monoskis, sit-skiis and straps (21). To work towards prevention of sports injuries in Para Alpine Skiing there is a need to better understand the epidemiology of sports injuries, and especially the mechanisms behind (19).

2. Aim and Objective

The overall aim of this thesis is to describe the types of sports injuries (injury onset, mechanisms and anatomical area) in Para Alpine Skiing during the Paralympic Winter Games from 2014 to 2022. A second aim is to describe the incidence and injury type in the subgroups impairment, sex and age group during the Paralympics Games in Beijing 2022.

2.1 Research questions

i) What are the most common types of sports injuries (injury onset, mechanisms and anatomical area) reported in Para Alpine Skiing during the Winter Paralympic Games from 2014-2022?

ii) What differences in sports injuries can be found between the Winter Paralympic Games in Sochi 2014, PyeongChang 2018 and Beijing 2022?

iii) What is the incidence rate and the most frequent types of injuries reported in each impairment class, sex group and age group during the Beijing Paralympic Games in 2022?

iiii) What differences can be found between different impairment classes, sexes and age groups in the Beijing 2022 Winter Paralympic Game?

3. Method

3.1 Study design and project execution

This is a sub-analyzis of an epidemiological prospective study assessing sports injuries and illnesses during the Winter Paralympic Games in Sochi 2014, PyeongChang 2018 and Beijing 2022. Data were reported in real-time in a web-based survey developed and implemented in 2012 by the IPC Medical Committee (22). The benefits of prospective studies are, for instance, that there is a low risk of recall bias, and that factors related to risk factors can be collected in real time and based on sports exposure (23).

Data for this project was retrieved from the IPC athlete health data system in collaboration with the responsible researchers of the Paralympic Games athlete health data collection (Professor Wayne Derman and Dr Phoebe Runciman, Institute of Sports and Exercise Medicine, Stellenbosch University, South Africa, (SA)). The authors visited Stellenbosch during eight weeks in October and November 2023. In SA, Dr Phoebe Runciman co-supervised this project and at the same time Dr Kristina Fagher, Lund University, supervised from Sweden. The authors of this thesis (MJ and KD) have conducted the analysis of the data in this project with guidance from the supervisors.

3.2 Participants

The participants in this study were Paralympic Alpine Skiers competing in the skiing events, Super-G, Downhill, Giant slalom and Slalom, during the Paralympic Winter Games 2014, 2018 and 2022. To be eligible for the study, the inclusion criterias were that the athletes had to be an IPC classified Para athlete and qualified Para Alpine athlete for the Paralympic Games 2014, 2018 and/or 2022.

The number of participants differed in each game. In Sochi 2014, 219 Para athletes competed in Para Alpine Skiing, consisting of 163 men and 56 women. Four years later, in Pyeongchang 2018, 140 Para Alpine Skiers participated, including 100 men and 40 women. In the Beijing Games 2022, there were 170 Para Alpine athletes, consisting of 117 men and 53 women.

3.3 Data Collection

The original data were collected during Paralympic Games 2014, 2018 and 2022. The data was collected in two different ways; either through the respective national medical teams or by the local medical support. All data collected by teams were entered into IPC´s web-based injury and illness surveillance system, WEB-IISS, and data from local polyclinic services used a local data portal and after the games they gave it further to the research team of the epidemiological study (12, 17, 18). All national medical teams received an email prior the Games about the study and overall instructions about the system and its various functions. During the pre-competition period, all national team physicians got more detailed information

about the system and how to report their injuries. Each medical team did also get a tablet computer to document their data (12, 17, 18).

The collected data included the incidence rate, injury onsets (acute (sudden onset), repetitive (gradual onset), repetitive (sudden onset)), mechanisms (non contact, contact, weather conditions, was out of control/fall, equipment, unknown) and anatomical area (head/face, neck, chest, spine, abdominal/trunk, shoulder, arm, elbow, wrist/hand/fingers, hip/groin, thigh, stump, knee, lower leg, foot/ankle/toe, unknown).

3.4 Definitions

Below is a summary of all definitions used in this thesis. Table 1 describes medical terms of impairment types.

Table 1. Medical terms of impairment types used for classifying injuries in the epidemiological study.

Limb deficiency (LD)	Limb Deficiency refers to a total or partial lack of bones or joints as a consequence of trauma, illness or congenital limb deficiency (5).
Visual impairment (VI)	Visual Impairment refers to decreased or no vision as a consequence of damage to the eye structure, optical nerves or optical pathways, or visual cortex of the brain (5).
Spinal cord related disorders (SCRD)	Spinal cord related disorder is a group of multiple impairments caused by a spinal cord injury. This can example be impaired muscle power and hypertonia (6).
Neurological disorders (ND)	Neurological disorders refers to an impairment in the neurological system. It can be shown as ataxia, hypertonia and athetosis (6).
Brain disorders (BD)	Brain disorders indicate impairment caused by an injury in the brain. For example cerebral palsy, stroke and multiple sclerosis (6).
Impaired passive ROM (IPROM)	Impaired Passive Range of Movement refers to reduced or a lack of passive movement in one or more joints (5).

3.4.1 Definition of injury

The definition of an injury in Paralympic studies were *"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 Sochi 2014, PyeongChang 2018 and Beijing 2022 Winter Paralympic Games".* To specify the type of injury, injuries were further defined as being an acute injury, chronic injury (overuse with gradual onset) or an acute on chronic injury (overuse injury with sudden onset). Acute injuries are defined as "*an injury that was caused by an acute precipitating traumatic event*", chronic ones as "*an injury that developed over days, weeks or months and was not associated with any acute precipitating event"*, and lastly acute on chronic "*an acute injury in an athlete with symptoms of a chronic injury in the same anatomical area"* (12, 17). During the Paralympics in Beijing 2022, slightly other terms were used to describe different injury onsets and this thesis will use those terms. However they have the same meaning as the definitions above. Acute injuries are synonymous with acute (sudden onset) injuries, chronic injuries as repetitive (gradual onset) injuries and acute on chronic injuries has the same meaning as repetitive (sudden onset) injuries (18).

3.5 Categorization of data and data analysis

First, the overall frequency and type of injury onsets, mechanisms and anatomical area in Para Alpine Skiing were described using descriptive statistics. The same procedure were used to describe the frequency of type of injury onset, mechanisms and anatomical area in sex (female or male), age group (12-25 years, 26-34 years and 35-75 years) and impairments (limb deficiency, visual impairment, spinal cord related disorders, neurological disorders, brain disorders, impaired passive range of movement) in Beijing. Incidence proportion (portion of injured athletes) were also described for each Paralympics and were descriptive compared between each game.

Furthermore, analytical statistics, using Chi-square statistics, was applied to compare data among various subgroups. The primary aim of the Chi-square test is to use the null hypothesis to assess whether there is a statistical significance in proportion of injured athletes between subgroups. Within this thesis, the subgroups Paralympic Games and sex were included. Due to few participants in the other subgroups no analytical tests were conducted for them. The shown result is a comparison of distribution between each group and is

presented with p-value (p), where $p < 0,05$ indicates that there is a statistic significant difference between the subgroups (24).

3.6 Ethics

Data used for this project was extracted from an ongoing research project. The project has been approved by the Ethical Commitees´ at University of Brighton (FREGS/ES/12/11), United Kingdom and University of Stellenbosch (N16/05/067), South Africa. The project follows the World Medical Association´s (WMA) Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects.

The collected data are protected according to South African data regulation rules, and data can only be analysed by those with permission, which the authors obtained by submitting a request. The ethical committee, Stellenbosch University, then approved that the authors of this study could retrieve and analyze data from the project.

It was voluntary for the national teams to report injuries and illnesses from their team. By signing the Paralympic Games participant contract, the athletes give consent that their data will be used for various purposes such as research. All data used in this project are de-identified, and data will not be used for any other purpose than this project.

4. Results

4.1 Frequency of injuries reported during three Paralympic Games

Among all Para Alpine Skiers in the three games (n=529) there were 210 reported injuries, reported by 208 athletes. In Beijing, two athletes reported two injuries each. No other duplicates of injuries were found. Specifically, in Sochi 2014, there were 120 reported injuries by 219 competing athletes, resulting in an incidence proportion of 55%. In Pyeongchang 2018, 46 injuries were reported among 140 skiing athletes, resulting in an IP of 33%. In Beijing 2022, 170 athletes participated, and 42 athletes reported an injury (IP 25%), see table 2 for further details.

4.2 Type of injuries in Para Alpine Skiers over three Paralympic Games

4.2.1 Injury onset

During all three Paralympic Games, a majority of the injuries reported were acute (sudden onset) injuries, followed by repetitive (gradual onset) - and repetitive (sudden onset) injuries. In more detail, participants in Sochi 2014 reported 58% acute injuries, Pyeongchang 2018 83% and 2022 Beijing Games 89%. A significantly higher proportion of acute injuries were reported during the most recent Paralympic Games in Beijing 2022, compared to Sochi 2014 and Pyeongchang 2018 (p= 0.02) (Table 2).

4.2.2 Mechanism of injuries

Regarding mechanisms of injuries reported during the past three Winter Paralympic Games, most of the total injuries were caused by falls and loss of control. In Sochi 2014, one third of all injuries were related to loss of control/fall (32%)). In Pyeongchang 2018, a majority of the injuries had an unknown mechanism (39%) and the second most common injury mechanism was out of control/fall (33%). In Beijing 2022, the most frequent injury mechanism (34% of all injuries) was contact injuries (for example injuries related to a collision with an artificial object, such as the safety netting) (Table 2).

4.2.3 Anatomical area

For all the three Paralympic Games, injuries in the upper extremities were more common, than injuries in the lower extremities, although the proportion differed for each game. In Sochi 2014, 59% of the injuries were reported in the upper extremities. In Pyeongchang 2018, 63% of the injuries occurred in the upper extremities, and in Beijing 2022 52% of the injuries were localized in the upper extremities.

Regarding specific anatomical locations the most affected anatomical area in Sochi 2014 was the knee (22% of all injuries). In Pyeongchang 2018, the wrist/hand/fingers were the most injured body location (15%), and in Beijing 2022 knee injuries were again most frequent (23%). Overall, of all injuries in the three games, knee injuries were the most prevalent injured body location, followed by head/face - and shoulder injuries (Table 2).

Table 2. Incidence proportion and types of injuries during the Winter Paralympic Game 2014, 2018 and 2022 reported as number of injuries and frequency (%). Significant differences in proportions are marked bold.

	Sochi 2014 (n= 219)	Pyeongchang 2018 (n=140)	Beijing 2022 (n=170)	All Games (n = 529)	Chi2 test, p-value
Incidence proportion [(%)]*	120 (55%)	46 (33%)	42 (25%)	208 (39%)	N/A
Total number of reported injuries	120	46	44	210	N/A
Injury onset [(%)]**					
Acute (sudden onset) injury	70 (58%)	38 (83%)	***39 (89%)***	147 (70%)	0,02
Repetitive (gradual onset) injury	16 (13%)	5 (11%)	4 (9%)	25 (12%)	N/A
Repetitive (sudden onset) injury	16 (13%)	3 (7%)	1 (2%)	20 (10%)	N/A
Unknown	18 (15%)	-	-	18 (9%)	N/A
Mechanisms [(%)]**					
Non contact injury	10 (8%)	4 (9%)	9 (20%)	23 (11%)	N/A
Contact injury	8 (7%)	5 (11%)	15 (34%)	28 (13%)	N/A
Weather conditions	14 (12%)	1 (2%)	8 (18%)	23 (11%)	N/A
Was out of control/Fall	38 (32%)	15 (33%)	5 (11%)	58 (28%)	N/A
Equipment	12 (10%)	3 (7%)	2 (5%)	17 (8%)	N/A
Unkown	38 (32%)	18 (39%)	5 (11%)	61 (29%)	N/A

Anatomical area [(%)]**					0,141
Upper extremity	71 (59%)	29 (63%)	23 (52%)	123 (59%)	
Lower extremity	45 (38%)	12 (26%)	18 (41%)	75 (36%)	
Head/Face	20 (17%)	6 (13%)	5 (11%)	31 (15%)	N/A
Neck	9 (8%)	5 (11%)	3 (7%)	17 (8%)	N/A
Chest	4 (3%)	2 (4%)	1 (2%)	7 (3%)	N/A
Spine	11 (9%)	-	3 (7%)	14 (7%)	N/A
Abdominal/ Trunk	2 (2%)	-	1 (2%)	3 (1%)	N/A
Shoulder	11 (9%)	6 (13%)	5 (11%)	22 (10%)	N/A
Arm	4 (3%)	1 (2%)	-	5 (2%)	N/A
Elbow	4 (3%)	2 (4%)	1 (2%)	7 (3%)	N/A
Wrist/Hand/Fingers	6 (5%)	7 (15%)	4 (9%)	17 (8%)	N/A
Hips/Groin	2 (2%)	-	2 (5%)	4 (2%)	N/A
Thigh	3 (3%)	-	2 (5%)	5 (2%)	N/A
Stump	2 (2%)	-	-	2 (1%)	N/A
Knee	26 (22%)	4 (9%)	10 (23%)	40 (19%)	N/A
Lower leg	4 (3%)	4 (9%)	3 (7%)	11 (5%)	N/A
Foot/Ankle/Toe	8 (7%)	4 (9%)	1 (2%)	13 (6%)	N/A
Unknown	4 (3%)	5 (11%)	3 (7%)	12 (6%)	N/A

n= Total number of participating alpine skiers in each Paralympic Game.

*= percentage is based on number of athletes reported an injury in each game

**= percentage is based on number of reported injuries in each game

Chi2 test= significance level of the subject in comparison between each game

N/A = not applicable due to few participants

4.3 Injuries during the Beijing Paralympics 2022, divided into the subcategories sex, age and impairment

4.3.1 Sex

During the 2022 Paralympics in Beijing one third of all participating women (32%) reported an injury, and one fifth of all participating men (21%) reported an injury (Table 3). Women were only affected by acute (sudden onset) injuries. Acute injuries were also most representative among male athletes (81%), although some men reported a few repetitive injuries, both gradual onset (15%) and sudden onset injuries (4%). It was statistically significant that women reported a higher proportion of acute injuries compared to men (p=0.048).

The most common mechanisms of injuries among women were contact injuries (28%) and poor weather conditions (28%). For men, it was most common with contact injuries (38%) followed by non-contact injuries (for example injuries due to twisted an extremity) (19%) (Table 3). Regarding body location and sex, both women and men suffered most injuries in their knees (22%, respectively 23%). The second most common body location among women were head/face (17%) and for men the shoulders (12%) (Table 4). There were no statistical significant differences in injuries in different body locations between men and women.

4.3.2 Age

The age group most susceptible to injuries during the Beijing Games was the youngest athletes aged 12-25, reporting 22 injuries. Athletes in the age group 26-34 years reported 12 injuries, and athlete aged 35-75 years reported 10 injuries (Table 3). In all age groups, acute injuries were the most common injury onset, accounting for 90%, 83% and 90% of the injuries respectively. Contact injuries was the primary mechanism behind injuries across all age groups (32%, 42% and 30%). Notable, is that athletes in the 35-75 age group also reported a high rate of injuries due to weather conditions (30%). The youngest participants also reported a high number of non-contact injuries (27%) (Table 3). Concerning body location and age, athletes aged 12-25 suffered most injuries in the knee (41%), while athletes in the age group 26-34 years reported the highest proportion of injuries in their shoulders (25%) and the athletes aged 35-75 years in wrist/hand/fingers, shoulders and neck (20% each). Lastly athletes in the youngest age group 12-25 reported a higher proportion of injuries in the lower extremity compared to their older peers (Table 4).

4.3.3 Impairment

Athletes from all impairment groups sustained injuries during the Beijing Paralympic Games. Athletes with limb deficiency and visual impairment athletes reported most injuries, 15 and 12 injuries respectively. Regarding injury onset, acute (sudden onset) injuries were most common in all impairment groups (Table 3). When it comes to common injury mechanisms within each group, athletes with visual impairment (33%), spinal cord related disorder (50%) and neurological disorder (50%) reported most injuries due to contact-factors. In contrast, athletes with limb deficiency primarily reported injuries due to weather conditions (27%), while athletes with brain disorders (50%) had injuries resulting from both non-contact and contact factors. Athletes with impaired passive range of movement reported only "was out of control/fall" as a mechanism (100%), see table 3. It was shown that in athletes with limb deficiency, visual impairment, neurological disorder and impaired passive range of movement all report that the knee was the most commonly affected anatomical area. Lastly, in athletes with spinal cord related disorders the shoulder was the most frequently injured area (30%), and in athletes with brain disorders the knee and wrist/hand/fingers were the most common injured location (50%) (Table 4).

Table 3. Incidence proportion and number of injuries reported in Para Alpine Skiing in Beijing described for the subgroups, sex, age and impairments. In total 42 of all participated athletes reported an injury. Significant differences in proportion are marked bold.

	Sex		Chi2-test, p-value	Age*			Impairment*					
	F (n = 53)	M (n= 117)		12-25	26-34	35-75	LD	VI	SCRD	ND	BD	IPROM
Incidence proportion [(%)]**	17 (32%)	25 (21%)	0.099	20	12	10	15	12	9	3	2	1
Total number of reported injuries for each category [(%)] **	18 (34%)	26 (22%)		22	12	10	15	12	10	4	2	1
Injury onset [(%)] ***												
Acute (sudden onset) injury	***18 (100%)***	21 (81%)	0,048	20 (90%)	10 (83%)	9 (90%)	12 (80%)	11 (92%)	9 (90%)	4 (100%)	2 (100%)	1 (100%)
Repetitive (gradual onset) injury	-	4 (15%)		1 (5%)	2 (17%)	1 (10%)	2 (13%)	1 (8%)	1 (10%)	-	-	-
Repetitive (sudden onset) injury	-	1 (4%)		1 (5%)	-	-	1 (7%)	-	-	-	-	-
Mechanisms [(%)]***			0.712									

Non contact	4 (22%)	5 (19%)	6 (27%)	1 (8%)	2 (20%)	3 (20%)	3 (25%)	2 (20%)	-	1 (50%)	-
Contact	5 (28%)	10 (38%)	7 (32%)	5 (42%)	3 (30%)	3 (20%)	4 (33%)	5 (50%)	2 (50%)	1 (50%)	-
Weather conditions	5 (28%)	3 (12%)	4 (18%)	1 (8%)	3 (30%)	4 (27%)	2 (17%)	2 (20%)	-	-	-
Was out of control/Fall	2 (11%)	3 (12%)	2 (9%)	1 (8%)	2 (20%)	2 (13%)	1 (8%)	-	1 (25%)	-	1 (100%)
Equipment	1 (6%)	1 (4%)	2 (9%)	-	-	1 (7%)	-	1 (10%)	-	-	-
Unknown	1 (6%)	4 (15%)	1 (5%)	4 (33%)	-	2 (13%)	2 (17%)	-	1 (25%)	-	-

*= lack of information regarding the total participants competing in the Beijing Paralympic Game

**= percentage is based of the number of injured athletes in each category

***= percentage is based of all reported injuries

Chi2-test = comparison of distribution between sex, age and impairment

LD = limb deficiency, VI = visual impairment, SCRD = spinal cord related disorders, ND = neurological disorders, BD = brain disorders, IPROM = impaired passive range of movement

Table 4. Injury location of injuries (n=44) reported in Para Alpine Skiing during the Beijing Paralympic Games described for the subgroups, sex, age and impairments. Significant differences in proportions are marked bold.

	Sex		Chi2-test, p-value	Age*			Impairment*					
	F (n = 53)	M (n= 117)		12-25	26-34	35-75	LD	VI	SCRD	ND	BD	IPROM
Anatomical area [(%)]**			0.398									
Upper extremity	11	12		8	8	7	5	6	9	2	1	0
Lower extremity	7	11		14	2	2	9	5	0	2	1	1
Head/Face	3 (17%)	2 (8%)		3 (14%)	2 (17%)	-	-	2 (17%)	2 (20%)	1 (25%)	-	-
Neck	2 (11%)	1 (4%)		1 (5%)	-	2 (20%)	1 (7%)	-	1 (10%)	1 (25%)	-	-
Chest	-	1 (4%)		-	1 (8%)	-	-	-	1 (10%)	-	-	-
Spine	2 (11%)	1 (4%)		1 (5%)	1 (8%)	1 (10%)	2 (13%)	1 (8%)	-	-	-	-
Abdominal/Trunk	-	1 (4%)		-	1 (8%)	-	-	-	1 (10%)	-	-	-

Shoulder	2 (11%)	3 (12%)	-	3 (25%)	2 (20%)	-	2 (17%)	3 (30%)	-	-	-
Arm	-	-	-	-	-	-	-	-	-	-	-
Elbow	-	1 (4%)	1 (5%)	-	-	1 (7%)	-	-	-	-	-
Wrist/Hand/Fingers	2 (11%)	2 (8%)	2 (9%)	-	2 (20%)	1 (7%)	1 (8%)	1 (10%)	-	1 (50%)	-
Hip/Groin	1 (6%)	1 (4%)	1 (5%)	1 (8%)	-	2 (13%)	-	-	-	-	-
Thigh	1 (6%)	1 (4%)	1 (5%)	-	1 (10%)	2 (13%)	-	-	-	-	-
Stump	-	-	-	-	-	-	-	-	-	-	-
Knee	4 (22%)	6 (23%)	9 (41%)	-	1 (10%)	3 (20%)	3 (25%)	-	2 (50%)	1 (50%)	1 (100%)
Lower leg	1 (6%)	2 (8%)	3 (14%)	-	-	2 (13%)	1 (8%)	-	-	-	-
Foot/Ankle/Toe	-	1 (4%)	-	1 (8%)	-	-	1 (8%)	-	-	-	-
Unknown	-	3 (12%)	-	2 (17%)	1 (10%)	1 (7%)	1 (8%)	1 (10%)	-	-	-

*= lack of information regarding the total participants competing in the Beijing Paralympic Game

**= percentage is based of all reported injuries

Chi2-test= comparison of distribution between sex, age and impairment

LD = limb deficiency, VI = visual impairment, SCRD = spinal cord related disorders, ND = neurological disorders, BD = brain disorders, IPROM = impaired passive range of movement

5. Discussion

The results from this study indicate that participants in Sochi reported the highest incidence proportion of injuries (55%) compared to PyeongChang (33%) and Beijing (25%). Overall, acute injuries were the most common type (70%) and the most affected anatomical area during all three games was the knee (19%). The study identified two statistical significant differences: first, athletes in Beijing reported more acute injuries compared to PyeongChang and Sochi (p=0.02), and second, women reported more acute injuries compared to men in Beijing 2022 (p=0.048).

5.1 Result discussion

5.1.1 Injury incidence proportion

The results demonstrate that the Sochi Paralympic Games 2014 had the highest incidence proportion of injury compared to Pyeongchang 2018 and Beijing 2022. The incidence proportion has since 2014 decreased for each Paralympic Games, which is positive for the continuous development of the Paralympic movement. In Sochi, most injuries were reported in alpine skiing and snowboarding compared to other included sports in the Winter Paralympics. One potential explanation of the high injury rate could be the weather conditions, which should be considered as an extrinsic risk factor for injury (25). During daytime in Sochi, the temperature reached about 18 degrees Celsius, and at night, it did not consistently drop below freezing. Consequently, the warm climate resulted in unfavorable snow conditions (such as heavy snow and many bumps), which could have contributed to the high injury rate. Sports such as nordic skiing and biathlon had lower incidence proportion compared to alpine skiing and snowboarding, despite competing in similar conditions. The combination of high velocity and poor snow could therefore be a possible explanation of the high IP in the alpine sports in Sochi (12).

Due to many severe accidents in Sochi the IPC Medical Committee and the World Para Alpine Skiing management team implemented several safety measures before the Games 2018 and 2022. For instance, it is now possible to start competitions earlier in the day to compete in the best possible snow conditions. Furthermore, the competition course should be placed in the most suitable parts of the slope, i.e. the most steep sections and tight turns could be avoided if there are bad conditions. It has also been suggested that small waves pose a risk to Paralympic mono skiers, therefore efforts are now made to reduce these waves. Finally,

another suggestion is to appoint an independent safety director for each competition that is responsible for making decisions regarding safety issues, changing start times, and, if necessary, canceling an event based on the conditions of the slopes and the environment around (26).

Moreover, in recent years there has been a significant advancement in equipment in Para Alpine Skiing, which could be a potential explanation for the decrease in injuries from Sochi 2014 to Beijing 2022. For instance, injuries to head and face have decreased from 2014-2022, and it could be hypothesized that better and safer helmets have contributed to this trend (15, 27). The use of helmets has also increased, which could have resulted in the lower risk of minor and moderate head injuries. Also, the use of back protection in alpine sports have increased and protective equipment in general are an important part for the reduction of injuries (28).

Further on, previous studies have indicated that a risk factor for tibial shaft fractures, which are quite common in alpine skiing, is the failure of bindings to release during falls. Thanks to the development of bindings and boots, it seems like there is a reduced risk of those injuries, as well as injuries in feet, ankles and toes (15). This could probably also explain why injuries due to equipment-mechanisms have decreased for each game. Despite the advancements in boots and bindings resulting in a reduction of injuries in lower leg and feet, the knee joint is still exposed to injuries such as ACL- or meniscus injuries (15), and more research about knee injury prevention in both abled-bodied and Para Alpine Skiing is needed.

Another explanation of the injury reduction during Paralympic Games over time could be that preventive training nowadays more often is a regular part of each athlete's training schedule. In recent years, the implementation of prehabilitation and injury prevention training has led to various benefits, including a decrease in the number of injuries in several sports due to improved preparation for performance (25). For example, a recent qualitative study showed that improved physical fitness and preparedness was one of the reasons for a large injury reduction in the Paralympic summer sports 2012-2016 (25). It is also noteworthy to discuss the importance of recovery and rest. In a previous study it was shown that elevated training volumes were correlated with sports-related musculoskeletal pain among disabled athletes.

Therefore, reducing training volume and allowing time for recovery should be considered as an effective preventive measure to decrease the incidence of injuries (25).

Studies based on able-bodied athletes also demonstrate that injury prevention through injury awareness training is very effective. In a recent study, alpine skiers learned how to recognize situations with a high risk of ACL injuries, i.e. how to fall safe and how to regain control. The awareness training resulted in a 62% decrease in severe knee injuries compared to a group of skiers that did not get the awareness training (15). To the best of the authors knowledge there are no studies that have evaluated awareness training in Para Alpine Skiers, and it is recommended to evaluate the method in future studies within Para sport. However, one should be aware of challenges related to the implementation of several of the existing injury prevention programmes such as knee control in Para sport as many athletes are, for example, amputees or wheelchair users. An awareness training programmes could also be a challenge for blind athletes, and it is therefore important to specifically adapt injury prevention measures to Para athletes. Previous research has suggested that injury prevention in Para sport advantageously could facilitate health promotion, including athlete health and safety education for both coaches and athletes themselves (29).

5.1.2 Acute injuries most frequent

Acute injuries were the most frequent type of injury in Para Alpine Skiing during each Paralympic Games, and also in total. Acute injuries in sports are a concern for the individual athlete as they quite often lead to serious injuries, and sometimes also a long-term impairment, for example, osteoarthritis following a joint or ligament injury (30). In this study, it was statistically significant that athletes in the most recent Beijing Games reported a higher number of acute injuries compared to athletes competing in Sochi and Pyeongchang (p=0.02). Previous studies have indicated that icy slopes are a risk factor of sustaining an acute injury in alpine sports (31). In Beijing, olympians and paralympians competed in the same slopes (8), it could be hypothesized that some slopes were not adapted for Para athletes and their equipment. The conditions on the slopes were also unfavorable in some events. The Paralympic Games were held in March (compared to the Olympic Games that were held in February), and during the early spring in China 2022 there were large temperature fluctuations between days and nights. Daytime temperatures were as high as 23 degrees Celsius, whereas the nights were cold (32). These temperature variations resulted in icy

slopes in the mornings and melting artificially snow later during day, both mechanisms that possibly contributed to the high risk of acute injuries (25).

Another important finding in this study was that women reported statistically significant more acute injuries than men, p=0.048. Previous studies in able-bodied sports have shown that women are more prone to some acute sports injuries such as acute knee injuries and concussion compared to male athletes. It has been suggested that factors such as poor stretches, joint laxity, hormone fluctuations and a higher willing to report injuries contribute to this mechanism (33, 34). A concern is that there are few studies that specifically have assessed the female athletes' health in Para sport, and it is recommended that future studies more in depth focus on specific risk factors that female Para athletes may be exposed to.

5.1.3 Risk factors of injury in Para Alpine Skiing

Previous studies indicate, in general, that paralympians report a higher rate of injuries compared to olympians. For example, the injury incidence rate in Sochi was three times higher during the Winter Paralympics compared to the Winter Olympics (12). It has been suggested that Para athletes are exposed to other risk factors of injuries compared to able-bodied athletes (25).

Risk factors for injuries can be categorized into extrinsic- and intrinsic factors. Extrinsic risk factors are related to the environment beyond the athlete, for instance weather conditions. Conversely intrinsic factors are related to the individual athlete. It has been suggested that the impairment itself (i.e. being blind and ski downhill) can be an intrinsic risk factor in Para sport. For instance, studies have demonstrated that vision significantly influences postural stability and proprioception and therefore blind athletes suffer a higher risk of getting injured. Also, the specific equipment that Para athletes use can be a risk factor for injury. For example, it is common with shoulder injuries in athletes using a wheelchair. As these athletes often use wheelchairs both in their sports and daily life, it often leads to inadequate rest and recovery time, and thereby increasing the risk of repetitive injuries (25). It is also noteworthy that these athletes often are affected in their daily lives even by minor or moderate injuries since they rely on the use of their upper extremity. Consequently, athletes with impairments are more often significantly affected by sports injury compared to able-bodied athletes (25). Another risk factor that these athletes are exposed to is that they often are strapped in their

sit-ski, which probably increases the risk of certain injuries, mostly in the upper extremity. Taken together, each individual Para athlete are exposed to different intrinsic and extrinsic risk factors, which is important to consider in injury prevention measures.

Interestingly, data also indicates that there are higher incidence rates of injuries being reported during the Winter Paralympics in comparison with Summer Paralympics. This could partly be explained by the inclusion of high risk collisions sports in Winter Paralympics, i.e. Para ice hockey and alpine skiing (12). However during the Summer Games there are also several collision sports such as wheelchair rugby, football and horse riding (9). A hypothesis to the higher injury rate in Winter Games compared to Summer Games, is that some athletes may not have the same opportunity and time to practice in a colder climate and in a similar environment as the competition. Consequently, they may not be adequately prepared for the challenges they will face during the event .

5.1.4 Knee injuries

Knee injuries were the highest represented anatomical area during both the Sochi and Beijing Paralympic Games, and knees were also one of the most represented areas in the different sex-, age- and impairment groups in Beijing. It is noteworthy that athletes with spinal cord related disorders did not report any knee injuries. As mentioned above it probably indicates that athletes with different impairment are exposed to different risk factors.

Previous studies on able-bodied alpine athletes have shown similar results. For instance, one study reported that knee injuries account for 20-30% of all injuries sustained by alpine skiers (35). Furthermore, another study discovered that the total number of injuries in alpine skiers have decreased during the last 25 years, but unfortunately knee injuries have instead increased (36). Together with the findings from this project it highlights that knee injuries seem to be an existing problem among alpine skiers and Para Alpine Skiers.

One significant risk factor for knee injuries may be the equipment used in alpine skiing. For example studies have shown that injuries in the lower extremity, including the knee, are 2.3 times more likely to occur during a fall when one of the ski bindings does not release. This risk increases to 3.3 times if both skis remain attached. Older bindings are only released if there is a lateral force on the front of the boot or if the heel leans forward, leading to that they

will not release if this does not happen (37). Furthermore, today´s ski boots and bindings are designed to avoid the risk of fractures and injuries in the ankle, foot and tibia regions (36). Consequently, there has been a reduction of injuries in the category “ankle/foot/toe”, both in this thesis and in other studies (36). However, the problem with these new boots and bindings are instead that they expose the knee joint for high force, and the knee is also the first unprotected joint when athletes fall (15).

Knee injuries are problematic as they often cause multiple damage within the knee. A prevalent injury among alpine skiers is the tear of anterior cruciate ligament (ACL) (35, 38). ACL injuries in combination with meniscus injuries are together a significant risk factor for developing posttraumatic osteoarthritis (OA) in the injured knee. Studies have indicated that 0-39% of isolated ACL injuries incur osteoarthritis, while the range increases to 21-100% when ACL and meniscus injuries occur together (30). Symptoms often start 10 to 15 years after the injury (39), and a concern is that the youngest age group in Beijing reported most injuries, indicating that some of these athletes may experience symptoms of OA already in their early 30s. Symptoms of OA often impact the individuals´s quality of life by affecting sleep, limiting activities and participation, which are important for a meaningful and high-quality life. The development of OA has also a big socioeconomic impact within the society. One study shows that the direct costs associated with OA, including physician visits, pharmacological treatments and surgeries, can cost 1-2,5% of a country's gross national product. Indirect factors also have a significant impact. For example OA-related pain can lead to reduced productivity at work and even time off from work. Unfortunately, OA has also been associated with premature mortality, which also entails further costs and suffering (40).

Efforts have been done to reduce the burden of knee injuries. For instance, a review article highlight that ACL injuries in alpine skiing decreased by 62% when getting instruction about how to act in a fall. This could include having the knees bent and avoiding standing up if you still slide. Further on, the review also mentions conditioning as an important factor to prevent injuries (37). This, combined with neuromuscular training, is commonly highlighted as an important injury prevention to avoid severe knee injuries, such as ACL injuries (41, 42). These are important factors that probably also could be better implemented for standing Para Alpine Skiers in order to avoid knee injuries.

5.2 Methodological discussion

An important aspect to consider in this thesis is the relatively small population with few participants in Para Alpine Skiing during the Paralympic Games, which is a limitation. For example, the category limb deficiency represented 15 athletes, while impaired passive range of movement just represented one. Subsequently, the limited population made it challenging to conduct analytic tests in some subgroups, and due to the lower participant rate, it is not possible to test for causal associations. Another limitation is that data only were collected during three major championships, which often inquiries special circumstances for both the athletes and the medical team. To obtain more valid data it is recommended to also collect data over athletes' normal training season. A hypothesis is that overuse injuries and other chronic symptoms may not be reported in this data collection phase.

Another issue in this thesis is that the authors have not collected the data themselves, since it is data from a larger research project. The authors did not have the ability to control the data collection, resulting in a limited range of options to analyse. If the thesis were to be conducted again, the authors would choose to collect the data themselves in order to avoid limitations considering lack of data.

5.2.1 Missing data

A main limitation of this study is that the collected data from each games contains varying information, primarily due to a development of the WEB-IISS system. For example, there were no data describing in which event the injury happened in Sochi, however it was reported in both Pyeongchang and Beijing. The system was established to gather data regarding injuries and illnesses during Summer Paralympics in London 2012 (22). Since then, the system has been developed continuously. To not be able to full compare data, is a limitation in all studies within the field. However, in 2020 the Para translation of the IOC consensus of recording and reporting injuries and illnesses in sport was published (6), and hopefully this will lead to more consistent data in the future.

Another noteworthy limitation related to missing data, is the different ethical rules between South Africa and Sweden. Because of strict data sharing rules in South Africa it was not possible to disclose all individual athlete information, which limited the authors in doing some analyses. For instance, the writers did not have access to data regarding sex, age and

impairment in Sochi and Pyeongchang, which made it difficult to compare all three games together. The presentation of such data is an opportunity for future research. Additionally, there was also missing data regarding age and type of impairment for all participating athletes in Beijing. Therefore, the incidence proportion could just be statistically compared within the subgroup sex, and it is recommended that future studies examine if there are any associations between injury, impairment and age.

Another main limitation of the data is that it is not presented which countries that reported and do not report injuries. As it is voluntary to participate in the studies there is a risk for so called self-selection bias, which means that the sample may not be representative for the population as a whole. For example, athletes or countries may choose “to mask” injuries for a coach or other competitors.

Furthermore, another limitation in the data is the category “unknown-data”, which probably is a result of missing information from the WEB-IISS registration conducted by each medical team. The high rate of using “unknown-data” could be due to the voluntary reporting of an injury, the medical team’s lack of knowledge to answer the question, language barriers or their inability to report data. Due to the high rate of “unknown-data” in this project it was difficult to conduct statistical analysis. In the future it is recommended to rule out why there are a high rate of answers “unknown”.

Lastly, data from Sochi and Pyeongchang partially lacked information regarding date of birth, age, sex and impairment, which made it difficult to find out whether athletes reported multiple injuries. In Beijing, it was possible because the data collection was almost fully valid regarding age, date of birth, impairment and sex, resulting in the opportunity to look for duplicates. Two duplicates were found in the data set from Beijing, and these were removed from the incidence proportion calculation. However, it is not possible to exclude duplicates in the results.

5.2.2 Limitations in Para Alpine Skiing studies

Based on the author's experience from writing this thesis, their perception is that it is difficult to compare the data with other studies in the field, as there are few studies among Para Alpine Skiers, and especially in comparison studies about able-bodied skiers. For instance,

impairments and risk factors are not included in most studies, resulting in problems when adapting the able bodied research on Para athletes.

Another concern is that in some sports in Winter Paralympics there are no or very few women, for instance in Para ice hockey. This restriction partially contributes to the higher participation of men compared to women in each game. Subsequently, men will also be mostly represented in studies and research and women will be an understudied population. Still, women represent some significant results in this thesis (acute injuries). This issue is a serious concern since there are physiological sex differences between men and women, and thereby it can be hard to apply all research based on men to women. For example, there is no data on menstruation and use of contraceptive pills collected in the studies from the Paralympic Games.

5.2.3 Strengths

A strength of the thesis is that it contains prospective data from three different games during a period of eight years. Prospective studies involve real-time data collection to examine progress over time. An alternative approach to data-collection is retrospective studies, where information is gathered afterwards (43). The author's thoughts about relying on prospective data, is that the data conducted in real-time will reduce the risk of recall bias. This, since it becomes a lower risk of missing and reporting inaccurate data when the teams document the injury and its belonging details directly when it occurs, in contrast with the retrospective data-collection, when relying on the medical team’s memory.

Another strength of the present study is that the authors have analysed the data in close collaboration with researchers responsible of the data collection. During the writer's time (eight weeks) at Stellenbosch University, South Africa, they have learned a lot about epidemiological data collection during large sport events. The authors believe this knowledge will help them in their future career as Physiotherapists. For example, they have learned a lot about how to assess risk factors in sports, and they have also increased their understanding about important of conducting epidemiological studies in order to work towards preventive measures.

5.3 Practical perspectives

The results from this study can help physiotherapists, other medical professionals and sports organizations to understand how injuries can be reduced in the actual sports setting. For example, it is important to be aware that acute injuries still are a problem and that females especially are exposed to acute injuries. It could be suggested that sports organizers should investigate this reason more in detail and implement measures. Introducing preventive training, including strength training and neuromuscular training (40, 42) could probably also help female athletes as well as the overall problem with knee injuries. Concerning the overall rate of acute injuries, some measures were implemented after the Sochi Games. Still, many acute injuries occurred in Beijing and the snow conditions with artificial snow and warm weather was not optimal. To reduce the rate of injuries it could be suggested that competitions should be held in cold weather with good snow conditions.

Another noteworthy clinical perspective is that physiotherapy plays an important part in an athlete's return to sport after an injury in Para Alpine Skiing. For example, research shows that specialized rehabilitation programs, administered by a physiotherapist, are beneficial for a successful return to the sport following acute knee injuries (44). It is important that the rehabilitation is specialized to the demands of the specific sport. For instance, alpine skiers need to develop strength in slow eccentric loading, endurance and weight-bearing power (44).

Furthermore, it could be recommended that Para Alpine Skiers have an established physiotherapy contact both before and during competitions to facilitate prehabilitation and acute management and rehabilitation if needed. As physiotherapists have an unique understanding of the human body they can also contribute with knowledge about specific risk factors related to the specific impairment. In a Swedish study published in 2016 it was shown that physiotherapists play an important role in Para athletes' lives (45). In addition, physiotherapists also have expertise in planning recovery times among athletes, which is especially important in Para sport as Para athletes may be exposed to higher energy demands due to for example spasticity or wheelchair driving in daily life. Furthermore, the study also mentioned that preventive training, including core stability, balance and flexibility, has an important impact on preventing sport-related injuries in Para sport. It could therefore be recommended that each national Paralympic team has one or several physiotherapists in their medical team both during training and competitions (45).

5.4 Future research

This thesis only included quantitative data concerning mechanisms of injury, and quite much data were missing. Moreover, it is still partly unknown why Para Alpine Skiers are exposed to a high risk of acute injuries. To identify more specific risk factors, it could be suggested that a qualitative method interviewing athletes, coaches and medical staff could contribute with valuable information regarding risk factors and prevention strategies.

As previously mentioned, there is also a need of larger studies including more Para athletes. Prospective multi-center studies over time including several countries is one option. Another option is that the International Ski Federation (FIS) implement injury surveillance during all their Regional and World Cups.

Regarding the studies conducted at the Paralympic Games it would be valuable to include more data concerning the equipment. For example, the use of poles, the height of the ski, type of boots and ski bindings (much of this information is already controlled by the technical committee before each event). Moreover, more data about the risk of being strapped in a sit-ski is needed. It is also recommended to include data about weather and type of event in forthcoming Paralympic Games studies. Furthermore, the authors suggest that video analyses of injuries could contribute with important information. Such attempts have been conducted in several able-bodied sports (46).

Lastly, an important aspect is how the global warming will affect athlete health and the risk of injury in alpine sports in the future. With warmer weather, more artificially snow, and uncontrolled weather phenomena, such as unpredictable storms and heavy rains (46). It could be hypothesized that injury risk in alpine sport will remain high.

6. Conclusion

Results from this project show that the incidence proportion of injuries in Para Alpine Skiing has decreased from 2014 to 2022. However, a concern is that a high proportion of acute sports injuries still are being reported and acute injuries remained high during the most recent Beijing Paralympic Games. Most of these injuries were related to falls and loss of control. Another concern is that females report a high proportion of acute injuries, and it is

recommended that this athlete group should be a target for prevention. Data also revelated that the knee was the most commonly affected anatomical area overall, and it is recommended that future studies assess the specific injury mechanisms of knee injuries in Para Alpine Skiing. Taken together, this is the first project that specifically has described the mechanism and type of injuries in Para Alpine Skiing over three Paralympic Games, and the results could guide future epidemiological research in Paralympic sport medicine. Moreover, the result could be used by stakeholders for planning future competition events and medical services within the Paralympic Movement.

7. Acknowledgements

The authors of this essay would like to send a grateful thank you to their supervisor Dr Kristina Fagher for her engagement and dedicated time in the development of the article. Her guidance and support have been important for the finished article. Furthermore, special thanks are extended to Dr Phoebe Runciman at Stellenbosch University for her help and generous assistance during the work and time in Stellenbosch, South Africa. The authors are also thankful that Dr Phoebe Runciman, together with the leader of the research team Professor Wayne Derman made it possible for them to work with their collected data. Finally, Susanne Brokop at Lund University, deserves a heartfelt appreciation for making this journey possible.

References

1. Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. CMAJ. 2006 Mar 14;174(6):801-9. Available from: https://pubmed.ncbi.nlm.nih.gov/16534088/
2. International Paralympic Committee. Paralympics History [Internet]. Bonn: International Paralympic Committee [cited date 2024-05-20]. Available from: https://www.paralympic.org/ipc/history
3. Tuakli-Wosornu Y. Hart A. Blauwet C. Lexell J. Physical Medicine and Rehabilitation: Principles and Practise. Chapter 42: Paralympic Sports. 6th edition. Editor: Frontera WR. Philadelphia, US: Wolters Kluwer. 2020.
4. Vanlandewijck Y & Thompson W. Training and coaching the Paralympic Athlete. Chichester, West Sussex, UK: John Wiley & Sons, Ltd. 2016
5. International Paralympic Committee. IPC Classification [Internet]. Bonn: International Paralympic Committee [cited date 2023-09-08]. Available from: https://www.paralympic.org/classification
6. Derman W, Badenhorst M, Blauwet C, Emery CA, Fagher K, Lee YH, Kissick J, Lexell J, Miller IS, Pluim BM, Schwellnus M, Steffen K, Van de Vliet P, Webborn N, Weiler R. Para sport translation of the IOC consensus on recording and reporting of data for injury and illness in sport. Br J Sports Med. 2021 Oct;55(19):1068-076. Available from: Para sport translation of the IOC consensus on recording and reporting of data for injury and illness in sport - PubMed (nih.gov)
7. Tweedy SM, Vanlandewijck YC. International Paralympic Committee position stand--background and scientific principles of classification in Paralympic sport. Br J Sports Med. 2011 Apr;45(4):259-69. Available from: https://pubmed.ncbi.nlm.nih.gov/19850575/
8. International Paralympic Committee. Paralympics Games [Internet]. Bonn: International Paralympic Committee [cited date 2024-05-20]. Available https://www.paralympic.org/paralympic-games
9. International Paralympic Committee. Paralympic sports [Internet]. Bonn: International Paralympic Committee [cited date 2023-09-20]. Available from: https://www.paralympic.org/sports

10. Oh H, Johnson W, Syrop IP. Winter Adaptive Sports Participation, Injuries, and Equipment. Sports Med Arthrosc Rev. 2019 Jun;27(2):56-59. Available from: https://pubmed.ncbi.nlm.nih.gov/31046009/
11. Parasport/Sverige. Träna och tävla [Internet]. Stockholm: Parasport/Sverige; 2022 [updated date 2023-08-04; cited date 2023-09-14]. Available from: https://parasport.se/trana-och-tavla
12. Derman W, Schwellnus MP, Jordaan E, Runciman P, Van de Vliet P, Blauwet C, Webborn N, Willick S, Stomphorst J. High incidence of injury at the Sochi 2014 Winter Paralympic Games: a prospective cohort study of 6564 athlete days. Br J Sports Med. 2016 Sep;50(17):1069-74. Available from: https://pubmed.ncbi.nlm.nih.gov/27307272/
13. International Paralympic Committee. Classification in Para Alpine Skiing [Internet]. Bonn: International Paralympic Committee [cited 2023-09-07]. Available from: https://www.paralympic.org/alpine-skiing/classification
14. Webborn N, Willick S, Emery CA. The injury experience at the 2010 winter paralympic games. Clin J Sport Med. 2012 Jan;22(1):3-9. Available from: https://pubmed.ncbi.nlm.ni1h.gov/22222596/
15. Davey A, Endres NK, Johnson RJ, Shealy JE. Alpine Skiing Injuries. Sports Health. 2019 Jan/Feb;11(1):18-26. Available from: Alpine Skiing Injuries - PMC (nih.gov)
16. Soligard T, Steffen K, Palmer-Green D, Aubry M, Grant ME, Meeuwisse W, Mountjoy M, Budgett R, Engebretsen L. Sports injuries and illnesses in the Sochi 2014 Olympic Winter Games. Br J Sports Med. 2015 Apr;49(7):441-7. Available from: Sports injuries and illnesses in the Sochi 2014 Olympic Winter Games - PubMed (nih.gov)
17. Derman W, Runciman P, Jordaan E, Schwellnus M, Blauwet C, Webborn N, Lexell J, van de Vliet P, Kissick J, Stomphorst J, Lee YH, Kim KS. High incidence of injuries at the Pyeongchang 2018 Paralympic Winter Games: a prospective cohort study of 6804 athlete days. Br J Sports Med. 2020 Jan;54(1):38-43. Available from: High incidence of injuries at the Pyeongchang 2018 Paralympic Winter Games: a prospective cohort study of 6804 athlete days - PubMed (nih.gov)
18. Derman W, Runciman P, Eken M, Boer PH, Blauwet C, Bogdos E, Hirschmueller A, Jordaan E, Kissick J, Lexell J, Mohammadi F, Patricio M, Schwellnus M, Webborn N, Zhou JX. Incidence of injury and illness at the Beijing 2022 Paralympic Winter

Games held in a closed-loop environment: a prospective cohort study of 7332 athlete days. Br J Sports Med. 2024 Feb 28:bjsports-2023-107525. Available from: Incidence of injury and illness at the Beijing 2022 Paralympic Winter Games held in a closed-loop environment: a prospective cohort study of 7332 athlete days - PubMed (nih.gov)

19. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. Sports Med. 1992 Aug;14(2):82-99. Available from: Incidence, severity, aetiology and prevention of sports injuries. A review of concepts - PubMed (nih.gov)
20. Fagher K, Dahlström Ö, Jacobsson J, Timpka T, Lexell J. Injuries and illnesses in Swedish Paralympic athletes-A 52-week prospective study of incidence and risk factors. Scand J Med Sci Sports. 2020 Aug;30(8):1457-470. Available from: https://pubmed.ncbi.nlm.nih.gov/32302455/
21. Magno E Silva MP, Winckler C, Costa E Silva AA, Bilzon J, Duarte E. Sports injuries in paralympic track and field athletes with visual impairment. Med Sci Sports Exerc. 2013 May;45(5):908-13. Available from: https://pubmed.ncbi.nlm.nih.gov/23247703/
22. Willick SE, Webborn N, Emery C, Blauwet CA, Pit-Grosheide P, Stomphorst J, Van de Vliet P, Patino Marques NA, Martinez-Ferrer JO, Jordaan E, Derman W, Schwellnus M. The epidemiology of injuries at the London 2012 Paralympic Games. Br J Sports Med. 2013 May;47(7):426-32. Available from: The epidemiology of injuries at the London 2012 Paralympic Games - PubMed (nih.gov)
23. Andersson I. Epidemiologi för hälsovetare. Uppl 3. Lund: Studentlitteratur; 2021. Kapitel 3, Analysera; s. 85-146.
24. Ejlertsson G. Statistik för hälsovetenskaperna. 2 ed. Lund: Studentlitteratur; 2013.
25. Fagher K, Lexell J. Sports-related injuries in athletes with disabilities. Scand J Med Sci Sports. 2014 Oct;24(5):e320-31. Available from: https://pubmed.ncbi.nlm.nih.gov/24422719/
26. Derman W, Blauwet C, Webborn N, Schwellnus M, Vliet PV, Lazarovski D. Mitigating risk of injury in alpine skiing in the Pyeongchang 2018 Paralympic Winter Games: the time is now! Br J Sports Med. 2018 Apr;52(7):419-20. Available from: https://pubmed.ncbi.nlm.nih.gov/29351955/
27. Haider AH, Saleem T, Bilaniuk JW, Barraco RD; Eastern Association for the Surgery of Trauma Injury ControlViolence Prevention Committee. An evidence-based review:

efficacy of safety helmets in the reduction of head injuries in recreational skiers and snowboarders. J Trauma Acute Care Surg. 2012 Nov;73(5):1340-7. Available from: https://pubmed.ncbi.nlm.nih.gov/23117389/

28. Hasler RM, Benz J, Benneker L, Kleim B, Dubler S, Zimmermann H, Exadaktylos AK. Do alpine skiers and snowboarders wear protective equipment more often after an accident? Swiss Med Wkly. 2011 Oct 27;141:w13283. Available from: https://pubmed.ncbi.nlm.nih.gov/22030562/
29. Fagher K, Kunorozva L, Badenhorst M, Derman W, Kissick J, Verhagen E, Ahmed OH, Jederström M, Heron N, Khoshnood AM, Silva A, Kenttä G, Lexell J. Safe and Healthy Para sport project (SHAPE): a study protocol of a complex intervention within Para sport. BMJ Open Sport Exerc Med. 2022 Aug 25;8(3):e001392. Available from: https://pubmed.ncbi.nlm.nih.gov/36101569/
30. Thomas AC, Hubbard-Turner T, Wikstrom EA, Palmieri-Smith RM. Epidemiology of Posttraumatic Osteoarthritis. J Athl Train. 2017 Jun 2;52(6):491-496. Available from: https://pubmed.ncbi.nlm.nih.gov/27145096/
31. Posch M, Ruedl G, Greier K, Faulhaber M, Tecklenburg K, Schranz A, Schliernzauer B, Burtscher M. Impact of Environmental Factors on the ACL Injury Risk in Recreational Alpine Skiing. Int J Sports Med. 2023 Sep 22. Available from: https://pubmed.ncbi.nlm.nih.gov/37739010/
32. Berkeley G. Athletes deal with heat at Winter Paralympics as temperature rises in Beijing [Internet]. Inside the games; 2022 [cited 2023-10-24]. Available from: https://www.insidethegames.biz/articles/1120296/temperature-rises-winter-paralympics
33. Lexell J, Lovén G, Fagher K. Incidence of sports-related concussion in elite para athletes - a 52-week prospective study. Brain Inj. 2021 Jul 3;35(8):971-977. Available from: https://pubmed.ncbi.nlm.nih.gov/34185611/
34. Ireland ML. The female ACL: why is it more prone to injury? Orthop Clin North Am. 2002 Oct;33(4):637-51. Available from: https://pubmed.ncbi.nlm.nih.gov/12528906/
35. Paletta GA, Warren RF. Knee injuries and Alpine skiing. Treatment and rehabilitation. Sports Med. 1994 Jun;17(6):411-23. Available from: https://pubmed.ncbi.nlm.nih.gov/8091049/

36. Natri A, Beynnon BD, Ettlinger CF, Johnson RJ, Shealy JE. Alpine ski bindings and injuries. Current findings. Sports Med. 1999 Jul;28(1):35-48. Available from: https://pubmed.ncbi.nlm.nih.gov/10461711/
37. Koehle MS, Lloyd-Smith R, Taunton JE. Alpine ski injuries and their prevention. Sports Med. 2002;32(12):785-93. Available from: https://pubmed.ncbi.nlm.nih.gov/12238941/
38. Flørenes TW, Bere T, Nordsletten L, Heir S, Bahr R. Injuries among male and female World Cup alpine skiers. Br J Sports Med. 2009 Dec;43(13):973-8. Available from: https://pubmed.ncbi.nlm.nih.gov/19945979/
39. Friel NA, Chu CR. The role of ACL injury in the development of posttraumatic knee osteoarthritis. Clin Sports Med. 2013 Jan;32(1):1-12. Available from: https://pubmed.ncbi.nlm.nih.gov/23177457/
40. Werner DM, Golightly YM, Tao M, Post A, Wellsandt E. Environmental Risk Factors for Osteoarthritis: The Impact on Individuals with Knee Joint Injury. Rheum Dis Clin North Am. 2022 Nov;48(4):907-930. Available from: https://pubmed.ncbi.nlm.nih.gov/36333003/
41. Arundale AJH, Silvers-Granelli HJ, Myklebust G. ACL injury prevention: Where have we come from and where are we going? J Orthop Res. 2022 Jan;40(1):43-54. Available from: https://pubmed.ncbi.nlm.nih.gov/33913532/
42. LaBella CR, Hennrikus W, Hewett TE; Council on Sports Medicine and Fitness, and Section on Orthopaedics. Anterior cruciate ligament injuries: diagnosis, treatment, and prevention. Pediatrics. 2014 May;133(5):e1437-50. Available from: https://pubmed.ncbi.nlm.nih.gov/24777218/
43. Dychawy Rosner I. Aktionsforskning och fallstudier. In: Höglund Nielsen B, Granskär M. Tillämpad kvalitativ forskning inom hälso- och sjukvård. 3. ed. Lund: Studentlitteratur; 2021. p. 33-50.
44. Kokmeyer D, Wahoff M, Mymern M. Suggestions from the field for return-to-sport rehabilitation following anterior cruciate ligament reconstruction: alpine skiing. J Orthop Sports Phys Ther. 2012 Apr;42(4):313-25. Available from: https://pubmed.ncbi.nlm.nih.gov/22467124/
45. Fagher K, Forsberg A, Jacobsson J, Timpka T, Dahlström Ö, Lexell J. Paralympic athletes' perceptions of their experiences of sports-related injuries, risk factors and

preventive possibilities. Eur J Sport Sci. 2016 Nov;16(8):1240-9. Available from: https://pubmed.ncbi.nlm.nih.gov/27329262/

46. Della Villa F, Buckthorpe M, Grassi A, Nabiuzzi A, Tosarelli F, Zaffagnini S, Della Villa S. Systematic video analysis of ACL injuries in professional male football (soccer): injury mechanisms, situational patterns and biomechanics study on 134 consecutive cases. Br J Sports Med. 2020 Dec;54(23):1423-1432. Available from: https://pubmed.ncbi.nlm.nih.gov/32561515/