

# **Illness and Injury in Athletes with Visual Impairment at the London 2012 Paralympic Games**

**A dissertation prepared by Louise Stopforth (*MLLLOU002*) in  
partial fulfillment of the requirements for the Master of Philosophy  
degree in Sports and Exercise Medicine (MPhil Sports and Exercise  
Medicine) from the University of Cape Town**

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## Declaration

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Signed by candidate

(Signature)

21 May 2017

(Date)

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*“A day spent without learning something, is a day wasted”*

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## List of abbreviations

AO	All Other Impairments
Ath	Athletics
AVG	Average
CI	Confidence Interval
CP	Cerebral Palsy
Dig	Digestive system illness
EMDCS	Electronic medical data capture system
IAAF	International Association of Athletics Federation
Inf	Infective illness
IPC	International Paralympic Committee
IP	Incidence Proportion
IR	Incidence Rate
LD	Limb Deficiency
LOCOG	London Organizing Committee of the Olympic Games and Paralympic Games
Neuro	Neurological illness
SEM	Sport and Exercise Medicine
Skin	Skin and subcutaneous tissue illness
VI	Visually impaired
WEB-IISS	Web-based Injury and Illness Surveillance System

## **Abstract**

### **Background**

Participation in sport by athletes with impairment has grown and evolved rapidly since the inception of the Paralympic Games. Athletes with visual impairment were first included in the Paralympic Games in 1976. Surveillance of illnesses and injuries forms the first important step in determination of the epidemiology and an understanding of the risk factors for both illness and injuries in these populations. Thus, surveillance can therefore assist medical teams in implementing prevention strategies.

Few studies have evaluated the incidence of illness and injuries amongst athletes with impairment. For this reason, a novel web based injury and illness surveillance system (WEB-IISS) was developed for use by the team physicians at the London 2012 Paralympic Games. To our knowledge, no study has specifically researched the epidemiology of illness and injuries in athletes with visual impairment during a major sport event such as the Paralympic Games.

### **Objective**

To determine the incidence associated with illness and injuries in athletes with visual impairment during the London 2012 Paralympic Games. We further aim to describe any differences between sports, age groups, gender and body systems affected in this cohort of athletes.

### **Methods**

This study was a retrospective analysis of a component of the large prospective cohort study on the epidemiology of injury and illness conducted over a 14-day period at the London 2012 Paralympic Games. The data from 711 of the 791 athletes with visual impairment who participated in the London 2012 Paralympic Games were analyzed.

The following data sources were used: Firstly, de-identified information regarding age, gender, impairment, country code and sports code of athletes obtained from the International Paralympic Committee database.

Secondly, information collected from the electronic medical data capture system (EMDCS) used at all the London Organizing Committee for the Olympic and Paralympic Games (LOCOG) medical stations; and thirdly a novel web-based injury and illness surveillance system (WEB-IISS) used by the team physicians. This is the most comprehensive reporting system used in elite athletes with impairment to date. Data were collected on a daily basis from 3 days prior to the start of the Paralympic Games (pre-competition period) until the last day of the 11-day Paralympic Games (competition period).

### **Definitions**

In order to determine the nature and extent of illnesses and injuries as well to enable uniformity in research studies evaluating the data collected during the London 2012 Paralympic Games, the following definitions were implemented:

*Illness* was defined as ‘any newly acquired illness as well as exacerbation of pre-existing illness that occurred during training or competition, and during or immediately before the London 2012 Paralympic Games’.

*Injury* was defined as ‘any newly acquired injury as well as exacerbation of pre-existing injury that occurred during training and/or competition period of the London 2012 Paralympic Games’.

*Incidence rate (IR) of illness or injury* is the number of illnesses or injuries per 1000 athlete days.

*Incidence proportion (IP) of illness or injury* is the proportion of athletes affected by illness or injury (n/100).

### **Results**

Incidence rate of illness (IR 11.9; 95% CI 9.0 - 15.7) was similar to incidence rate of injuries (IR 14.5; 95% CI 11.3 - 18.5) in VI athletes. The IR of illness for VI athletes (IR 11.9; 95% CI 9.0 - 15.7) compared well to that of illness for all impairment groups (IR 12.7; 95% CI 10.2 - 16.0). Furthermore, the IR of injuries for VI athletes (IR 14.5; 95% CI 11.3 - 18.5) compared well to that of injuries for all impairment groups (IR 12.6; 95% CI 10.3 - 15.4). Gender and age did not affect the risk of illness or injuries in VI athletes. Furthermore, there was a higher IR of illness for swimmers with visual impairment compared to other sports, but this was not statistically significant. The IR of illness for VI athletes participating in swimming was 12.5 (95% CI 8.8 - 17.8) compared to that of VI non-swimmers, IR 11.8 (95% CI 8.9 - 15.6).

Participation in athletics (track and field) was associated with a slightly higher risk for injury for athletes with VI compared to other sports, but this was not statistically significant. The IR of injury was 15.8 (95% CI 11.6 - 21.5) and the IP 22.1 (95% CI 16.3 - 30.1) for VI track and field athletes. The IR of injury was 13.0 (95% CI 9.6 – 17.4) and IP 18.1 (95% CI 13.5 - 24.3) amongst VI athletes not participating in track and field athletics. VI swimmers had a lower IR of injury (IR 4.1; 95% CI 1.8 - 9.5) than VI non-swimmers (IR 16.1; 95% CI 12.6 - 20.7) ( $p=0.002$ ). There was a higher IR and IP of lower limb injuries compared to upper limb injuries in athletes with visual impairment. The IR for lower limb injuries in athletes with visual impairment was 7.7 (95% CI 5.8 - 10.3) and the IP was 10.8 (95% CI 8.1 - 14.4). The average IR of lower limb injuries for all para-athletes was 4.5 (95% CI 3.5 - 5.7). The IR for upper limb injuries in athletes with visual impairment was 3.0 (95% CI 1.9 - 4.5) and the IP was 4.1 (95% CI 2.7 - 6.3). The average IR for upper limb injuries for all para-athletes was 4.5 (95% CI 3.5 - 5.9).

### **Conclusion**

The findings of this study suggest that Paralympic athletes with VI had a similar incidence rate of illness and injury compared to other impairment groups; and IR of illness was similar to that of injuries. Risk of illness or injury was not affected by age group or gender, but rather sport specific differences were observed. Of particular interest was the fact that athletes with VI had a higher incidence rate of lower limb injuries than upper limb injuries.

### **Key words**

Visually impaired athletes, illness, injury, Paralympic Games

# Chapter 1

## Introduction and scope of the thesis

The first official Paralympic games was held in Rome in 1960, where 400 athletes from 23 countries competed. Athletes with visual impairment (VI) were included for the first time in the Paralympic Games in 1976, in Toronto. A total of 187 athletes with visual impairment participated at this event. Since the first Paralympic Games held in Rome in 1960, the number of athletes with impairment competing at this elite level has grown and evolved rapidly.

A total of 4,176 athletes from 164 delegations participated at the London 2012 Paralympic Games, of which 791 were athletes with VI.

Despite significant growth in this unique focus area of sports medicine, few studies have evaluated the incidence of illness and injuries amongst athletes with impairment. In particular, very few studies have investigated injury and illness by sport and impairment type. Surveillance of illness and injuries forms the first and important step of the initiation of prevention programs. Indeed, determination of the epidemiology and an understanding of the risk factors for both illness and injuries in these populations can assist the medical team in implementing prevention strategies. Few research studies have evaluated injuries specifically in athletes with VI but to our knowledge, no study has ever evaluated the epidemiology of illness in this group of Paralympians. Therefore, the epidemiology and specific risk factors for illness and injury in elite para-athletes with visual impairment is still poorly understood.

In this dissertation we aimed to determine:

- 1) The incidence rate and incidence proportion of illness amongst athletes with visual impairment at the London 2012 Paralympic Games
- 2) The epidemiology of illness specifically comparing systems affected, age groups, gender and different sports amongst athletes with VI

- 3) The incidence rate and incidence proportion of injuries amongst athletes with visual impairment at the London 2012 Paralympic Games
- 4) The epidemiology of injuries specifically comparing anatomical region (body segments) mainly affected, age groups, gender and different sports in athletes with VI.

Chapter 2 contains a review of the existing literature on illness and injuries in para-athletes with VI.

In Chapter 3, the original research study on the epidemiology of illness and injury in para-athletes with VI at the London 2012 Paralympic Games is presented. This study is a secondary analysis of data collected from the London 2012 Paralympic Games, describing specifically the group of athletes with VI. Our study will focus on the cohort of 706 athletes with visual impairment out of 3009 athletes included in the data analysis.

Finally, the findings of the dissertation and advise on strengths and shortcomings of this research is summarized, which will hopefully assist future research studies in this field.

## Chapter 2

### **A review of documented Studies in Illness and Injury in Athletes with Visual Impairment**

#### **2.1. Background & Introduction**

Exercise is widely recommended for its' health benefits and is frequently prescribed as preventative measure for risk reduction of chronic diseases such as cardiovascular disease, diabetes, the metabolic syndrome and cancer. Sports participation worldwide is becoming more popular, be it for health purposes, recreation or competition. Over the last few decades, exercise and sports participation in athletes with impairments has also been emphasized and has steadily increased <sup>(2, 4, 5)</sup>.

Participation in Paralympic sport, which forms the pinnacle of sports competition for athletes with impairment, has been increasing exponentially. The first organised athletic day for athletes with impairment coinciding with the Olympic Games, took place on the opening day of the 1948 summer Olympics in London, United Kingdom. Only 16 athletes (fourteen injured service men and two service women) competed in archery and this event became known as the Stoke Mandeville Games. The first official Paralympic games, not only open to war veterans, was held in Rome in 1960 where 400 para-athletes from 23 countries competed. Para-athletes with visual impairment were included for the first time in the Paralympic Games in 1976, in Toronto and 187 athletes with visual impairment participated at the event <sup>(1, 2)</sup>. The Paralympic Games have grown and evolved rapidly over this relatively short period and a total of 4,176 athletes from 164 delegations participated at the London 2012 Paralympic Games <sup>(2, 3)</sup>.

Participation in competitive sport, irrespective of whether the athlete is able bodied or classified with impairment, predisposes the athlete to illness and injury<sup>(2, 36, 37, 38)</sup>. Therefore, illness and injury prevention programs should be implemented wherever possible within the competitive sport setting. Surveillance of illness and injuries forms the first and important step of the initiation of prevention programs. Indeed, determination of the epidemiology and an understanding of the risk factors for both illness and injuries in these populations can assist the medical team in the eventual implementation of prevention strategies<sup>(2, 3, 4, 5, 6, 36)</sup>.

Competitive sport has become a highly specialized field, where the elite athlete's performance can be influenced by miniscule changes. Traveling to a sporting event for competition, especially for such a prolonged period as during the Paralympic Games, brings on various challenges and stressors over and above that of training and competition. Changes in familiar nutrition, changes of training facilities and routine, sleeping patterns, exposure to foreign environment and possible allergens or pathogens; and lack of the athlete's familiar psychological support network are all factors that can influence the health and performance of the para-athlete.

Paralympic sports pose many health challenges that may not be faced in Olympic sports. Earlier studies have found overall rates of injuries to be comparable to injury rates in able-bodied athletes<sup>(12, 15)</sup>. Recently, higher incidence rates for both illness and injury in impaired athletes compared to their able bodied counterparts at a similar event, have been described by Derman et al (2016) during the Sochi 2014 Winter Paralympic Games<sup>(36, 37, 38)</sup>. Risk factors for illness and injury depend on the nature of the sport as well as the specific impairment. Risk factors can further be seen as either intrinsic or extrinsic risk factors. Van Mechelen (1987) described these intrinsic (personal) and extrinsic (external) risk factors<sup>(19)</sup>. In athletes with impairment, the impairment itself can be seen as an intrinsic risk factor, which often cannot be modified. In certain impairments, the degree of impairment can be managed with the use of orthotics, braces, etc. The degree of impairment can either improve or worsen with time, which again can influence classification of the impairment as well as risk factors for illness or injury.

In spite of significant growth in this unique field of sports medicine, few studies have evaluated the incidence of illness and injuries amongst athletes with specific impairments<sup>(2, 3, 4, 5)</sup>. The term

para-athletes will be used in this dissertation to refer to athletes with impairment competing at the Paralympic level, to differentiate from athletes with impairment on other competitive levels.

Furthermore, inconsistencies in which the incidence rates of illness and injuries have been reported in previous research studies, the lack of uniform definitions and poor research design, further contribute to confusion when comparing data. For this reason, a novel web based injury and illness surveillance system (WEB-IISS) was developed for use by the medical team physicians at the London 2012 Paralympic Games<sup>(4)</sup>. The results of this WEB-IISS showed that the overall incidence rate (IR) and incidence proportion (IP) of illness and injury were similar to the observed rate in other elite competitions<sup>(4, 7)</sup>. These values are lower than the IR and IP of illness and injury that have subsequently been reported during the Sochi 2014 Winter Paralympic Games<sup>(37, 38)</sup>. The findings of the Sochi data will be discussed in further detail under sections 2.4 and 2.5. The contrast of these findings compared to previous studies could be the result of higher risk sports in which athletes compete in the Winter Games setting, and specific environmental factors associated with the Sochi Games<sup>(39)</sup>. This highlights the need for more specific research evaluating various sports, impairment groups and considering environmental risk factors.

Another shortcoming of previous research studies is the fact that very few studies have investigated injury and illness by sport and impairment type. Most studies use a cross-impairment design, merging different sport modalities and impairments. Interpreting such results creates the challenge that we are still not able to clearly identify the most relevant conditions for a specific group of para-athletes. Specifically, little is still known about the epidemiology and specific risk factors for injury and illness in elite athletes with visual impairment.

Vision impairment arises from a variety of conditions: genetics, prenatal development issues, or from illness or trauma. Vision can be impacted by either an impairment of the eye structure, optical nerves or optical pathways, or visual cortex of the central brain<sup>(28)</sup>. Elite athletes with visual impairment competing at domestic or international level go through a classification system in order to compete, based on the level of useful vision they possess<sup>(8, 18, 27, 28)</sup>.

Visual impairment brings with it many challenges. Vision is the dominant, integrating sense and without it, the other senses need to be trusted and more developed. Contrary to the general belief

that blind people have extraordinary senses of touch and hearing, this is actually the result of increased concentration and training. In fact, individuals who are newly blind or have impaired vision struggle to gather environmental information from the remaining senses<sup>(29, 33, 34)</sup>.

This could be partly because sight plays such an important role in maintaining orientation<sup>(29, 33, 34, 35)</sup>. Without sight, individuals can lose a sense of where they are, and their immediate surroundings. Sound can be helpful, but is not as localizing or specific as vision and only provides information about people or objects emitting sound. Sighted individuals rely on peripheral vision as a warning system. Without this, there is impaired reaction time, which can increase injury risk. Visually impaired individuals rely on touch more than sighted individuals, but this sense is restricted to arm's length<sup>(33)</sup>.

Loss of vision can have certain restrictions on the independence of an individual. Often, there is a loss of control, freedom and security in the environment and newly blinded or visually impaired individuals become more dependent on others. Visual impairment brings with it a loss of basic skills and mobility. The brain receives less stimulation and this can lead to a sense of isolation in such individuals<sup>(33)</sup>.

It is important to remember that blindness does not equate with darkness. The vast majority of people who are legally blind have light perception or functional vision. This is of particular importance in the setting of competitive sport to ensure fair and equal competition; therefore, it was necessary to develop a classification system of visual impairment.

## **2.2. Classification of Visual Impairment:**

To ensure competition is fair and equal, all Paralympic sports have a system in place which ensures that winning is determined by skill, fitness, power, endurance, tactical ability and mental focus; these are the same factors that account for success in sport for able bodied athletes.

This process is called classification and its purpose is to minimise the impact of impairment on the activity (sport discipline). Having the impairment is not sufficient, the impact on the sport

must be proved. In each Paralympic sport, the criteria of grouping athletes by the degree of activity limitation resulting from the impairment are named ‘Sport Classes’. Through classification, it is determined which para-athletes are eligible to compete in a sport and how the para-athletes are grouped together for competition. This, to a certain extent, is similar to grouping athletes by age, gender or weight<sup>(18, 27, 28)</sup>.

Classification is sport-specific, since impairment affects the ability to perform in different sports to a different extent. As a consequence, an athlete may meet the criteria for impairment classification in order to compete in one sport, but may not meet the impairment classification criteria for competing in another sport.

**Table 1: Visual Classification according to degree of Visual Impairment**

Visual Classification	Degree of Visual Impairment
B1	total blindness (may have light perception but unable to recognise the shape of a hand at any distance);
B2	vision is impaired (able to recognise the shape of a hand but visual perception not more than 2/60 or visual field less than 5° in the best eye with best correction);
B3	visual acuity above 2/60, less than 6/60 or visual field of less than 20°, more than 5° in the best eye with best practical correction)

This classification is then further modified according to the sport the athlete is competing in, for instance T11-13 for track athletics, F11-13 for field athletics, S11-13 for swimming, etc.

Sport Classes T11-13 and F11-13:

T11/F11 - These athletes have a very low visual acuity and/or no light perception.

T12/F12 - Athletes with a T12/F12 sport class have a higher visual acuity than athletes competing in the T11/F11 sport class and/or a visual field of less than five degrees’ radius.

T13/F13 - Athletes with a T13/F13 sport class have the least severe visual impairment eligible for IPC Athletics. They have the highest visual acuity and/or a visual field of less than 20 degrees' radius.

### Sport Classes S11-13

Swimmers with visual impairment compete in the sport classes 11-13, with 11 meaning a complete or nearly complete loss of sight and 13 describing the minimum eligible visual impairment. Athletes in sport class 11 compete with blackened goggles.

Further rules are applied in various sports such as goal ball, where eye patches and black out masks are used to ensure a level playing field; and the use of blackened goggles by S11 competitors in swimming. In certain sports, visually impaired athletes can compete with a sighted guide, such as cycling and running <sup>(10,11,13)</sup>.

## **2.3. Description of visually impaired athletes' sports participation at the Summer Paralympic Games London 2012**

At the London 2012 Summer Paralympic Games visually impaired athletes participated in the following sports: <sup>(18, 27, 28)</sup>

### *2.3.1 Athletics*

Athletes with all impairments can participate in athletics, but a system of letters and numbers is used to distinguish between them. The letter "F" is used for field athletes and the letter "T" for track athletes. Athletes who are totally blind compete in Class 11 and are permitted to run with a sighted guide and have to wear blindfolds or black-out masks. Class 13 athletes have more sight than Class 12 athletes. A runner in Class 13 will have limited sight but may not use a guide runner to compete. For Class T12 athletes it is optional to run with a sighted guide or not. Field athletes in class F11 and F12 are also permitted use of acoustic signals (voice, acoustic signaling, clapping etc) for instance in the sprint distances (100m), long jump, high jump and triple jump.

### 2.3.2 *Cycling*

Visually impaired athletes are currently only allowed to compete in Track Cycling at the Paralympic Games. VI athletes compete together with other athletes with various impairments. There is no separate classification system for VI athletes only, but VI athletes ride in tandem with a sighted guide or pilot in front.

### 2.3.3 *Equestrian*

All impairment groups can compete in equestrian sport but riders are divided into four grades. Grade 3 includes athletes with good balance, leg movement and coordination, such as visually impaired (including B1) athletes. Visually impaired athletes make use of 'callers' to find their way around the arena.

### 2.3.4 *Football 5-a-side*

This sport is played by athletes with VI and was first included as a paralympic sport in Athens, 2004. Classification is according to their level of sight i.e. B1, B2 or B3. All four outfield players must wear black-out masks to ensure fairness, but the goalkeeper is fully sighted.

### 2.3.5 *Goalball*

This sport was designed specifically for people with VI and a special rule in this sport is that there is no need for classification. Participants wear black-out masks to ensure everyone competes equally.

### 2.3.6 *Judo*

No categorization as athletes are classified according to weight.

### 2.3.7 *Rowing*

Currently there are four boat classes. Athletes with impairment but have movement in the legs, arms and trunks are included in the LTA4+ class. This is a four person sweep-oar boat plus cox with sliding seats. Athletes row as a mixed cox four, of which no more than

two may have a visual impairment and the cox is not required to have an impairment in order to be eligible.

### 2.3.8 *Sailing*

This is a multi-impairment sport with amputee, cerebral palsy, visually impaired, wheelchair and other physical impairment groups competing together. Competitors are ranked according to a points system. Severely impaired athletes receive a lower score and those with less severe impairment a higher score.

### 2.3.9 *Swimming*

Classes S11-13 are allocated to swimmers with visual impairment. Class S11 has little or no vision; Class S12 can recognise the shape of a hand and have some ability to see and Class S13 have greater vision than the other 2 classes, but less than 20 degrees of vision. S11 visual class athletes must wear opaque goggles to standardise light perception amongst competitors. The prefix “S” denotes the class for Freestyle, Backstroke and Butterfly. The prefix “SB” denotes the class for Breaststroke. The prefix “SM” denotes the class for Individual Medley.

### 2.3.10 *Wheelchair basketball*

One athlete with impairment coding for VI participated in wheelchair basketball. This means the athlete had more than one impairment; as this is not a sport frequently played by visually impaired athletes.

## **2.4. Epidemiology of illness patterns in the Paralympic Games**

There is limited research describing factors associated with illness in athletes with impairment participating at an elite level. During the London 2012 Paralympic Games, an extensive web-based injury and illness surveillance system (WEB-IISS) was introduced for team medical staff, in order to address the lack of detailed and accurate data in Paralympic athletes. This was a large prospective cohort study involving 3565 athletes and information was gathered for a total of 49

910 athlete days<sup>(4, 7)</sup>. The epidemiology of illness during the pre-competition and competition period was included as part of this prospective study.

Derman et al described that illness was at least as prevalent as injuries in para-athletes at the London 2012 Paralympic Games<sup>(4)</sup>. This is a different pattern than that seen in some studies in able-bodied athletes. Palmer-Green and Elliot (2015) described the incidence of injuries being double that of illness in members of the Great Britain Olympic Team during the Sochi 2014 Winter Olympic Games<sup>(20)</sup>. Similarly, Engebretsen et al (2010) reported a higher incidence of injuries than illnesses amongst able-bodied athletes during the Vancouver 2010 Winter Olympic Games<sup>(22)</sup>; and during London 2012 Summer Olympic Games (Engebretsen et al, 2013)<sup>(21)</sup>. Soligard et al (2015) recently reported a higher rate of injury than illness in able-bodied athletes during the Sochi 2014 Olympic Winter Games<sup>(36)</sup>. The incidence of injury was reported as IP of 14 injuries per 100 athletes (95% CI 12.6 – 15.4) compared to IP of illness of 8.9 illnesses per 100 athletes (95% CI 7.8 – 10)<sup>(36)</sup>. The injury and illness data compared well to the rate of illness and injury at the Vancouver Games and London 2012 Olympic Games<sup>(4, 36)</sup>.

However, Derman et al (2016) reported much higher rates of both illness and injury amongst para-athletes during the Sochi 2014 Winter Paralympic Games<sup>(37, 38)</sup>. Illness IR was reported as 18.7 (95% CI 15.1 – 23.2)<sup>(37)</sup> whilst the risk for injury was found to be almost double; IR of injury 26.5 (95% CI 22.7 – 30.8)<sup>(38)</sup>.

Derman et al (2013) further described illness epidemiology of the WEB-IISS data from the London 2012 Paralympic Games, reporting on the IR and IP of illness according to systems affected<sup>(4)</sup>. The IR of illness during the competition period was reported as 12.8 (95% CI 11.7-13.9) and IP of illness as 10.2 in this study<sup>(4)</sup>. The system most affected by illness was the respiratory system, followed by skin and subcutaneous tissue and the gastro-intestinal system. Schwellnus et al (2013) reported an IR of illness of 13.2 (95% CI 12.2-14.2) and IP of Illness of 14.2 (95% CI 13.0-15.3) for the total period (pre-competition and competition period)<sup>(7)</sup>. However, comparison of these results to previous studies reporting IP of illness in various competitions and championships are limited by inconsistencies in reporting data and different durations of championships of the various studies<sup>(4)</sup>.

Schwellnus et al (2013)<sup>(7)</sup> described the effect of factors including competition period, sport, age group and gender on illness in para-athletes at the London 2012 Paralympic Games. Schwellnus et al (2013) reported no significant difference in IR of illness in pre-competition compared to competition period. In general, the IP was found to be higher in the Paralympic athletes than in the able-bodied athletes and the systems mainly affected were the respiratory, skin, digestive, nervous and genitourinary systems<sup>(7)</sup>.

IR of illness was similar in male and female athletes and across age groups. IR of illness varied between sports, with athletics being associated with a significantly higher risk of illness compared to other sports<sup>(7)</sup>.

More recent findings at the Sochi 2014 Winter Paralympic Games by Derman et al (2016) suggest a higher IR of illness in paralympians during Winter compared to Summer Games. The Illness IR for all athletes with impairment at Sochi 2014 Winter Paralympic Games of 18.7 (95% CI 15.1 – 23.2)<sup>(37)</sup> was much higher than that reported at the London 2012 Summer Paralympic Games, where Illness IR for all athletes with impairment was reported as 12.8 (95% CI 11.7-13.9)<sup>(4)</sup>. This would suggest that para-athletes are at higher risk of contracting an illness during winter Paralympic Games than during summer Paralympic Games. These findings require further investigation and differences amongst summer and winter sporting categories as well as environmental factors should be examined.

The fact that illness was found to be at least as prevalent as injury in para-athletes at the London 2012 Paralympic Games, is significant. Sport and Exercise Medicine (SEM) physicians often emphasize prevention strategies for injuries whereas illness prevention strategies are somewhat neglected. The consequences of illness can be just as devastating to an athlete.

Whilst the WEB-IISS study conducted during the London 2012 Paralympic Games was the largest prospective cohort study evaluating illness in para-athletes to date, data comparing the different impairment groups has not yet been described.

## 2.5. Epidemiology of injuries in athletes with visual impairment

VI affects motor control, proprioception and balance, which can affect gait and biomechanics, thus adding to the injury risk above that of able-bodied athletes. These result in an increased risk of both acute and overuse injuries of the lower extremities. VI para-athletes may experience an increased feeling of apprehension and anxiety of colliding with obstacles or fellow competitors; a factor that well might influence performance. <sup>(29, 33, 34, 35)</sup>

The most frequently described lower leg injuries in athletes with visual impairment are that of tendinopathy, strain and contusion <sup>(8, 9, 10, 11)</sup>. Unfamiliar surroundings during training and/or competing with the lack of guides or assistive devices, further predispose these athletes to injury <sup>(8, 11, 13)</sup>. Although previous studies have suggested that athletes with impairments do not have significantly higher overall risk or incidence rate of illness and injury than their able bodied counterparts, these injuries can often have considerably greater general functional consequences for the athlete with impairment <sup>(14, 15)</sup>.

Magno e Silva et al (2011) studied the aspects of sports injuries in Brazilian athletes with visual impairment in various studies <sup>(8, 9, 10)</sup>. The frequency of sports injuries, site of injury, mechanism of injury as well as visual class were studied in members of the Brazilian team in athletics, football 5-a-side, goalball, judo and swimming in international competitions between 2004 and 2008 <sup>(8)</sup>. An incidence of 2,8 injuries per athlete was found with female athletes presenting slightly more injuries than their male counterparts, but no statistically significant difference was found between gender. Regarding visual class, athletes classified as B1 were more prone to injury than those classified as B2, who were again more prone to injury than those classified as B3. Statistical difference was found only between B1 and B3 athletes. Athletes with visual impairment had a similar incidence between acute and overuse injuries. The study also indicated that there were more injuries involving the lower limb, followed by upper limb, spine, head and trunk. The most frequent diagnoses were tendinopathies, contractures, contusions and sprains <sup>(8)</sup>.

A review of the Brazilian Paralympic track and field athletes competing between 2004 and 2008 by Magno e Silva et al (2013) reported injury prevalence of 78%, clinical incidence of 1.93

injuries per athlete and incidence rate of 0.39 injuries per athlete per competition. Clinical incidence is used in this particular study and others by Magno e Silva et al <sup>(9, 10, 14, 17)</sup> to describe incidence rate. It is defined as a hybrid measure of incidence that represents the average number of injuries per athlete; and is calculated by dividing the number of injuries by the number of athletes at risk. Incidence rates of injury were however, reported as injuries per match and not per 1000 athlete days. Overuse injuries accounted for 82% and traumatic injuries for 18% of injuries. Overuse injuries predominantly affected the lower limbs, particularly the thighs, lower legs and knees. Tendinopathies, muscle spasms and strains were the most frequent diagnoses. No statistically significant differences were found in injuries between visual classification or gender <sup>(9)</sup>.

Further evaluation by Magno e Silva et al (2013) of 28 elite swimmers with VI from the Brazilian Paralympic team competing between 2004 and 2008 <sup>(10)</sup>, showed the injury prevalence of 64%, clinical incidence of 1.5 injuries per athlete and the incidence rate 0.3 injuries per athlete per competition <sup>(10)</sup>. Overuse injuries (80%) were once again more frequent than traumatic injuries (20%), a finding very similar to that reported for VI track and field athletes. Concerning body segment, the highest proportion of injuries was found in the upper limbs, followed by the spine and then lower limbs. The shoulder was the most affected body part, followed by cervical and thoracic spine. The most frequent diagnosis was muscle spasm, followed by tendinopathy. Prevalence of injury amongst the S13 swimmers was found to be slightly higher, followed by S11 and S12; and the incidence of injury was higher in S11 and S13 swimmers than for S12 swimmers. However, these trends were not found to be statistically significant. No statistical difference was found in clinical incidence when comparing male and female athletes <sup>(10)</sup>.

Silva et al <sup>(14, 17)</sup> further reported an injury prevalence of 84,6% in a population of Brazilian soccer players with VI during five major competitions. There was a clinical incidence of 2,7 injuries per athlete, with contusions and sprains described as the most common injuries. The lower limb, specifically the knee, was most frequently affected. Contrary to the findings in the track and field athletes and the swimmers, acute traumatic injuries were more prevalent than overuse injuries <sup>(14, 17)</sup>.

In a systematic literature review, Fagher and Lexell (2013) summarised the injury epidemiology found in 25 studies over the period of 1985 to June 2013, including athletes with impairment participating in organised sports or Paralympic sports<sup>(14)</sup>. This review adds to previous studies showing lower extremity injuries to be more common in athletes with visual impairment compared to upper extremity injuries.

Evaluating data from the London 2012 Paralympic Games, Willick et al (2013) reported that football 5-a-side had the highest incidence rate followed by goalball with 54% and 77% of these injuries classified as acute, respectively<sup>(5, 14)</sup>. These two sports are played exclusively by athletes with visual impairment therefore it is possible that acute injuries might be more prevalent than overuse injuries. Injury rates in male able-bodied athletes have been studied extensively and injury rates have been reported as 27 injuries per 1000 player days<sup>(26)</sup> and IP of football injuries at the London 2012 Summer Olympic Games have been reported as 27 injuries/100 players<sup>(21)</sup>. Webborn et al (2015) described the epidemiology of injuries in football at the London 2012 Paralympic Games<sup>(23)</sup>. Football 5-a-side was identified as the sport with the highest injury incidence rate (IR 22.4; 95% CI 14.1-33.8) and injury incidence proportion (IP 31.4; 95% CI 20.9-43.6). Further analysis of this data showed that the sighted goalkeepers in Football 5-a-side experienced no injuries during this period. Therefore, the risk of injury amongst the VI players was even higher and calculated as an IR of 28.1(95% CI 17.7-42.2) and IP amongst VI players as 39.3 (95% CI 26.5-53.2)<sup>(23)</sup>. Again, this high rate of injury emphasizes the importance of determining risk factors for injury per sport and per impairment group so that prevention programs can be implemented.

Swimming had a lower IR of injury amongst athletes with impairment as a group compared to overall injury during the London 2012 Paralympic Games<sup>(5, 14)</sup>, but no comparison has yet been made between the different impairment groups.

Recently, Derman et al have reported significantly high incidence rates of injury at the Sochi 2014 Winter Paralympic Games<sup>(38)</sup>. The IP of injuries was found to be very similar during the Sochi 2014 Winter Paralympic Games when compared to those reported at the Vancouver 2010 Winter Paralympic Games (24.4% for Sochi and 23.8% for Vancouver). Derman et al (2016)

reported an injury IR of 26.5 (95% CI 22.7 - 30.8) at the Sochi 2014 Winter Paralympic Games<sup>(38)</sup>. This was three times the incidence of injury recorded at the Sochi 2014 Winter Olympic Games (IR 7.8) as reported by Soligard et al (2015)<sup>(36)</sup>, suggesting athletes with impairment are at higher risk for injury compared to their able-bodied counterparts at a similar competition. This finding is in contrast to previous research which states that injury profiles are similar between able-bodied athletes and athletes with impairment<sup>(14, 15, 20)</sup>. The IR of injury at the Sochi Games was twice the rate of injury reported at the London 2012 Summer Paralympic Games (IR of 26.5 vs 12.7)<sup>(38)</sup>. This significant difference could be the result of high-risk sports in which athletes compete in the Winter Games setting, or specific environmental factors associated with the Sochi Games<sup>(39)</sup>, further research is therefore needed.

## 2.6. CONCLUSION

Few studies have investigated the risks and epidemiology of illness and injuries specifically in athletes with visual impairment participating at the Paralympic level. Illness and injury can have devastating effects on the ability of athletes with impairment to perform both in training and competition, but can also affect the normal daily functioning of athletes with impairment more so than in the able-bodied athlete.

Although most studies report a similar risk for illness and injuries in athletes with impairments compared to their able-bodied counterparts, more recent studies evaluating data from the Sochi 2014 Winter Paralympic Games suggest that athletes with impairment might even be at a higher risk for both illness and injury. Athletes with visual impairment have intrinsic risk factors related to the visual impairment that might predispose them to be at higher risk for certain injuries; and possibly medical illnesses that might be more prevalent in this cohort than in other impairment groups. Thus it is important to first establish the epidemiology of the incidence of illnesses and injuries in this cohort of athletes, in order for us to employ prevention programs in future Paralympic competitions.

Therefore, the aim of this study is to better define the epidemiology of illness and injuries amongst athletes with visual impairment, specifically evaluating data from the London 2012

Paralympic Games. Better understanding of the epidemiology will highlight specific covariates that might increase the risk of illness or injury in these athletes. In the present study, we specifically aimed to investigate the IR and IP of illnesses and injuries in athletes with visual impairment. Differences between sports, age groups, gender and body systems mainly affected was investigated. Knowledge of increased risk for certain sports, age groups and possibly gender differences will enable the health team, coaches and athletes to implement prevention strategies in future competitions.

## **Chapter 3**

### **Original research study – Illness and Injury in athletes with visual impairment at the London 2012 Paralympic Games**

#### **1. INTRODUCTION**

Participation in competitive sport, irrespective of whether the athlete is able-bodied or impaired, predisposes the athlete to injury and illness. Therefore, injury and illness prevention programs should be implemented wherever possible within the competitive sport setting. Surveillance of illnesses and injuries forms the first and important step of the initiation of prevention programs. Indeed, determination of the epidemiology and an understanding of the risk factors for both illnesses and injuries in these populations can assist the medical team in implementing prevention strategies <sup>(2, 3, 4, 5, 6)</sup>.

There are a number of risk factors for both illness and injury associated with sport. These depend on the nature of the sport as well as the specific impairment, and are considered intrinsic risk factors. In athletes with impairment, the impairment itself could be seen as an intrinsic risk factor that very often cannot be modified. In certain impairments, the degree of impairment can be managed with the use of orthotics, braces, etc. The degree of impairment can either improve or worsen with time, which again can influence classification of a para-athlete's impairment as well as risk factors for illness or injury.

In spite of significant growth in this unique field of sports medicine, few studies have evaluated the incidence of illness and injuries amongst athletes with impairment <sup>(2, 3, 4, 5)</sup>.

For this reason, a novel web based injury and illness surveillance system (WEB-IISS) was developed for use by the team physicians at the London 2012 Paralympic Games <sup>(4, 5)</sup>. This surveillance system allowed for the collection of a significant body of epidemiological data regarding illness and injury in the Paralympic cohort. The findings documented in the preliminary studies indicated that the overall incidence rate (IR) and incidence proportion (IP) of illness and injury were similar to that observed in other elite competitions <sup>(4)</sup>. However, different profiles of illness and injury have been reported in athletes with impairment in comparison with their able bodied counterparts.

Very few studies have investigated illness and injury by sport and impairment type and therefore the epidemiology and specific risk factors for illness and injury in elite athletes with visual impairment is still poorly understood. A handful of research studies have evaluated injuries specifically in athletes with visual impairment, but no study has evaluated the epidemiology of illness in this group of Paralympians.

It has previously been documented that lower limb injuries were more frequent in athletes with visual impairment than upper limb injuries; with tendinopathy, strain and contusion as the most frequently described injuries <sup>(8, 9, 10, 11)</sup>. Visual impairment affects motor control, proprioception and balance, which adds to the injury risk above that of able bodied athletes as this can affect gait and biomechanics. This results in increased risk of both acute and overuse injuries of the lower extremities. Unfamiliar surroundings; and training and/or competing with the lack of guides or assistive devices in such surroundings further predispose these athletes to injury <sup>(8, 11, 13)</sup>.

## **2. AIMS**

The aim of this study was to document the frequency, severity and nature of illnesses and injuries in athletes with visual impairment during the London 2012 Paralympic Games.

For illness, the aim was to determine the incidence rate (IR) as well as incidence proportion (IP) of illness; analyse the systems most frequently affected; evaluate factors associated with IR and

IP (gender, age and sport) and identify possible risk-factors. For injuries, the aim was to determine the incidence rate (IR) and incidence proportion (IP) of all injuries reported; analyse body areas mostly affected and evaluate independent cofactors such as gender, age and sport on IR and IP of injury. These findings could assist future research and implementation of illness and injury prevention strategies.

This study is a secondary analysis of data collected from the London 2012 Summer Paralympic Games, describing specifically the group of athletes with visual impairment. Athletes with visual impairment participated in the following sports at the London 2012 Paralympic Games: athletics (track and field), swimming, judo, goalball, football 5-a-side, cycling (road and track), rowing, sailing and equestrian.

### **3. METHODOLOGY**

#### **3.1 STUDY DESIGN**

This study is a retrospective secondary analysis that was conducted as part of an ongoing prospective surveillance study of injury and illness in Para-athletes. This part of the study was conducted over the 14-day period of the London 2012 Paralympic Games (3-day pre-competition and 11-day competition period). A novel web-based injury and illness surveillance system (WEB-IISS) was developed for use by the medical team physicians at the London 2012 Paralympic Games and has been described in other studies<sup>(4, 5, 7)</sup>.

Information was obtained from three data sources. Firstly, comprehensive de-identified athlete information was obtained from the IPC athlete database. The second data source was from an electronic medical data capture system (EMDCS; ATOS, France). This system was used at all of the London Organising Committee of the Olympic Games and Paralympic Games (LOCOG) medical stations and LOCOG medical staff and physicians entered standardised forms via this system for all medical encounters regarding illness and injury. The third data source was obtained from medical encounters of staff providing care to their own teams. This data reporting was collected via the WEB-IISS through either desktop computer, tablet or smart phone. Details of the WEB-IISS have been described and will not be discussed further in this study<sup>(4, 5, 7)</sup>.

#### **3.2 STUDY PARTICIPANTS & DEMOGRAPHICS**

During the London 2012 Paralympic Games, 3565 para-athletes from 164 countries participated, of which 4 countries elected not to participate in the data collection. In addition to this group, a number of para-athletes (556) could not be classified according to the information from the International Paralympic committee (IPC). Thus, for the purposes of this study, 3009 para-athletes were included. These para-athletes were classified according to impairment in the following categories: athletes with cerebral palsy (CP), athletes with a limb deficiency (LD), athletes with spinal cord injury (SCI), athletes with visual impairment (VI) and all other impairments (AO). The category All Other Impairments included smaller categories of athletes with impairments that could not be classified in one of the other classifications (CP, SCI, LD or VI). These included para-athletes with Polio, athletes with intellectual impairment, athletes classified as short of stature, athletes with impaired muscle power such as athletes with spina bifida or poliomyelitis, and others including such as impaired joint range of motion or ataxia due to brain injury or multiple sclerosis.

The number of para-athletes with an illness or injury and the number of illness and injuries were reported. For illness, the four most commonly affected systems of illness (respiratory, digestive, skin and subcutaneous, and neurological) were reported and for injuries the two main anatomical regions (upper limb, lower limb) were reported.

Infective diseases of the digestive tract included diarrhoea and gastroenteritis. Infective diseases of the skin included bacterial skin infection; fungal skin infection; viral skin infection or other skin infection. These were all included in the respective system affected (respiratory, digestive or skin and subcutaneous tissue.)

Data collected via the WEB-IISS regarding illnesses, included the option for an illness to be reported as an infective illness or non-infective illness. It was not possible to report each infective illness in its own category, due to small numbers for less frequent illnesses. Illness reported and recorded as infective illness included infections of the respiratory, digestive, skin and subcutaneous tissues and other illnesses not classified under any of these systems. However, the only system in which infective illness made up significant numbers was the respiratory system. Respiratory infection included the following diagnosis as captured by health care

providers during the London 2012 Paralympic Games : acute infective rhinitis; acute infective sinusitis; acute upper respiratory infection; influenza; other acute lower respiratory tract infection.

### **3.3. DEFINITION OF ILLNESS, INJURY, INCIDENCE RATE AND INCIDENCE PROPORTION**

In order to determine the nature and extent of illnesses and injuries as well to enable uniformity in research studies evaluating the data collected during the London 2012 Paralympic Games, the following definitions were implemented:

**3.3.1.** *Illness* was defined as ‘any newly acquired illness as well as exacerbation of pre-existing illness that occurred during training or competition, and during or immediately before the London 2012 Paralympic Games’.

**3.3.2.** *Injury* was defined as ‘any newly acquired injury as well as exacerbation of pre-existing injury that occurred during training and/or competition period of the London 2012 Paralympic Games’.

**3.3.3.** *Incidence rate (IR) of illness or injury* is the number of illnesses or injuries per 1000 athlete days

**3.3.4.** *Incidence proportion (IP) of illness or injury* is the proportion of athletes affected by illness or injury ( $n/100$ ).

### **3.4 INCIDENCE RATE AND INCIDENCE PROPORTION OF ILLNESS AND INJURIES**

The Incidence Rate (IR) for illness and injuries were calculated as the number of illness and injuries per 1000 athlete days. The Incidence Proportion (IP) was calculated as the number of illness and injuries per 100 athletes in the different subgroups.

### **3.5 STATISTICAL ANALYSIS**

Data were analysed using SAS, Version 9.4. Poisson regression was used to model the incidence of illness and injuries. Covariates included in the Poisson regression model were gender, age, illness systems and an indicator variable for the 2 most common sport types (athletics, swimming). Gender and age (tertiles) were included in all models, i.e. models including the sport

type were adjusted for age and gender. For illness, the main systems affected were included (respiratory, digestive, skin and subcutaneous and neurological systems). For injuries, reporting the IR for a specific anatomical region (upper limb, lower limb) we considered an athlete without an injury in the specific region as a non-injury for the specific anatomical region (control).

#### 4. RESULTS

Of the 3009 para-athletes with impairment included in this study, 2006 (66.7%) were males and 1003 (33.3%) females. These para-athletes were distributed into the different age tertiles as follows:  $\leq 25$  (n=1046, 35%), 26–34 (n=1046, 35%) and  $\geq 35$  years (n=917, 30%). Of these, 706 (23.5%) were para-athletes with visual impairment, 538 (17.9%) para-athletes with cerebral palsy, 892 (29.6%) para-athletes with a limb deficiency, 709 (23.6%) para-athletes with spinal cord injury and 164 (5.4%) para-athletes with various impairments coded as All Others. Thus for the group of 706 para-athletes with visual impairment we describe the incidence of illness and injury in the 9884 athlete days that constituted the observation period.

The number of para-athletes in the gender groups and in the age category tertiles are shown in Table 2. Of the para-athletes with visual impairment, 468 (66%) were males and 238 (34%) were females. These para-athletes were distributed into the different age tertiles as follows:  $\leq 25$  (n=293, 41.5%), 26–34 (n=265, 37.5%) and  $\geq 35$  years (n=148, 21%).

**Table 2: Number of para-athletes for gender and age in all impairment groups**

Impairment	Males	Females	Age 13-25	Age 26-34	Age 35-67
CP	376	162	225	206	107
LD	596	296	348	282	262
SCI	477	223	82	244	383
VI	468	238	293	265	148
All other	89	75	98	49	17
Total	2006	1003	1046	1046	917

Abbreviations: CP, Cerebral Palsy; LD, Limb deficiency; SCI, spinal cord injury, VI, Visual Impairment

The number of para-athletes with visual impairment participating in each sport are shown in Table 3. The highest number of Paralympic athletes competed in athletics (track, field and marathon) followed by swimming, judo and goalball.

**Table 3: Number of visually impaired para-athletes participating in each sport**

Sport	Number of athletes
Athletics	259
Swimming	115
Judo*	115
Goalball*	110
Football 5-a-side*	56
Cycling Road	29
Cycling Track	21
Rowing	12
Sailing	4
Equestrian	3

\*These sports are exclusively played by para-athletes with visual impairment

## 4.1 ILLNESS

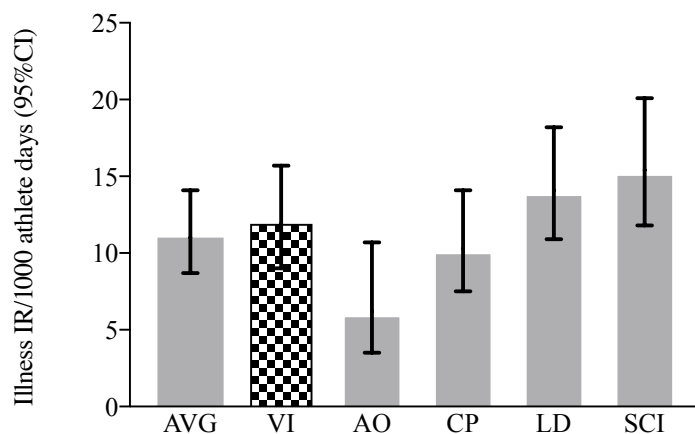
### 4.1.1. Incidence Rate and Incidence Proportion of All Illness

For the purposes of this study, illness was reported according to following systems: respiratory, digestive, skin and subcutaneous, and neurological. These were the 4 systems most frequently reported according to the WEB-IISS questionnaires.

The reported number of illnesses and IR for all illnesses for all athletes with an impairment over the entire competition period has previously been reported by Schwellnus et al (2013)<sup>(4, 7)</sup> as 657 illnesses with an IR of 13.2 illnesses/1000 athlete days (95% CI 12.2 - 14.2) in 505 athletes. However, for the purposes of this study, we only had impairment information for 3009 of all

para-athletes, and for these para-athletes a total number of 549 illnesses were reported in 422 para-athletes for all impairment groups during the total (pre-competition and competition) period. The IR of all illness for athletes with a known impairment was 12.7 (95% CI 10.2 - 16.0).

For para-athletes with visual impairment 124 illnesses were reported in 94 athletes and the IR of illness was very similar to the average IR (of all impairment groups) at 11.9 (95% CI 9.0 - 15.7;  $p = 0.447$  compared to the average illness IR of all other impairment groups). The incidence rates of all illness for the different impairment groups are summarised in Figure 1.



**Figure 1: Incidence Rate of all illness for different impairment groups**

AVG, average all impairments; VI, Visually impaired; AO, All others;

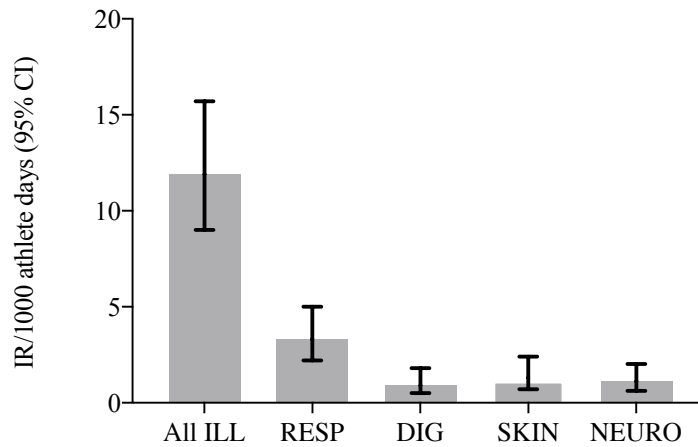
CP, Cerebral Palsy; LD, Limb deficiency; SCI, Spinal cord injury

The average incidence proportion (IP) for all illnesses for athletes with a known impairment ( $n=3009$ ) was 17.8 (95% CI 14.2 – 22.4) and for the VI group it was 16.6 (95% CI 12.6 – 22.0).

#### 4.1.2. Incidence Rate and Incidence Proportion of Illness by System affected

The system most affected by illness for all athletes with impairment was the respiratory system (155 illnesses in 138 athletes; average IR 3.0; 95% CI 2.2 - 4.1), followed by skin and subcutaneous tissue (93 illnesses in 79 athletes; IR of 2.2; 95% CI 1.5 – 3.1), the digestive system (83 illnesses in 74 athletes; IR of 1.7; 95% CI 1.1 - 2.4) and lastly neurological system (46 illnesses in 39 athletes; IR 1.0; 95% CI 0.7 - 1.5). In athletes with visual impairment, respiratory illness was the most frequently reported (41 illnesses reported in 34 athletes, IR 3.3; 95% CI 2.2 - 5.0), followed by illness affecting the digestive system (14 illnesses in 14 athletes,

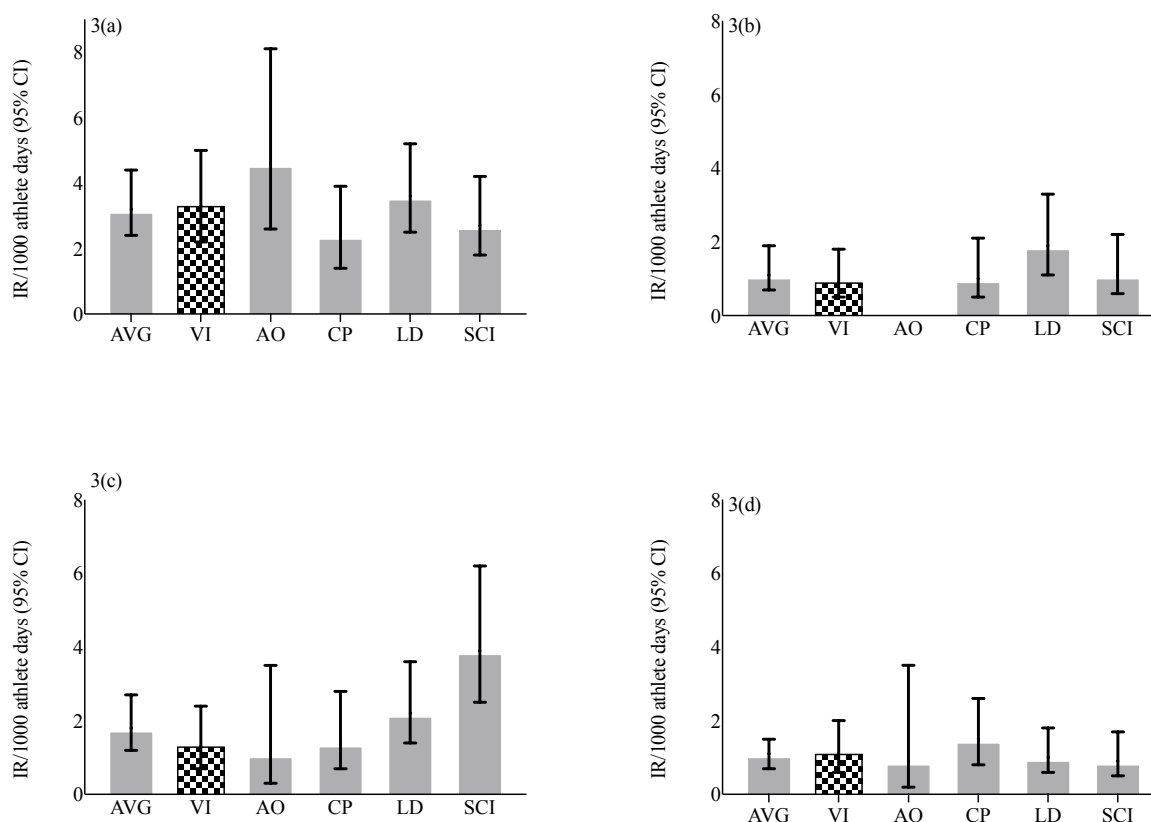
IR 1.2; 95% CI 0.7-2.3), skin and subcutaneous tissue (14 illnesses in 12 athletes, IR 1.3; 95% CI 0.7 - 2.4) and lastly illness affecting the neurological system (11 illnesses reported in 9 athletes, IR 1.1; 95% CI 0.6 - 2.0). A summary of IR of Illness for athletes with VI comparing the systems affected can be seen in Figure 2.



**Figure 2: Incidence Rate of illness according to system affected for visually impaired athletes**

All Ill, All illnesses; Resp, Respiratory illnesses; Dig, Digestive system illnesses; Skin, Skin & Subcutaneous tissue illnesses; Neuro, Neurological illnesses

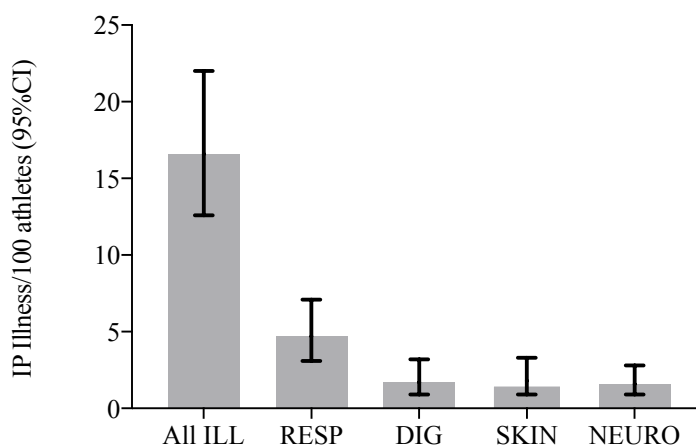
The IR of illness according to system affected for the different impairment groups affected are shown in Figures 3(a)-3(d).



**Figure 3: Incidence Rate of illness according to system affected for different impairment groups; 3(a) Respiratory Illness; 3(b) Digestive Illness; 3(c) Skin & Subcutaneous Tissue Illness; 3(d) Neurological Illness**  
All Ill, All illnesses; Resp, Respiratory illnesses; Dig, Digestive system illnesses; Skin, Skin & Subcutaneous tissue illnesses; Neuro, Neurological illnesses; AVG, average all impairments; VI, Visually impaired; AO, All others; CP, Cerebral Palsy; LD, Limb deficiency; SCI, Spinal cord injury

The average Incidence Proportion (IP) for respiratory illness for all impairments was 4.2 (95% CI 3.1 – 5.8) and similar for athletes with visual impairment IP 4.7 (95% CI 3.1 - 7.). For the digestive system, the average IP of illness was 2.3 (95% CI 1.6 – 3.4) for all impairment groups and 1.7 (95% CI 0.9 - 3.2) for the VI group. The average IP for illness affecting the skin and subcutaneous tissue was 3.1 (95% CI 2.1 – 4.4) for all impairment groups and 1.8 (95% CI 0.9 - 3.3) for the VI group. The IP of Neurological illnesses was 1.4 (95% CI 0.9 - 2.1) for all impairment groups and for the VI group it was 1.6 (95% CI 0.9 - 2.8). The incidence proportions

for all illness and illness affecting the respiratory, digestive, skin & subcutaneous tissue and neurological systems for athletes with visual impairment are shown in Figure 4 below.



**Figure 4: Incidence Proportion of illness according to system affected for visually impaired athletes**

All Ill, All illnesses; Resp, Respiratory illnesses; Dig, Digestive system illnesses; Skin, Skin & Subcutaneous tissue illnesses; Neuro, Neurological illnesses

Amongst all athletes with impairment included in this study, a total of 549 illnesses were reported. Respiratory illness accounted for 155 illnesses of which 110 were respiratory infective illnesses. Amongst athletes with VI a total of 124 illnesses were reported. Respiratory illness accounted for 41 illnesses of which 26 were respiratory infective illnesses. The IR for Respiratory infective illness for all impairments was 1.8 (95% CI 1.3 - 2.6) and for athletes with VI the IR of Respiratory infective illness was 1.7 (95% CI 1.0 - 2.8); therefore no significant difference ( $p=0.62$ ) was found. The IR for Respiratory non-infective illness for all impairment groups was 1.1 (95% CI 0.7 - 1.8) and for athletes with VI the IR of Respiratory non-infective illness was 1.5 (95% CI 0.8 - 2.7). Again this was not of statistical significance ( $p=0.30$ ).

#### **4.1.3. Incidence Rate of illness by gender, age and different sports for athletes with visual impairment:**

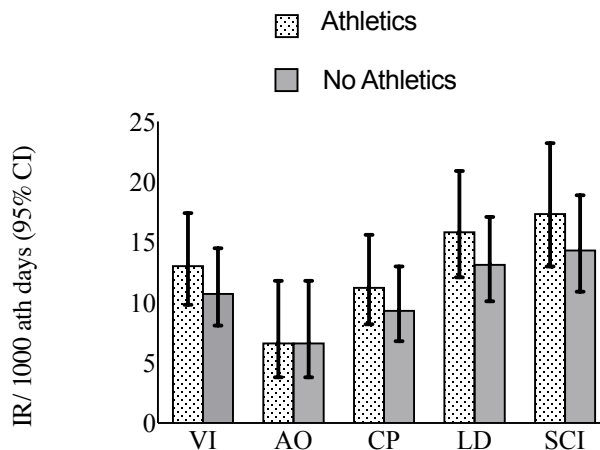
The number of athletes with visual impairment according to gender and age groups has been discussed previously and are outlined in Table 2.

There were 32 females and 62 males with 47 and 77 illnesses respectively. For all impairment groups, including visually impaired athletes, there was a significantly higher IR of illness in female athletes compared to male athletes ( $p=0.016$ ). For female VI athletes, the illness IR was 13.7 (95% CI 10.2 - 18.5) and for male VI athletes the illness IR was 11.0 (95% CI 8.2-14.6) (comparison of female vs male for VI,  $p=0.098$ ).

In order to evaluate influence of age as a predictor, athletes were divided in three age categories; 13-25, 26-34 and 35-67 years. The distribution of athletes in each age category was depicted in Table 2. In visually impaired athletes, there were 293 athletes  $\leq 25$  yrs with 61 reported illnesses in 44 athletes (IR=12.4; 95% CI 9.2 - 16.7). In age category 26 – 34 yrs there were 265 athletes reporting 39 illnesses in 32 athletes (IR=11.6; 95% CI 8.6 - 15.8). In age category 35-67 yrs there were only 148 athletes and 24 illnesses were recorded in 18 athletes (IR=11.3; 95% CI 8.2 - 15.5). For all impairment categories, including visually impaired athletes, age was not found to be an independent risk factor associated with illness ( $p=0.94$ ).

Of all sports, athletics (track and field) was the sport with the highest number of participants in athletes with VI. 259 athletes with visual impairment participated in athletics and 60 illnesses were reported in 46 of these athletes. Of these, 36 para-athletes reported only one illness and 10 athletes reported more than one illness.

For athletes with VI, the illness IR for athletics was 13.1 (95% CI 9.8 - 17.4) and for non-athletics the IR was 10.8 (95% CI 8.1 - 14.5). However, the incidence rates for the athletics group vs other sport groups were not significantly different for any of the impairment groups ( $p=0.058$ ). The IR of illness for the different impairment groups, comparing individuals competing in athletics to those competing in other sports was shown in Figure 5.



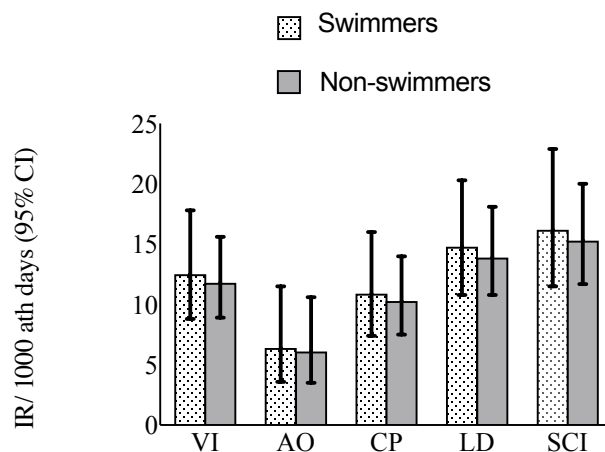
**Figure 5: Incidence Rates of illness for athletes competing in Athletics vs No Athletics for all impairment groups**

VI, Visually impaired; AO, All others; CP, Cerebral Palsy; LD, Limb deficiency; SCI, Spinal cord injury

VI swimmers are the second largest disability group among swimmers, LD swimmers are the largest group with 641 athletes. In the 115 VI swimmers, 29 illnesses were reported in 20 athletes. Of these, 15 athletes reported one illness only and 5 athletes reported more than one illness.

The IR for illness in swimmers compared to non-swimmers for all impairment groups is shown in Figure 6.

In athletes with visual impairment, there was a slightly higher incidence rate for illness in swimmers than non-swimmers, but this was not statistically significant (Figure 6). The IR of illness for swimmers was 12.5 (95% CI 8.8 - 17.8) and for non-swimmers the IR of illness was 11.8 (95% CI 8.9 - 15.6). There was no significant difference in IR between swimmers and non-swimmers for any of the other impairment groups ( $p < 0.05$ ).



**Figure 6: IR of illness for Swimmers vs Non-Swimmers for all impairment groups**

VI, Visually impaired; AO, All others; CP, Cerebral Palsy; LD, Limb deficiency; SCI, Spinal cord injury

115 athletes with visual impairment participated in judo and 9 athletes reported 15 illnesses. Of the 110 visually impaired athletes participating in goalball, 13 athletes reported 13 illnesses. For both judo and goalball there were no statistical difference in IRs for those athletes taking part in the sport compared to those athletes not taking part in the sport ( $P > 0.1$ ).

## 4.2. INJURIES

### 4.2.1 Incidence Rate and Incidence Proportion of all Injuries

The reported IR for all injuries (633 injuries and 3565 athletes) for all athletes has previously been reported by Schwellnus et al<sup>(4, 5)</sup> as 12.7/1000 athlete days (95% CI 11.7 -13.7). However, for the purposes of this study, we only had impairment information for 3009 of all athletes, and for these athletes with impairment information, a total of 528 injuries (IR 12.6; 95% CI 10.3 - 15.4) were reported in 441 athletes (IP 17.7, 95% CI 14.5 - 21.6). A total of 148 injuries were reported in visually impaired athletes (IR 14.5; 95% CI 11.3 - 18.5) and 119 of the 706 visually impaired athletes suffered injuries (IP 20.3; 95% CI 15.8 - 25.9). The IR of injuries was similar for athletes with visual impairment compared to the average IR of the other impairment groups ( $p=0.166$ ).

**Table 4: The Incidence Rate (IR) of all injuries and Incidence Proportion (IP) of all injuries according to Impairment Category**

Impairment	Number of			Number of athletes with injuries	IP	95%CI
	injuries	IR	95% CI			
Cerebral Palsy	67	8.8	6.5 - 11.9	58	12.3	9.1 - 16.7
Limb Deficiency	151	12.2	9.6 - 15.5	136	17.1	13.5 - 21.8
Spinal Cord	118	12.5	9.7 - 16.2	96	17.5	13.5 - 22.7
Visual Impairment*	148	14.5	11.3 - 18.5	119	20.3	15.8 - 25.9
All Other	44	18.2	12.8 - 25.9	32	25.5	17.9 - 36.3
Avg All other but VI*	380	12.9	10.5 - 15.8	322	18.0	14.7 - 22.1
<b>AVG All</b>	<b>528</b>	<b>12.6</b>	<b>10.3 - 15.4</b>	<b>441</b>	<b>17.7</b>	<b>14.5 - 21.6</b>

\*comparison p=0.166

#### 4.2.2 Incidence of injury by anatomical region

Evaluation of injury by anatomical region affected revealed a statistically significant different IR and IP for injuries of the upper limb (p=0.016) and the lower limb (p=0.0001) when comparing the visually impaired athlete cohort to the average IR for all other impairment groups. For the visually impaired athlete there were fewer upper limb injuries and a preponderance of lower limb injuries. The IRs and IPs as well as 95% CI for upper limb injuries are shown in Table 5. The IR for upper limb injuries in athletes with visual impairment was 3.0 (95% CI 1.9 - 4.5) and the IP was 4.1 (95% CI 2.7 – 6.3). The average IR for upper limb injuries for all athletes was 4.5 (95% CI 3.5-5.9). 4.4 (95%CI: 3.4-5.8)

**Table 5: The upper limb Injury Incidence Rate (IR) per 1000 athlete days and Incidence Proportion (IP) per 100 athlete days with 95% CI for the impairment categories**

Impairment	Number of			Number of athletes with injuries	IP	95%CI
	injuries	IR	95% CI			
Cerebral Palsy	17	2.3	1.4 - 4.0	17	3.1	1.8 - 5.3
Limb Deficiency	64	5.0	3.6 - 7.0	60	7.1	5.1 - 9.8
Spinal Cord	64	6.4	4.6 - 8.9	56	8.9	6.4 - 12.5
Visual Impairment*	30	3.0	1.9 - 4.5	27	4.1	2.7 – 6.3
All Other	19	7.8	4.7 - 13.0	18	10.9	6.6 - 18.2
Avg All Other but VI*	164	4.4	3.4 - 5.8	151	6.2	4.8 - 8.1
AVG (all impairments)	194	4.5	3.5 - 5.9	178	6.4	4.9 - 8.2

\*Visual impairment significantly higher than Average all other; p=0.016; avg, average

The IRs and IPs as well as 95% CI for lower limb injuries for different impairment categories are shown in Table 6. The IR for lower limb injuries in athletes with visual impairment was 7.7 (95% CI 5.8 - 10.3) and the IP was 10.8 (95% CI 8.1 - 14.4). The average IR of lower limb injuries for all disabled athletes was 4.5 (95% CI 3.5-5.7). 4.2 (95%CI: 3.3-5.4)

**Table 6: The lower limb Injury Incidence Rate (IR) per 1000 athlete days and Incidence Proportion (IP) per 100 athlete days with 95% CI for the impairment categories**

Impairment	Number of			Number of athletes with injuries	IP	95%CI
	injuries	IR	95% CI			
Cerebral Palsy	32	4.3	2.9 - 6.4	32	6.0	4.1 - 9.0
Limb Deficiency	48	4.0	2.9 - 5.6	47	5.6	4.0 - 7.8
Spinal Cord	13	1.4	0.8 - 2.5	13	2.0	1.1 - 3.6
Visual Impairment*	77	7.7	5.8 - 10.3	68	10.8	8.1 - 14.4
All Other	15	6.8	3.9 - 11.7	14	5.4	4.2 - 7.0
Avg All Other but VI*	108	3.6	2.7 - 4.7	104	5.0	3.8 - 6.6
AVG (all impairments)	185	4.2	3.3 - 5.4	172	6.3	5.0 - 8.0

\*Visual impairment significantly higher than Average all other; p=0.0001; avg, average

#### **4.2.3 Incidence Rate and Incidence Proportion of injury by age and gender for visually impaired athletes**

In para-athletes with VI, similar IRs were reported for all three age tertiles.

In the youngest age tertile (<25 yrs) 58 injuries were reported in 45 VI athletes. The IR of injury was 13.0 (95% CI 9.9 - 17.1) with an IP of 18.2 (95% CI 13.9 - 24.0). In the middle age tertile (26 - 34 yrs) 63 injuries were reported in 51 VI athletes. The IR of injuries was 16.6 (95% CI 12.7 - 21.8) with an IP of 23.3 (95% CI 17.8 - 30.5). In the oldest age tertile (35 - 67 yrs) 27 injuries were reported in 23 VI athletes. The IR of injuries in this group was 13.8 (95% CI 10.3 - 18.6) and IP 19.3 (95% CI 14.4 - 26.0).

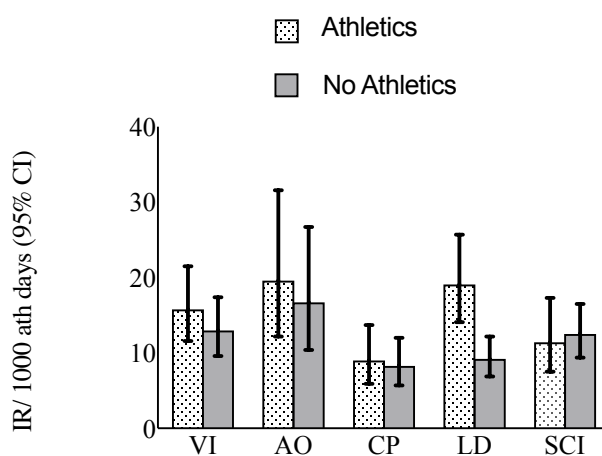
The IRs of injuries reported in VI athletes were very similar for both genders and no statistical difference was found. Female athletes with VI reported 37 injuries in 31 athletes (IR 13.8; 95% CI 10.4 - 18.2) and male athletes with VI reported 111 injuries in 88 athletes (IR 14.8; 95% CI 11.5 - 19.1).

#### 4.2.4 Incidence of injuries by sport for athletes with visual impairment

The different sports in which athletes with visual impairment participated are shown in Table 3. Athletics was the sport with most participants (259 athletes with VI) followed by swimming (115 athletes with VI) and then Judo (115 athletes). Goalball (110 athletes) and Football 5-a-side (56 athletes) were two sports exclusively played by athletes with visual impairment, but due to small participant numbers Football 5-a-side could not be included in the analysis for this study. The incidence rate of injuries for the various sports was compared.

The incidence rate and incidence proportion for injury in track and field athletes with visual impairment was slightly higher than those not competing in track and field events, however this was not statistically significant ( $p=0.05$  overall). Of the 151 injuries reported in visually impaired athletes, 66 injuries were documented in 52 VI athletes participating in athletics. The IR of injury was 15.8 (95%CI 11.6 - 21.5) and the IP 22.1 (95% CI 16.3 - 30.1). In the visually impaired group not participating in athletics, 82 injuries were reported in 67 athletes. The IR of injury was 13.0 (95% CI 9.6 - 17.4) and IP was 18.1 (95% CI 13.5 - 24.3).

The IR for injuries for athletics compared to no athletics for all impairment groups are shown in Figure 7.

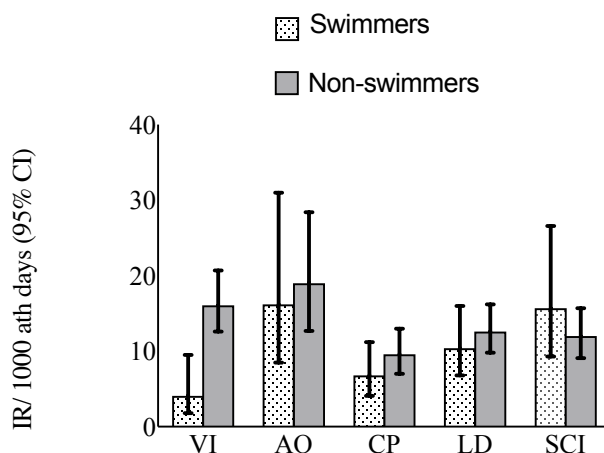


**Figure 7: Incidence rates of injuries for athletes competing in Athletics vs No Athletics for all impairment groups**

VI, Visually impaired; AO, All others; CP, Cerebral Palsy; LD, Limb deficiency; SCI, Spinal cord injury

Comparing athletes with VI competing in swimming to VI non-swimmers, there was a significantly lower incidence of injury amongst VI swimmers compared to the VI non-swimmers ( $p=0.002$ ). Six injuries were reported in six VI swimmers, IR 4.1 (95% CI 1.86 - 9.5) and 142 injuries were reported in 113 VI athletes not participating in swimming, IR 16.1 (95% CI 12.6 - 20.7).

The IR for injuries for swimmers compared to non-swimmers for all disability groups are shown in Figure 8.



**Figure 8: Incidence rates of injuries for Swimmers vs Non-swimmers for all impairment groups**

VI, Visually impaired; AO, All others; CP, Cerebral Palsy; LD, Limb deficiency; SCI, Spinal cord injury

For judo, 19 athletes reported 25 injuries and for goalball 24 athletes reported 30 injuries. For both judo and goalball there were no statistical difference in IRs for those athletes taking part in the sport compared to those athletes not taking part in the sport ( $p > 0.1$ ).

## 5. Discussion

Existing studies within the area of epidemiology of illness and injuries in para-sport have wide variations in study methods, injury definitions, populations, data collection and analytical methodologies. Few studies have been impairment or sport specific and even fewer have focused on the epidemiology of illness in para-sport.

Following the model set by van Mechelen et al. (1992)<sup>(19)</sup>, the first step of injury prevention would be to identify and describe the extent of the problem (injury) and secondly to identify the risk factors and mechanisms for such injuries, in order to introduce measures aimed at decreasing future injuries. The same model can be applied to illness. Therefore, illness and injury surveillance is of utmost importance for the implementation of preventive strategies. The conduct of the illness and injury surveillance study at the London 2012 Paralympic Games has created the opportunity to evaluate sub-groups and specific impairment groups; enabling us to use uniform research methodologies reporting patterns of medical conditions across this heterogenous field of athletes. This study is the first study reporting incidence rate (IR) and incidence proportion (IP) of illness and injuries in athletes with visual impairment. It is also the first study evaluating the epidemiology of illness in athletes with visual impairment. The main aim of the study was to document the incidence of illness and injury in athletes with visual impairment at the London 2012 Paralympic Games.

The first important finding was that within the cohort of athletes with visual impairment, the IR of illness and injuries were similar (11.9 illnesses vs 14.5 injuries/1000 athlete days). When comparing IR's of illness and injuries of para-athletes to IRs for illness and injuries reported in elite athletes without impairment, outcomes of studies are not consistent. During the London Summer Olympic Games 2012, the IR for injuries was higher than for illness and similar values have been reported during the Vancouver Winter Olympic Games 2010<sup>(21,22)</sup>. However, during the FINA World Championships 2009 the incidence rates for injury and illness reported were similar in able bodied swimmers<sup>(30)</sup>. Illness can have just as devastating effects on the performance of these athletes, yet the epidemiology of illness has never been researched in visually impaired athletes. This emphasises the need for future research to identify factors related to illness in these athletes for the implementation of preventive measures wherever possible.

Secondly, we found that the IR and IP for illness was similar in VI athletes compared to the total group of impaired athletes. The IR of all illness in athletes with VI was 11.9 compared to 12.7 for the IR in all para-athletes with impairment ( Fig 1). Schwellnus et al <sup>(7)</sup> and Derman et al <sup>(4)</sup> reported the IR of illness for all impairment groups as 13.2. The discrepancy in IRs and IPs reported between our study and previously reported studies from the London 2012 Paralympic Games is due to the fact that, of the 3565 athletes as included in the original WEB-IISS data collection, 556 athletes were not included in our study as they could not be classified according to the information from the International Paralympic committee (IPC). Thus, for the purposes of this study, only 3009 athletes were included. No difference was found in the IP for illness of VI athletes (IP 16.6; 95% CI 12.6 to 22.0) when compared to IP for all impairment groups (IP 17.8; 95% CI 14.2 - 22.4)( Figure 2).

The third important finding was that illness affecting the respiratory system was more prevalent than illnesses affecting the other systems in visually impaired athletes. The IR of illness affecting respiratory system in VI athletes (IR 3.3) was similar to the IR for athletes of all impairments (IR 3.0). Respiratory tract illness has been previously reported as the most frequently affected system in studies evaluating single and multiple sports codes both in athletes with and without impairment <sup>(4, 7, 20, 21)</sup>. Our study confirms that this is similar for athletes with visual impairment. Airborne pollutants, allergens and other irritants and the increased ventilatory rate during high intensity exercise, puts the respiratory system under significant stress. In addition, there is an increased risk of spread of infectious respiratory conditions with athletes living in close contact with each other, crowding in competition areas and immune-suppression caused by over-training <sup>(21, 30, 31, 32)</sup>. Visually impaired athletes rely strongly on touch for tactile feedback, helping them with orientation and reading; probably more so when they are training and living in unfamiliar surroundings. Respiratory diseases are typically spread through droplet contamination such as when a person coughs or sneezes. These droplets can contaminate surfaces and stay infective for a period after droplet contamination. Touching these affected surfaces could further increase the frequency of respiratory infections <sup>(31,32,33)</sup>. Illness prevention in VI para athletes should include the implementation of prevention strategies such as increased frequency of hand washing and the use of hand disinfectant in this population.

IR of illness affecting skin and subcutaneous tissue was slightly lower in athletes with VI (IR 1.3) compared to athletes of all impairment groups (IR 2.2). Amputees, who were included in the cohort of other impairments, have an increased incidence of skin infection and abrasions associated with prosthetic limbs – a risk factor that is not applicable to the athlete with VI. There was no significant difference in IR of illness affecting the digestive system in athletes with VI (IR 0.9) when compared to all impairments (IR 1.7). The neurological system had the lowest IR of illness for both VI athletes (IR 1.1) and athletes of all impairments (IR 1.0) and again these incidence rates were very similar.

Within the visually impaired group of athletes, when considering factors in a multiple model in order to determine independent risk factors such as type of sport; swimming had the highest IR of illness. Of particular interest was the higher incidence of respiratory illness in VI swimmers compared to other sports, indicating that swimmers with visual impairment might be at an increased risk of contracting respiratory illness. However, these results should be interpreted with caution as it might also be related to spread of respiratory disease within this cohort of athletes during the event, especially due to close exposure in confined spaces such as pre-event warm-up areas and time spent in the event call rooms.

In a univariate analysis the IR for illness was not different for gender or age within the group of visually impaired athletes. Of interest is that the VI athletes were a younger group of athletes than the general athlete population. Most VI athletes were between the ages of 13 and 34, with only 148 of the 706 VI athletes in the 35-67 year age category. There were almost twice as many male athletes (468) than female athletes (238) in the VI group.

This is the first time illness as an entity has been reported in athletes with visual impairment. The importance of implementation of prevention programs is highlighted again by the fact that the risk of illness and injury are very similar in athletes with visual impairment. Athletes live within very close confines during an event such as the Paralympic Games and therefore communicable diseases can easily be spread. This can be minimised through implementation of prevention programs such as washing of hands, use of alcohol hand gels, avoiding unnecessary hand contact and early reporting and isolation of athletes with illness.

In contrast to illness, injuries have been previously reported in visually impaired athletes but never in such a large event as the Paralympic Games. Injury characteristics are influenced by athlete impairment type (classification) <sup>(22)</sup>. Previous studies on injuries in VI athletes mainly evaluated specific sports such as swimming, track and field athletics, goalball and football 5 <sup>(8, 9, 10, 16, 17, 23)</sup>.

There was a slightly higher IR (14.5) and IP (20.3) for injuries than for illness (IR 11.9 and IP 16.6) in the visually impaired group, but this was not statistically of significance. Derman et al <sup>(4)</sup> previously described a similar IR of illness (12.8) and injuries (12.1) at the London 2012 Paralympic Games for all impairment groups. However, this was evaluating data of the competition period only, whereas our study is evaluating data collected for the total period of 14 days (3-day pre-competition and 11-day competition period). The overall IR and IP of injuries for visually impaired athletes were comparable to the findings for all disabled athletes described in previous studies <sup>(4, 5)</sup>.

The IR for injuries was not different for gender for the visually impaired athlete group. A slightly higher incidence rate for injuries was found in the middle age group, but this was not statistically significant.

Visually impaired athletes sustained a higher proportion of lower limb injuries (IR 7.7; 95% CI 5.8 – 10.3) than upper limb injuries (IR 3.0; 95% CI 1.9 – 4.5). This is in contrast with the finding in other impairment groups, where there was a higher incidence of upper limb injury. This finding is not unexpected, as athletes with limb deficiencies and spinal cord injuries are frequently wheelchair users and dependent on the use of upper limb for both sports participation and activities of daily living. In contrast, athletes with visual impairment are not as dependent on upper limb function and additionally face other challenges that can lead to increased injuries to the lower limb. These include poor proprioception with increased risk of both acute and overuse injuries affecting the lower limb; and acute injuries to the lower limb due to direct trauma during competition and ambulation in foreign surroundings <sup>(11)</sup>. Visually impaired athletes are especially at risk for lower limb injuries when competing in high impact sports such as football 5-a-side. Injury patterns in football injuries at the London 2012 Paralympic Games have recently been described <sup>(23)</sup>. Webborn et al (2015) documented an injury IR of 22.4 injuries per 1000 athlete days in athletes competing in football 5-a-side <sup>(23)</sup>. This is the highest IR of injuries amongst all

summer Paralympic sports and the findings are of significance for our study as this sport is played solely by visually impaired athletes. The lower extremities were reported as being most commonly injured followed by head and neck injuries<sup>(23)</sup>.

Our study did not evaluate the IR of injuries in football 5-a-side due to smaller numbers. Of the four sports with highest numbers of VI participants (athletics, swimming, judo and goalball), athletics was the sport with the highest incidence rate of injury in the visually impaired athlete, whilst swimming had the lowest IR of injuries (Fig 7 & 8).

### **Limitations and Strengths**

One of the main limitations of this study was that we did not have impairment coding for all athletes participating at the London 2012 Paralympic Games. Therefore we had to omit the data of the 556 athletes without impairment coding and could only use data of 84.4% of the athletes. A further limitation was the relatively small number of athletes with visual impairment in each sport. In order for any results to be of clinical significance we could only evaluate the whole cohort to assess the impact of certain covariates on risk factors and focus only on the sports with highest number of participants. Sports played exclusively by athletes with visual impairment, such as goalball and football 5-a-side, were not evaluated in detail in this study due to small numbers. Results on football 5-a-side have since been published<sup>(23)</sup>.

We were not able to evaluate the incidence of illness and injury for the different visually impaired subgroups according to visual classification (B1, B2 & B3) due to small sample size. However, following the Rio de Janeiro 2016 Paralympic Games, the prospective data will be re-analysed as much larger numbers will be available. Future studies should evaluate the impact of severity of visual impairment (visual classification) on incidence rate and incidence proportion of illness and injuries.

Furthermore, too few injuries in some sports and too few illnesses in some of the systems do not allow for an in depth analysis. The data collected through the EMCDS relied on data reporting by the team physician and team medical staff and did not allow for more detailed analysis of illnesses and injuries.

Despite these limitations there are a number of important strengths in this study.

Firstly, this is the largest study to date reporting on illness and injuries in visually impaired athletes at the Paralympic Games. In fact, no previous study has reported specifically on illness data in visually impaired athletes. Secondly, capturing exposure data in terms of athlete-days provides the ability to report illness and injury IRs and not only IPs. This is important in epidemiological studies as it allows for comparison with other sport events of varying duration. The implementation of a custom built web-based survey provided the ability to capture more detailed information on illness and injuries than using the standard medical encounter form alone.

### **Conclusions and clinical implementations of this study**

This is the largest illness and injury surveillance study conducted in visually impaired athletes at Paralympic level. It is also the first time that the epidemiology of illness in visually impaired athletes has been described. The incidence rate of illness was similar to the incidence rate of injuries in visually impaired athletes at the London 2012 Paralympic Games. Illness can influence performance just as significantly as injuries, yet the epidemiology of illness in visually impaired athletes has never been studied before. Future studies should focus on specific illnesses in this cohort of Paralympians in order to determine risk factors associated with illness and implement preventive measures in future. The IRs of both illness and injuries for visually impaired athletes compared well to that reported in other impairment groups. Gender and age were not risk factors for illness or injuries in visually impaired athletes. IRs and IPs of illness and injuries differed by sport, with swimming proposing a higher risk of illness and athletics being associated with a higher risk for injuries in visually impaired athletes. These findings require a more in depth analysis and future research should focus on identifying sport specific mechanisms and risk factors for both illness and injuries in the visually impaired Paralympian.

Respiratory illness was the most prevalent illness amongst athletes with visual impairment at the London 2012 Paralympic Games. As respiratory illness is spread via droplet infestation and airborne pathogens, it is recommended that air-conditioning and air filtration systems be installed in areas where athletes will be in close confinement. Swimming was identified as the sport with the highest risk of contracting a respiratory illness amongst VI para-athletes. Attention should be given to ventilation conditions in the call-rooms where swimmers spend time in close

confinement prior to their events and strict hygiene regimens should be implemented before and after entering the pool and regular testing and cleaning of the pool should be emphasized. SEM physicians and other members of the medical team should further ensure that athletes suffering a respiratory illness, be isolated so as to prevent further spread of these infections.

Athletes with visual impairment suffer a relatively high amount of lower limb injuries. These can be sustained during competition but also during ambulation to and from training and competition in unfamiliar surroundings. Prevention strategies that can be put in place at future Paralympic Games include the following:

- Improving ease of ambulation in the race village by building walkways that are specifically aimed at use by para-athletes with visual impairment; making use of tactile stimuli, well demarcated walkways and possibly auditory stimuli and auditory warning signals. At the Rio de Janeiro 2016 Paralympic Games, specific walkways were built in the race village for athletes with visual impairment to make ambulation through the race village safer for these para-athletes.
- Ensuring competition and training areas are implementing similar strategies to decrease injuries sustained because of unfamiliar surroundings.
- More in-depth analysis of injuries sustained per sport will allow us to determine areas where modification of rules could ensure a decreased risk for the most prevalent injuries.

The findings of this dissertation should be implemented at future Paralympic Games and similar events to ensure prevention of both illness and injuries in athletes with visual impairment, wherever possible. Further research should aim to be more sport specific, as the type of sport predicts patterns for both illness and injuries in athletes with visual impairment.

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