Upper limb injuries in athletes participating at the London 2012 Paralympic Games

A dissertation prepared by Mark Roussot (*RSSMAR024)* in partial fulfillment of the requirements for the Master of Philosophy degree in Sport and Exercise Medicine (MPhil Sport and Exercise Medicine) from the University of Cape Town

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Declaration

I, Mark Roussot, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

Signed by candidate

(Signature)

6 September 2014

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(Date)

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"True teachers are those who use themselves as bridges over which they invite their students to cross; then, having facilitated their crossing, joyfully collapse, encouraging them to create their own."

Nikos Kazantzakis

Dedicated to Nerea Emaldia Echeandia, whose love and support is my foundation.

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List of abbreviations and definitions

CI	-	Confidence interval, reported as 95% confidence interval
EMDCS	-	Electronic Medical Data Collection System
IP	-	Incidence proportion, number of injuries per 100 athletes
IPC	-	International Paralympic Committee
IR	-	Incidence rate, number of injuries per 1000 athlete days
Incidence	-	Number of injuries per 1000 athlete days
LOCOG	-	London Organization Committee of the Olympic and Paralympic Games
MRI	-	Magnetic resonance imaging
US	-	United States
USA	-	United States of America
WEB-IISS	-	Web-based injury and illness surveillance system

Abstract

Background The International Paralympic Committee (IPC) has witnessed growing participation in the Games since its inception and has made strong efforts to collect comprehensive injury and illness data during the London 2012 Paralympics. Until now, no studies have comprehensively evaluated upper limb injuries at the Paralympic Games.

Objective To describe the epidemiology and clinical characteristics of upper limb injuries in athletes participating in the London 2012 Paralympic Games and identify the groups of athletes at risk.

Methods This study forms a component of the large prospective cohort study conducted over the 14-day period of the London 2012 Paralympic Games, coordinated through the IPC Medical Committee. Data were collected in two phases. Phase 1 involved the determination of the incidence and severity for 3,565 athletes (85% of the Paralympic athletes) from a collation of three data sources, providing 46,606 athlete days of data for analysis. Phase 2 involved the collection of more detailed medical data using a novel web-based surveillance system for 3,329 athletes participating in the study (80% of Paralympic athletes). Incidence proportion (IP) has been defined as the number of injuries per 100 athletes (%) during the study period. Incidence rate (IR) has been defined as the number of injuries per 1000 athlete days for the study period and 95% confidence intervals (CI) are reported in parentheses.

Results A total of 258 upper limb injuries were recorded in Phase 1, giving an overall IP of 7,2 (6,4 – 8,1) upper limb injuries per 100 athletes and an IR of 5,2 (4,6 – 5,8) upper limb injuries per 1000 athlete days. Shoulder injuries were encountered most frequently with an IR of 2,2 (1,85 – 2,7) per 1000 athlete days followed by injuries of the wrist and hand with an IR of 1,4 (1,1 – 1,82) per 1000 athlete days. Shoulder injuries were most frequent in the older athletes. The majority of acute upper limb injuries were minor, however, 31% of shoulder injuries resulted in time off sport. In different sports, the IR of shoulder injuries was 8,8 (5,4 – 13,5) per 1000 athlete days in powerlifting, 5,0 (2,1 – 9,8) per 1000 athlete days in Judo, 2,8 (1,2 – 5,6) per 1000 athlete days in wheelchair basketball, and 2,7 (1,6 – 4,2) per 1000 athlete days in swimming. The IR of injuries of the wrist and hand in different sports was 3,9 (1,4 – 8,5) per 1000 athlete days in goalball, 3,2 (1,5 – 6,0) per 1000 athlete days in wheelchair basketball, and 2,8 (1,3 – 5,4) per 1000 athlete days in table tennis. In Phase 2, more detailed information in 183 upper limb injuries showed that the majority of upper limb injuries occurred in athletes with spinal cord injuries (38,3%) and athletes with amputation or limb deficiency (28,4%). Rotator cuff impingement syndrome and chronic rotator cuff injury were the most frequent diagnoses in the upper limb injuries.

Conclusion To date, this is the largest study evaluating upper limb injuries at the Paralympic Games. The shoulder is the anatomical region most frequently injured and causes the greatest time lost from sport. Powerlifting, judo, goalball and wheelchair basketball are the sports that place athletes at highest risk of upper limb injuries. Older athletes and athletes with spinal cord injuries, amputation or limb deficiency are at increased risk of upper limb injuries. Pre-games assessment, accurate diagnosis during the Games and the introduction of standardised scores of upper limb function will assist in providing improved diagnostic and injury severity information in future studies.

Key words Upper limb injuries, Paralympic Games, athletes, impairment

Chapter 1

Introduction and scope of the thesis

The Paralympic Games provides a platform in which athletes with impairments are able to achieve remarkable levels of performance, demonstrate values of courage, determination and equality, and provide inspiration for athletes with and without impairment alike (Webborn & van de Vliet, 2012). Since the Stoke Mandeville Games in 1948 where athletes with impairments competed for the first time, sports for individuals with impairments have evolved significantly and the International Paralympic Committee has witnessed growing participation in the Paralympics. The London 2012 Paralympic Games included a record-breaking 4,176 athletes from 164 delegations (Willick *et al*, 2013).

The athlete's desire to compete and the perpetual drive to improve performance challenges the limits of human capacity, and this may increase the risk of acute and overuse injuries during training and competition. Importantly, the functional consequences of an injury can be more significant to an athlete with an impairment compared with the same injury in an athlete without impairment (Willick & *et al*, 2013; Magnus, 1987; Pepper & Willick, 2009; Fagher, 2014). For example, an injury to the wrist and hand in an athlete with contralateral upper limb impairment can result in inability to perform activities of daily living, such as eating, rendering the athlete dependent on others. The treatment of these injuries may be challenging – resting the upper limb in an athlete who needs to transfer to and from a wheelchair is impractical. Furthermore, the physical, psychological and social benefits of participating in sports and recreational activities have been well described in individuals with impairment (Bakalim, 1969; Yekutiel *et al*, 1989; Wetterhahn et al, 2002; Yazicioglu *et al*, 2007; Pepper & Willick, 2009) and these benefits have been shown to translate to improvements in quality of life, reduced risk of illness and a decrease in the utilization of hospital resources (Webborn & van de Vliet, 2012; Fernhall *et al*, 2008; Stevens *et al*, 2008; Stotts, 1986). Therefore, the

development of injury prevention strategies is quintessential in the care of athletes and non-athletes with impairments.

A model for the systematic development of sports injury prevention strategies has been described (van Mechelen *et al*, 1992), and begins with quantifying the problem in terms of incidence and severity, then establishing the etiology and mechanisms of injury, followed by the development and implementation of injury prevention strategies that can be assessed for effectiveness (**Figure 1**).

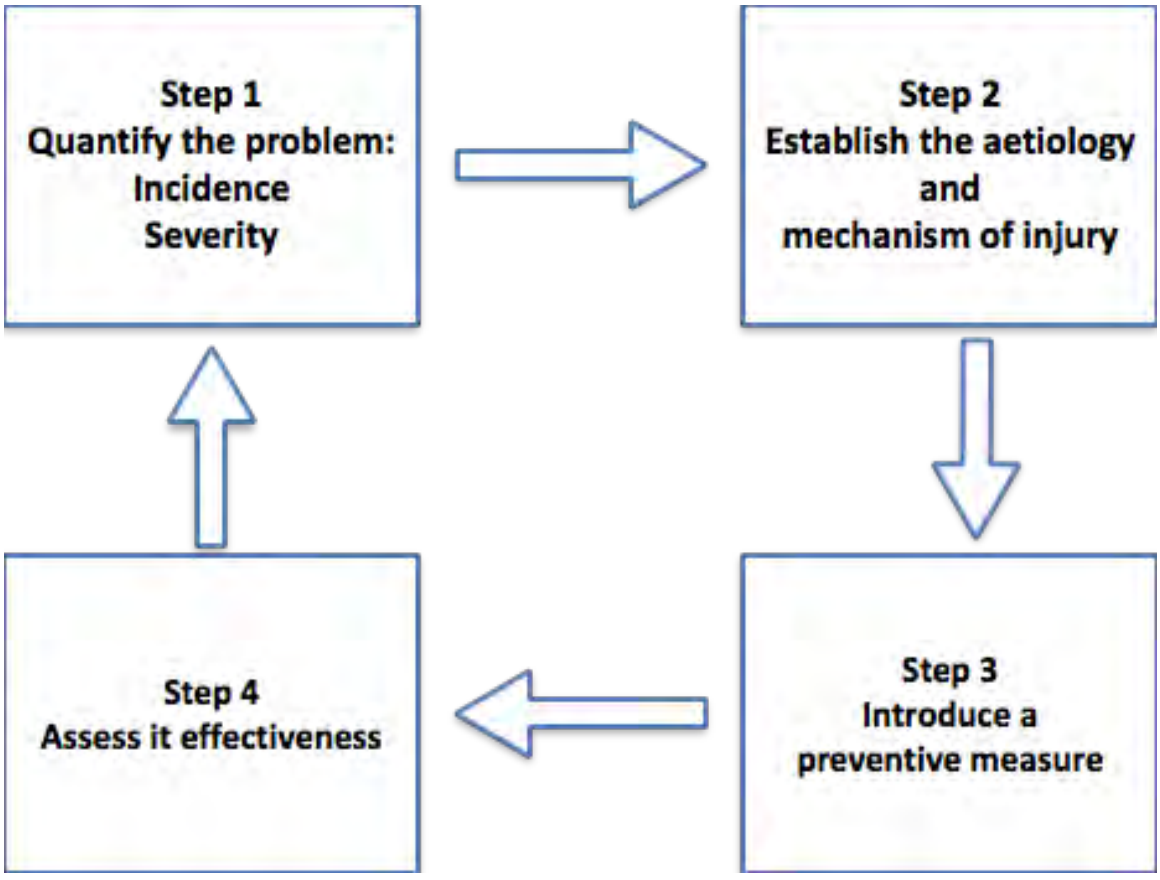

Figure 1: Systematic sports injury prevention (van Mechelen *et al*, 1992)

High quality injury surveillance is required to determine the incidence and severity of injuries in athletes with impairments and thereby forms an important, initial step in the development of sports injury prevention strategies (Webborn & van de Vliet, 2012, Junge *et al*, 2008; Junge *et al*, 2004; Derman *et al*, 2013). For

the first time, comprehensive injury and illness surveillance was conducted at the London 2012 Paralympic Games using novel data capture technology (Willick *et al*, 2013, Derman *et al*, 2013). From this surveillance, it was shown that the upper limb is the predominant anatomical region injured in Paralympic athletes and this is in contrast to previous findings of the predominance of lower limb injuries in athletes without impairment (Junge *et al*, 2009; Webborn & van de Vliet, 2012, Jacobsson *et al*, 2013).

Previous studies focusing on athletes using wheelchairs have demonstrated that upper limb injuries are more prevalent than lower limb injuries (Boninger, 1996; McKeag & Klenck, 2008). Specifically, bicipital tendinopathy and rotator cuff impingement have been described as the most common shoulder pathologies documented (Boninger, 1996; McKeag & Klenck, 2008; Finley & Rodgers, 2004). Furthermore, carpal tunnel syndrome and ulnar nerve entrapment are overuse conditions that have also been reported as common in athletes who use wheelchairs (Boninger, 1996; Klenck, 2007). However, to our knowledge, no studies thus far have comprehensively described upper limb injuries in all impairment categories of Paralympic athletes with respect to age, gender, type of impairment, sports category, mechanism, severity and duration of injury.

In Chapter 2, current knowledge on upper limb injuries in athletes with impairments is reviewed. An original research study to describe the nature of upper limb injuries in athletes participating in the London 2012 Paralympic Games with a view to identifying the groups of athletes at risk is presented in Chapter 3. This knowledge will provide the initial framework for future research aimed at injury prevention strategies. A summary and recommendations for future studies is presented in Chapter 4.

Chapter 2

A review of upper limb injuries in athletes with impairments

2.1. Introduction

The quantity and quality of research on injuries sustained during the Paralympic Games is not yet mirrored by the growing participation in the tournament (Webborn & Van de Vliet, 2012; Cain, Harmer, & Schiff, 2009). A recent comprehensive literature review on injuries in athletes with impairments identified a paucity of literature on the epidemiology, severity, impairment specific risk factors, and injury prevention strategies in athletes with impairments (Fagher and Lexell, 2014).

2.2. Literature review methodology

A literature search was conducted in PubMed and Google Scholar on 10 November 2013 and updated in August 2014. The following search criteria were used:

1. PubMed: "(upper limb injury OR upper limb injuries) AND (athletes with AND (disability OR impairment) OR Paralympic athletes)"
2. Google Scholar:
    a. With all of the words "athletes"
    b. With the exact phrase "upper limb injuries"
    c. With at least one of the words "disabilities", "impairments", or "Paralympic"
    d. Where my words occur anywhere in the article
    e. From 1970 - 2014

The PubMed search produced 65 results and the Google Scholar search produced 85 results. Duplicates were eliminated and studies not published in a peer-reviewed journal were excluded. Review articles were not included in this literature review; however, the references contained therein were examined to ensure that articles previously reviewed were not missed. **In this review, data from 27 key studies will be reviewed and summarized.**

The focus of this review is on the epidemiology, risk factors, severity, type, onset, investigation and prevention of **upper limb injuries** in athletes with impairments and the published articles will be discussed by their relevance to these topics. Generally, the first time the article is mentioned, a brief description of the relevant strengths and weaknesses is included.

2.3. Upper limb injuries in athletes with impairments

2.3.1. Introduction

In this section, the overall incidence and prevalence of upper limb injuries in athletes with impairments will be reviewed. This will be followed by a review of the onset of injuries (acute and chronic), severity of injuries, injuries related to type of sport, injuries related to impairment category, risk factors, mechanism of injury, investigations and prevention strategies for upper limb injuries in athletes with impairments. A summary of the current literature will be presented at the end of this chapter.

2.3.2. General epidemiology of upper limb injuries in athletes with impairments

2.3.2.1. Introduction

The upper limb, and more specifically, the shoulder, has been shown to be the anatomical region most frequently injured in several studies, most of which report the percentage distribution of injuries in each anatomical region. Earlier literature has been retrospective, conducted by the completion of questionnaires by the

athlete. However, the past decade has seen a trend to an increasing number of prospective studies with improvements in data collection techniques.

2.3.2.2. Questionnaire-based and retrospective studies

In one of the first questionnaire based studies, it was reported that soft tissue injuries, such as strains, sprains, tendonitis and bursitis, occurred frequently in the shoulders, elbows, wrists and hands of 128 athletes competing in wheelchair sports (Curtis and Dillon, 1985). It is important to note that the response rate to the questionnaire in this study was low, as over 1,200 questionnaires were sent out and only 128 completed and returned (±10%), which may introduce a significant selection bias. The authors were also not clear on which athletes with impairments the questionnaires were sent to.

In another study, 19 of the 65 athletes who were invited to participate at the National Wheelchair Athletic Association (USA) elite training camp reported that 58% of the recorded injuries involved the upper limb (Ferrara and Davis, 1990). While this is a small survey, its strength is in the authors reporting on the severity of the injury in terms of time lost from sport. In a study on 90 Canadian wheelchair athletes, it was reported that 21,3% of injuries in involved the hand and 16,7% involved the shoulder (McCormack *et al*, 1991). However, this study only reported on acute/traumatic injuries and included relatively minor ailments, such as “blisters”, as an injury.

Upper limb injuries, and specifically shoulder injuries, were also the most common anatomical site of injury in 426 wheelchair, visually impaired, and cerebral palsy athletes participating in a national competition in 1989 (Ferrara *et al*, 1992a). In a small of survey of 68 out of 125 skiers participating in the 1989 National Handicapped Sports and the US Associated for Blind Athletes Winter National Games, it was shown that 51% of injuries involved the upper extremity and the shoulder was the most common anatomical region injured (Ferrara *et al*, 1992b). In a survey of 53 wheelchair-racing athletes (±58% of the British Wheelchair racing Association) injuries in these athletes most commonly involve the wrist and hand (27%), and the shoulder (25%) (Taylor & Williams, 1995). The authors also reported on the severity of injuries in terms of time lost from sport. In

46 of the 94 athletes (48,9%) participating in the 1997 USA National Women's Wheelchair Basketball Tournament, the prevalence of pain since wheelchair use was 72% for the shoulder and 70% for the elbow (Curtis and Black, 1999).

In 227 out of 567 randomly selected athletes with locomotor impairments participating in selected national sports events, the overall prevalence of injuries was 50,7%, with 56% of injuries involving the shoulder (Bernardi *et al*, 2003). In this study it should be noted that the selection of sporting events might not be representative of the population of athletes with impairments. Finally, in a survey of 26 manual wheelchair-using athletes, matched with 26 manual wheelchair-using non-athletes, it was demonstrated that shoulder pain occurred in a third of these individuals (Finley & Rodgers, 2004). Notably, a longer duration of wheelchair use was a significant predictor of shoulder pain in both groups.

Self-reported injuries may not represent the true incidence of injury. For example, in two studies (Ferrara *et al*, 1992b; Taylor and Williams, 1995) it was reported that athletes sought medical attention for their injuries in 40% and 43% of cases respectively. This highlights the limitation of study designs incorporating self-reported injuries as the authors rely on the athlete to report an injury even if one was never formally diagnosed in the majority of cases.

Three retrospective reviews reported on the rate of upper limb injuries in athletes with impairments. In a review of the medical records of 151 Canadian athletes participating at the 1988 Summer Paralympic Games in Seoul, it was demonstrated that the shoulder was the most common anatomical region injured, with rotator cuff impingement syndrome the most common diagnosis (21,4%)(Burnham *et al*, 1991). This study also reported on the medical illnesses experienced by these athletes, and the biomechanical factors in rotator cuff impingement were discussed. In another retrospective study, the medical records of 205 British athletes attending the 1992 Summer Paralympic Games in Barcelona were reviewed (Reynolds *et al*, 1994). In this group of athletes, the spine was the most frequently injured anatomical region (28%), followed by the shoulder (9%) and the hand (6%). Finally, the physiotherapy records of 131 athletes attending the Paralympic Village Polyclinic Physiotherapy Department at

the 2004 Summer Paralympic Games in Athens were reviewed (Athanasopoulos *et al*, 2009). In this review, the shoulder was the most common site of injury (27,5% of all injuries); most injuries to the upper limb occurred in wheelchair athletes, and most injuries in the lower limb occurred in visually impaired athletes. This study also included injuries sustained by delegates, employees and volunteers (reported separately for some variables) and would not have recorded injuries sustained by delegations that brought their own medical staff.

2.3.2.3. Prospective studies

In one of the first prospective cohort studies, it was reported that 12,8% of all injuries sustained by 1,360 US athletes with impairments participating in the 1990 World Games and Championships, 1991 US Paralympic Trials, 1992 Paralympic Games, 1994 World Athletics Championship, and the 1996 Paralympic Games involved the shoulder (Ferrara *et al*, 2000). The only other anatomical region implicated in injury more frequently than the shoulder in this study, was the thorax/spine (13,3% of injuries). In this study, team medical staff recorded medical encounters and a reportable injury was defined as any injury/illness that was evaluated by the US Medical Staff during these competitions (Ferrara *et al*, 2000).

A prospective study was also conducted in a cohort of 304 USA team athletes participating at the 1996 Summer Paralympic Games in Atlanta Nyland *et al* (2000). In this study shoulder injuries accounted for 20,9% of injuries overall. In this study the IPC impairment category was used to define the athletes' impairment. A prospective cohort study was also conducted on 416 athletes participating in the 2002 Winter Paralympic Games in Salt Lake City (Webborn *et al*, 2006). In this study, 83,3% of chronic injuries involved the upper limb. Strengths of this study included the reporting on the severity of injury in terms of time lost from sport, the timing of injury in relation to training or competition, and the development and implementation of an injury surveillance system in the form of a Microsoft Access database for the collection of data. However, none of the latter 3 studies reported on injuries in terms of the exposure of the athlete to sport.

The incidence rate of a cohort of 210 athletes from 8 special education high schools in California with various impairments participating in basketball, softball, football, and field hockey, was reported as 2,0 injuries per 1000 athlete exposures (Ramirez *et al*, 2009). Each athlete exposure was estimated to be approximately 1 hour for a session of training or competition. Upper limb injuries accounted for 26,3% of cases and lower limb injuries accounted for 44,7% of injuries, in contrast to previous findings. However, the 8 high schools that were selected for the study were schools for children with highly specialized needs, only representing approximately 3% of the total population of children with special needs. An overall incidence proportion (%) of 23,8 injuries per 100 athletes was reported in a cohort of 505 athletes participating at the 2010 Winter Paralympic Games in Vancouver (Webborn *et al*, 2012). Upper limb injuries were common (47,5%) in sledge hockey. The authors reported incidence rates for some of the Alpine and Nordic skiing events where the athlete exposures were known; however, injuries not treated at the Paralympic Village Polyclinic would not have been recorded.

The incidence (per 1000 athlete-hours) of injuries was also reported in a cohort of 14 wheelchair fencers and 10 able-bodied fencers from the Hong Kong National Squad (Chung *et al,* 2012). In this study the overall incidence rate was significantly higher in wheelchair fencers (3,9/1000 athlete-hours) in comparison to able-bodied fencers (2,4/1000 athlete-hours); wheelchair athletes showed a higher proportion of upper limb injuries (73,8%) than able-bodied athletes (16,1%); and elbow and shoulder strains were the most common injuries reported (32,6% and 15,8% respectively). Despite being a small study, the comparison between wheelchair and able-bodied athletes highlighted the differing injury profiles in these athletes.

In three separates publications, injuries encountered in 40 Brazilian track and field athletes (2013a), 13 male Brazilian football 5-a-side athletes (2013b), and 28 Brazilian swimmers (2013c) all with visual impairment and participating in a number of tournaments were reported (Magno e Silva *et al*.) The results of these cohort studies showed that shoulder injuries were the most common site of injury in the visually impaired swimmers (29,3% of all injuries in this group)

(Magno e Silva *et al*, 2013a), while the lower limb was most frequently injured in football 5-a-side athletes (80% of injuries in this group) (Magno e Silva *et al*, 2013b) and in track and field athletes (87% of injuries in this group) (Magno e Silva *et al*, 2013c). The small sample size of these studies limits their statistical power.

There was a very significant advancement in study methodology in the prospective cohort study of injuries in athletes with impairments during the 2012 Summer Paralympic Games in London. In this study, a novel, web-based injury surveillance system (WEB-IISS) was implemented for the first time, injuries in the all the athletes were documented (> 85% compliance rate), diagnoses were reported by team physicians and local organizing medical committee staff, and athlete exposure (athlete days) was documented.

In this study, the overall incidence of injury and illness was reported in 3,565 of the 4,176 athletes at the Games (85,4%) and 49,910 athlete-days of exposure. The results showed that Paralympic athletes sustain 12,7 injuries per 1000 athlete days and 13,2 illnesses per 1000 athlete days (Derman *et al*, 2013). Most injuries were acute and the highest incidence rate was seen in upper limb injuries. Injuries were further described in relation to sport, anatomical region and onset, reporting the highest incidence rates of injury in the shoulder (2,3/1000 athlete days) followed by the wrist and hand (1,4/1000 athlete days), elbow (1,1/1000 athlete days) and knee (1,0/1000 athlete days) (Willick *et al*, 2013). This demonstrates a predominance of upper limb injuries in Paralympic athletes in contrast to the predominance of lower limb injuries that has been reported in able-bodied athletes (Junge *et al*, 2009; Webborn & van de Vliet, 2012; Jacobsson *et al*, 2013). While these studies represent the largest injury surveillance conducted at the Paralympic Games thus far, there are still limitations: under-reporting of injuries is still possible; and the WEB-IISS was not the only system used to collect data, which necessitated collation of databases and deletion of duplicates.

2.3.2.4. Summary: Epidemiology of upper limb injuries in athletes with impairments

Early literature on the epidemiology of upper limb injuries in athletes with impairments is dominated by questionnaire-based studies and retrospective reviews reporting the proportion and prevalence of upper limb injuries. Prospective epidemiological data on this group of athletes has become more abundant in recent years, especially since the introduction of standardized injury surveillance systems, and has permitted the evolution of injury frequency reporting to incidence rates. However, studies vary in their definition of an “injury” and an “athlete exposure” that determines the incidence rate. The prevalence of upper limb injuries has been reported as high as 73,8%. The shoulder is the anatomical region most frequently implicated with reported incidence proportions of 9 – 72%, and an incidence rate of 2,3 injuries per 1000 athlete days in a recent, large, prospective study. One study directly compared wheelchair athletes to non-wheelchair athletes and demonstrated that upper limb injuries occur more frequently in wheelchair athletes.

2.3.3 Onset (acute, chronic or acute on chronic) of upper limb injuries in athletes with impairments

2.3.3.1. Introduction

The majority of the studies reviewed were able to report the frequency of acute and chronic injuries encountered and some included acute on chronic injuries. Few of the studies, however, defined the terms acute, acute on chronic, and chronic injuries, and **no studies reported the onset upper limb injuries specifically**.

2.3.3.2. Acute injuries

Acute injuries were reported as most common in 7 studies with proportions as high as 80% overall in football 5-a-side for visually impaired Brazilian athletes (Magno e Silva *et al*, 2013b) and incidence rate as high as 6,6 injuries per 1000 athlete days reported in the 2012 Summer Paralympic Games (Derman *et al*,

2013). Of note, only 5,7% of all injuries in the Brazilian football 5-a-side cohort involved the upper limb (Magno e Silva *et al*, 2013b).

2.3.3.3. Chronic injuries

Chronic injuries were reported as most common in a further 7 studies with proportions as high as 80% in visually impaired Brazilian Paralympic swimmers where the authors also reported that 34% of all injuries in this cohort involved the upper limb (Magno e Silva *et al*, 2013a). Webborn *et al* (2006) reported that 83,3% of chronic injuries involved the upper limb in a cohort of 416 athletes participating in the 2002 Winter Paralympic Games.

2.3.3.4. Acute on Chronic

The proportion of acute on chronic injuries encountered in all sports at the 2010 Winter Paralympic Games was 0,8% (Webborn *et al*, 2012), and the overall incidence rate of 2,2 injuries per 100 athlete days was reported at the London 2012 Paralympic Games (Derman *et al*, 2013).

2.3.3.5. Summary: Onset of upper limb injuries in athletes with impairments

There are no studies where the onset of **upper limb injuries** in terms of incidence rate with adequate definitions of “acute”, “chronic” and “acute on chronic” injuries has been reported.

2.3.4. Severity of upper limb injury in athletes with impairments

2.3.4.1. Introduction

The severity of injury was reported in 5 studies, usually as the number of days that the injury prevented the athlete from participating. However, the categorization of injury severity as minor, moderate or severe varied amongst authors, and no studies reported specifically on the severity of upper limb injuries.

2.3.4.2. Severity of injury

In one of the earliest studies, 57% of injuries in the cohort of 19 wheelchair athletes were reported as minor (≤7 days) (Ferrara and Davis, 1990), 11% were significant (8-21 days) and 32% were major injuries (≥22 days). Similarly, 32% of injuries were reported as major (≥22 days) in a cohort of 1,360 disabled US athletes (Ferrara *et al*, 2000). In a survey of 53 British wheelchair-racing athletes, most injuries (71%) prevented the athlete from training for a median of 14 days (Taylor and Williams, 1995) while in another study 27% of traumatic injuries resulted in time lost from training or competition (Webborn *et al*, 2006). It has also been reported that 4 out of 7 category B wheelchair fencers (57%) sustained major injuries (≥22 days) involving the rotator cuff (Chung *et al*, 2012).

2.3.4.3. Summary: Severity of injuries

The severity of injuries encountered has predominantly been reported in terms of time lost from sport, but there is no consensus as to what constitutes a minor, moderate or severe injury. Reports vary according to frequency of each category of severity. Importantly, there is a lack of literature reporting specifically on the severity of upper limb injuries in athletes with impairments.

2.3.5. Upper limb injuries in athletes with impairments related to type of sport

2.3.5.1. Introduction

The 2012 Summer Paralympic Games featured 23 sports including, Archery, Athletics, Boccia, Canoe, Cycling, Equestrian, Football 5-a-side, Football 7-a-side, Goalball, Judo, Powerlifting, Rowing, Sailing, Shooting, Swimming, Table tennis, Sitting volleyball, Triathlon, Wheelchair basketball, Wheelchair dance sport, Wheelchair fencing, Wheelchair rugby, Wheelchair tennis. Each sport requires unique biomechanical actions and utilizes different equipment. Importantly, some sports, such as Powerlifting and wheelchair-based sports may place greater risk on the upper limb in comparison to sports such as Football,

which may place greater risk on the lower limb. Few studies reporting the injury in relation to sport have done so with a focus on upper limb injuries.

2.3.5.2. Athletics

Also referred to as “track and field”, athletics has frequently been reported to have a high proportion of injuries overall. Earlier surveys reported the highest proportion of injuries occurring in track and field (30% and 30,9% respectively). (Curtis & Dillon, 1985; Ferrara & Davis, 1990). Somewhat intuitively, it has been observed that upper limb injuries are more prevalent in “arm-dominant sports” whereas lower limb injuries are more frequent in “leg dominant sports” (Burnham *et al*, 1991). A review of the medical records for the British athletes at the 1992 Summer Paralympic Games revealed a prevalence of injuries in 80% of track and field athletes (Reynolds *et al*, 1994). Injuries sustained by Greek athletes during athletics accounted for 51,2% of injuries at the 2004 Summer Paralympic Games (Athanasopoulos *et al*, 2009). In a survey of the 139 Greek athletes participating in the 2000 Pan-Hellenic Championship for Athletes with Disabilities the second highest proportion of injuries was reported in track and field events (23%), with wheelchair basketball and swimming showing injury proportions of 30,9% and 19,1% respectively (Patatoukas *et al*, 2011). An overall injury prevalence of 78% during 5 tournaments from 2004 to 2008 in a cohort of 40 Brazilian track and field athletes revealed an incidence rate of 0,39 injuries per athlete per competition (Magno e Silva *et al*, 2013c). At the 2012 Paralympic Games in London an incidence rate of 15,8 injuries per 1000 athlete days was reported in the cohort of 3,565 athletes (Willick *et al*, 2013).

2.3.5.3. Wheelchair sports

Wheelchair sports have received some attention. Wheelchair basketball and road racing were the sports implicated most frequently (24% and 22% respectively) in the injuries sustained by 128 wheelchair athletes, after track and field as mentioned above (Curtis and Dillon, 1985). McCormack *et al* (1991) showed similar findings with 30,9% of injuries occurring in basketball and 12,1% occurring in road racing in their survey of 90 Canadian wheelchair athletes.

Wheelchair basketball featured second in the sports most frequently associated with injuries in the cohort of 304 USA team athletes at the 1996 Summer Paralympic Games (Nyland *et al,* 2000). Chung *et al* (2012) were able to demonstrate an incidence of 3,9 injuries per 1000 athlete hours in the small cohort of 14 wheelchair fencers from the Hong Kong National Squad. Wheelchair fencing and wheelchair rugby were reported to have an incidence rates of 18,0 and 16,3 injuries per 1000 athlete days at the London 2012 Paralympic Games (Willick *et al*, 2013).

2.3.5.4. Swimming

Swimming represented 20% of the injuries sustained by the 19 wheelchair athletes surveyed by Ferrara and Davis (1990), superseded only by track and field in this study. Swimming was also the sport with the third highest proportion of injuries in the review conducted by Athanasopoulos *et al* (2009) and in the survey conducted by Patatoukas *et al* (2011).

2.3.5.5. Other sports

Powerlifting, judo and goalball are other sports that have been mentioned by authors as being frequently associated with high injury rates (Reynolds *et al*, 1994; Athanasopoulos *et al*, 2009). Recently, the Willick *et al* (2013) reported the incidence rate of goalball (19,5 injuries per 100 athlete days), powerlifting (19,3 injuries per 1000 athlete days) and judo (15,5 injuries per 1000 athlete days), which, together with football 5-a-side, athletics and some wheelchair sports were among the highest incidence rates of all the summer sports at the London 2012 Paralympic Games.

2.3.5.6. Summary: Upper limb injuries in athletes with impairments related to type of sport

There is a paucity of literature reporting specifically on the incidence of upper limb injuries in relation to type of sport. The sports most frequently implicated include athletics, wheelchair sports, swimming, goalball, powerlifting and judo. A

large, prospective cohort of 3,565 athletes at the London 2012 Paralympic Games has recently reproduced these findings.

2.3.6. Upper limb injuries in athletes related to impairment category

2.3.6.1 Introduction

In order to encourage fair competition at the Paralympic Games, the IPC categorizes each athlete according to the nature of the impairment. This categorization has evolved since the first Stoke Mandeville Games in 1948. Currently, the IPC recognizes 10 impairment types, namely:

- Impaired muscle power
- Impaired passive range of movement
- Limb deficiency
- Leg length difference
- Short stature
- Hypertonia
- Ataxia
- Athetosis
- Vision impairment
- Intellectual impairment

Sports are subsequently classified according to the impact of the impairment on the sport, which allows the grouping of athletes for competition and minimizes the impact of the impairment on the activity.

Three studies have reported injury rates in relation to impairment categories, however, there was no uniformity in the definition of categories of impairment.

2.3.6.2. Upper limb injuries related to impairment

In the survey of 426 athletes with impairments it was reported that shoulder injuries were the most frequently encountered injury in wheelchair athletes

(Ferrara *et al*, 1992a). In the review of 131 Greek athletes at the 2004 Summer Paralympic games it was shown that most injuries occurred in wheelchair athletes (48,8%) followed by visually impaired athletes (18,3%) (Athanasopoulos *et al*, 2009). Children with autism and children with a history of seizures were at highest risk of injury in the cohort of 210 athletes from 8 special education high schools in California (Ramirez *et al*, 2009). In summary, there is insufficient literature reporting on the injuries in relation to impairment category to identify a pattern.

2.3.7. Risk factors for upper limb injuries in athletes with impairments

2.3.7.1 Introduction

Risk factors can be considered as intrinsic (inherent characteristics of the athlete such as age, gender, strength) or extrinsic (factors that the athlete is exposed to such as the weather, equipment, surface). Three studies have described factors that are associated with injuries in athletes with impairments.

2.3.7.2. Intrinsic and extrinsic risk factors

It has been suggested that the nature of impairment (intrinsic) and type of sport (extrinsic) should be considered as risk factors for injury (Burnham *et al*, 1991). Increased body mass index (intrinsic) and increased training volume (extrinsic) were associated with injury in the survey of 227 athletes with locomotor impairments (Bernardi *et al*, 2003). Longer duration of wheelchair use (intrinsic) was reported to be a significant predictor of shoulder pain in 52 wheelchair users (26 athletes and 26 non-athletes) (Finley and Rodgers, 2004).

2.3.7.3. Summary: Risk factors

There is a paucity of literature investigating the risk factors for upper limb injuries in athletes with impairments. Intrinsic factors that have been suggested include type of impairment, body mass index and duration of wheelchair use, while suggested extrinsic factors include type of sport and training volume.

2.3.8. Mechanisms of upper limb injuries in athletes with impairments

2.3.8.1. Introduction

The mechanism of a sports injury can be described as the inciting event that has resulted in damage or harm to a part of the musculoskeletal system in a susceptible individual. It has been recommended that the description of the inciting event for a sports injury includes the following categories (Bahr and Krosshaug, 2005):

a) Important aspects of the playing situation
b) Athlete and opponent behavior
c) Gross biomechanical characteristics of the athlete
d) Detailed biomechanical characteristics of the joint or tissue involved

Two studies have reported on the manner in which the reported injuries occurred. No studies have included a description of the mechanism of injury as recommended by above by Bahr and Krosshaug (2005).

2.3.8.2. Mechanisms of injuries

Direct impact with another athlete, the ground, or equipment was the most common mechanism of injury in a survey of 19 wheelchair athletes at the National Wheelchair Athletic Association elite training camp (Ferrara and Davis, 1990). Similarly, 63,2% of injuries in the cohort of 210 disabled athletes resulted from collision with an object or person (Ramirez *et al*, 2009).

In summary, collisions or direct impact with another athlete, the ground or sports equipment is the mechanism of injury most frequently reported. Further research is required to improve our understanding of the mechanism of upper limb injuries for this group of athletes.

2.3.9. Investigation and prevention strategies

No studies reviewed herein evaluated the methods of investigation or methods of injury prevention of upper limb injuries in athletes with impairments.

2.4. Summary: Upper limb injuries in athletes with impairments

Prospective epidemiological data on injuries in athletes with impairments has become more abundant in recent times, especially since the introduction of standardized injury surveillance systems. The upper limb, and more specifically, the shoulder, has been implicated as the anatomical site of injury in numerous studies. The sports with the highest reported frequency of injuries are athletics, powerlifting, football 5-a-side, wheelchair-based sports, swimming, judo and goalball. Collisions with another athlete, the ground or sport equipment may be the most frequent cause of injuries.

Few studies report injury-specific incidence rates and even fewer use the same categorization of athlete impairments, which makes comparisons difficult. The methods of reporting the frequency of injuries encountered vary, with most studies reporting the proportion of injuries for each group in question.

There has been a lack of standardization of injury definitions and measures of severity; however, more recent studies have improved in this regard. The literature is markedly deficient in reporting the onset of upper limb injuries, the identification of risk factors, the evaluation of modes of investigation of injuries, and prevention strategies for these athletes.

It is evident that upper limb injuries account for a large proportion of injuries sustained by athletes with impairments, yet the literature is deficient in comprehensively describing the nature of these upper limb injuries and attempting to identify groups of athletes at risk, which is an important step in the direction of injury prevention in this group of athletes for who the consequences of an injury are often not limited to participation in sport, but may cause the loss of independence in activities of daily living.

Table 2-1. Summary of literature on injuries in athletes with impairments

Author, year, Study design	Population	Sport	Impairment categories	Injury definition	Notable results	Strengths	Weaknesses
Prospective Studies							
Derman *et al* 2013 **Prospective cohort**	3,565 of the 4,176 athletes participating at the 2012 Summer Paralympic Games	All Summer Paralympic Sports	All categories of impairment, not defined	Any newly acquired injury as well as exacerbations of preexisting injury that occurred during training and/or competition of the 14 day pre-competition and competition period of the London 2012 Paralympic Games	Overall injury IR 12,7 injuries/1000 athlete days Overall illness rate 13,2 illnesses/1000 athlete days Acute injury IR 6,3 Acute on chronic IR 2,2 Chronic injury IR 3,6 Highest injury IR in upper limb: Shoulder IR 2,0 Wrist and hand IR 1,5 Elbow IR 1,0 Respiratory, integumentary and digestive systems most commonly involved in illness	Largest, prospective study Introduction of a novel web-based injury and illness surveillance system (WEB-IISS) 49,910 athlete days of exposure Acute, acute on chronic and chronic injuries defined	Under-reporting of injury/illness still possible 2 different systems used to collect data with differing data fields, also requiring deletion of duplicate entries
Willick *et al* 2013 **Prospective cohort**	3,565 of the 4,176 athletes participating at the 2012 Summer Paralympic Games	All summer Paralympic Sports	All impairment types, no categories defined	Any sport-related musculoskeletal or neurological complaint prompting an athlete to seek medical attention, regardless of whether or not the complaint resulted in lost time from training or competition	Overall injury IR 12,7 injuries/1000 athlete days IP 17,8 injuries/100 athletes Acute injuries 51,5% Acute on chronic 16,7% Chronic injuries 31,8% Sports with highest IR: Football 5-a-side IR 22,4 Goalball IR 19,5 Powerlifting IR 19,3 Wheelchair fencing IR 18,0 Wheelchair rugby IR 16,3 Predominantly upper limb injuries, highest IR in: Shoulder injuries IR 2,3 Wrist & hand IR 1,4 Elbow IR 1,1 Knee IR 1,0	Largest, prospective study Introduction of a novel web-based injury and illness surveillance system (WEB-IISS) 49,910 athlete days of exposure Acute, acute on chronic and chronic injuries defined Severity of injury reported	Injury severity based on estimation of time lost from sport Injuries not reported in relation to impairment

Table 2-1. Summary of literature on injuries in athletes with impairments

Author, year, Study design	Population	Sport	Impairment categories	Injury definition	Notable results	Strengths	Weaknesses
Magno e Silva *et al* 2013a **Prospective cohort**	28 Brazilian swimmers from 2004 & 2008 Paralympic Games	Swimming	Visual impairment	Any injury that caused an athlete to limit, stop or modify participation for 1 day or more	Acute injuries 20% Overuse injuries 80% Shoulder most common site of injury (29,3%) Spasm (36,6%) and tendinopathy (26,8%) most common diagnosis	Prospective	Small sample size
Magno e Silva *et al* 2013b **Prospective cohort**	13 male Brazilian football 5-a-side athletes participating in the 2004 Paralympic Games, 2005 International Blind Sports Federation Pan-American Games, 2007 Para Pan-American Games, 2007 International Blind Sports Federation World championship, 2008 Paralympic Games	Football 5-a-side	Visual impairment class B1	Any injury that caused an athlete to limit, stop or modify participation for 1 day or more	2,7 injuries/athlete 0,12 injuries/match Acute injuries 80% Chronic injuries 20% Lower limb involved in 80% Contusions and sprains most common diagnosis	Prospective Recommendations for identifying risk factors discussed	Small sample size
Magno e Silva *et al* 2013c **Prospective cohort**	40 Brazilian track and field athletes participating in the 2004 Paralympic Games, 2005 International Blind Sports Federation Pan-American Games, 2007 Para Pan-American Games, 2007 International Blind Sports Federation World championship, 2008 Paralympic Games	Track and field	Visual impairment	Any injury that caused an athlete to limit, stop or modify participation for 1 day or more	Overall injury prevalence 78% Clinical incidence 1,93 injuries/athlete at risk 0,39 injuries/athlete/competition Acute injuries 18% Chronic injuries 82% Lower limb most commonly involved Spasm, tendinopathy, strain most common diagnosis	Prospective Exposure data reported	Small sample size

CP, cerebral palsy; IR, incidence rate; IP, incidence proportion; ODA, other disabled athletes; SCI, spinal cord injury; US, United States; USA, United states of America.
Summer Paralympic Sports: archery, boccia, cycling, equestrian, football 5-a-side and 7-a-side, goalball, judo, powerlifting, rowing, sailing, seated volleyball, shooting, swimming, track and field, wheelchair fencing, wheelchair basketball, wheelchair tennis, and wheelchair rugby.
Winter Paralympic Sports: alpine skiing, biathlon, cross-country skiing, ice sledge hockey and wheelchair curling.

Table 2-1. Summary of literature on injuries in athletes with impairments

Author, year, Study design	Population	Sport	Impairment categories	Injury definition	Notable results	Strengths	Weaknesses
Chung *et al* 2012 **Prospective cohort**	14 wheelchair fencers and 10 able-bodied fencers from Hong Kong National Squad	Fencing	Wheelchair athletes	Trauma that occurred during training or competition and prohibited fencing activity for at least 1 day	Injury incidence significantly higher in wheelchair fencers (3,9 injuries/1000 athlete hours) than able-bodied fencers (2,4) Injury incidence significantly higher in competition than training in both groups Higher percentage of upper limb injuries in wheelchair athletes (73,8%) versus able-bodied athletes (16,1%) Elbow strain (32,6%) and shoulder strain (15,8%) most common injuries	Injury diagnosed by orthopaedic specialist and physiotherapist IR reported as injuries per 1000 athlete-hours Relative risk reported Severity of injury reported	Small sample size Recall bias
Webborn *et al* 2012 **Prospective cohort**	505 athletes participating at the 2010 Winter Paralympic Games	All Winter Paralympic sports	All impairment types, no categories defined	Any sport-related musculoskeletal complaint causing the athlete to seek medical attention	Overall IP 23,8% Acute injuries 40,8% Acute on Chronic 0,8% Chronic injuries 57,5% Time loss injuries 11,8% Highest IP in Sledge hockey (IP 33,9%) and Alpine skiing (IP 21,1%) Upper limb injuries most common in sledge hockey (47,5%)	Large, prospective study IR for some sports reported	Injuries treated by team doctors may not have been recorded Athletes treated for muscle tightness/soreness may have been recorded as injuries Injury in relation to impairment not reported

CP, cerebral palsy; IR, incidence rate; IP, incidence proportion; ODA, other disabled athletes; SCI, spinal cord injury; US, United States; USA, United states of America.
Summer Paralympic Sports: archery, boccia, cycling, equestrian, football 5-a-side and 7-a-side, goalball, judo, powerlifting, rowing, sailing, seated volleyball, shooting, swimming, track and field, wheelchair fencing, wheelchair basketball, wheelchair tennis, and wheelchair rugby.
Winter Paralympic Sports: alpine skiing, biathlon, cross-country skiing, ice sledge hockey and wheelchair curling.

Table 2-1. Summary of literature on injuries in athletes with impairments

Author, year, Study design	Population	Sport	Impairment categories	Injury definition	Notable results	Strengths	Weaknesses
Ramirez *et al* 2009 **Prospective cohort**	210 athletes from 8 special education high schools in California	Basketball Softball Football Field hockey	Autism Emotional disturbance Learning impairment Intellectual impairment Orthopaedic impairment Sensory impairment Multiple impairments Other health impairment	"Injury episodes" defined as events resulting in immediate removal of the athlete from the session and medical treatment by school staff or transport to a hospital. "Injury diagnoses" defined as the physical trauma sustained to the body region of an athlete during the injury event.	Overall IR 2,0 injuries/1000 athlete exposures Sports with highest IR: football (IR 3,7) and basketball (IR 2,5) Impairment with highest IR: autism and history of seizures Lower limb injuries in 44,7% Upper limb injuries in 26,3% 63,2% of injuries resulted from collision with object/person Most frequent injuries: Abrasion/contusion in 57,9% Sprain/tear in 10,5% 71% during training	Prospective study IR reported	The 8 high schools included in the study were for children with highly specialized needs, which is approximately 3% of the population of children with special needs, and represents increased severity of impairment
Webborn *et al* 2006 **Prospective cohort**	416 athletes participating in the 2002 Winter Paralympic Games	Alpine skiing Nordic skiing Sledge hockey	All impairment types, no categories defined	All sports-related conditions that might conceivably affect the performance of the winter Paralympic athlete	39 injuries recorded Acute injuries 77% Chronic Injuries 15% Sprain in 32% Fractures in 21% 83,3% of chronic injuries involved the upper limb Most injuries in Alpine skiing and sledge hockey Time loss injury in 21% Half of injuries in training, half in competition	Prospective Implementation of an injury surveillance system	Injuries not reported by athletes or injuries treated by delegation medical staff may not have been included

CP, cerebral palsy; IR, incidence rate; IP, incidence proportion; ODA, other disabled athletes; SCI, spinal cord injury; US, United States; USA, United states of America.
Summer Paralympic Sports: archery, boccia, cycling, equestrian, football 5-a-side and 7-a-side, goalball, judo, powerlifting, rowing, sailing, seated volleyball, shooting, swimming, track and field, wheelchair fencing, wheelchair basketball, wheelchair tennis, and wheelchair rugby.
Winter Paralympic Sports: alpine skiing, biathlon, cross-country skiing, ice sledge hockey and wheelchair curling.

Table 2-1. Summary of literature on injuries in athletes with impairments

Author, year, Study design	Population	Sport	Impairment categories	Injury definition	Notable results	Strengths	Weaknesses
Ferrara *et al* 2000 **Prospective cohort**	1,360 US athletes participating in the 1990 World Games and Championships, 1991 US Paralympic Trials, 1992 Paralympic Games, the 1994 World Athletics Championship, and the 1996 Paralympic Games	Multiple sports	Wheelchair users Cerebral palsy Visual impairment Dwarfism	An injury/illness that was evaluated by the US Medical Staff during these competitions	0,8 injuries/athlete Acute injuries 67.9% Overuse injuries 20.6% Illness most common (29,8%) followed by muscle strain (22,1%) Most common anatomical region was the thorax/spine (13.3%) and the shoulder complex (12.8%) 33% were major injuries (≥22 days lost)	Large, prospective study Severity reported	Exposure data not reported
Nyland *et al* 2000 **Prospective cohort**	304 USA team athletes participating at the 1996 Summer Paralympics Games	All Summer Paralympic sports	IPC impairments: Impaired muscle power Impaired passive range of movement Limb deficiency Leg length discrepancy Hypertonia Ataxia Athetosis Short stature Visual impairment Intellectual impairment.	A strain, sprain, tendonitis, bursitis, or contusion	Acute injuries 67% Overuse injuries 33% Shoulder injuries 20,9% Sports with highest proportion of injuries: Athletics (34,5%) and wheelchair basketball (7,9%)	Large, prospective study IPC injury categories used	Exposure data not reported

CP, cerebral palsy; IR, incidence rate; IP, incidence proportion; ODA, other disabled athletes; SCI, spinal cord injury; US, United States; USA, United states of America.
Summer Paralympic Sports: archery, boccia, cycling, equestrian, football 5-a-side and 7-a-side, goalball, judo, powerlifting, rowing, sailing, seated volleyball, shooting, swimming, track and field, wheelchair fencing, wheelchair basketball, wheelchair tennis, and wheelchair rugby.
Winter Paralympic Sports: alpine skiing, biathlon, cross-country skiing, ice sledge hockey and wheelchair curling.

Table 2-1. Summary of literature on injuries in athletes with impairments

Author, year, Study design	Population	Sport	Impairment categories	Injury definition	Notable results	Strengths	Weaknesses
Retrospective Studies							
Patatoukas *et al* 2011 **Retrospective questionnaire**	139 Greek athletes participating in the 2000 Pan-Hellenic Championship for Athletes with Impairments	All Summer Paralympic sports	Spinal cord injury Cerebral palsy Other	Any injury that caused an athlete to modify, limit or stop participation for 1 day or more	1,47 injuries/SCI athlete 1,16 injuries/ODA athlete 0,97 injuries/CP athlete Soft tissue injuries in 58,9% Injuries in competition in 43,8% Injuries in training in 56,2% Sport most frequently involved: Wheelchair basketball (30,9%) Standing track & field (23%) Swimming 19,1%	139 of 180 questionnaires (77,2%) were completed	Retrospective, self-reported injuries
Athanasopoulos *et al* 2009 **Retrospective review of medical records**	2004 Summer Paralympic athletes 131 athlete reported injuries	All Summer Paralympic sports	Visually Impaired Cerebral Palsy Wheelchair athletes Ambulant athletes	Not reported	Acute injuries 64,1% Overuse injuries 22,1% Chronic injuries 13,8% Most injuries in wheelchair athletes (48,8%) followed by visually impaired athletes (26,0%) Shoulder most common site of injury overall (27,5% of all injuries), and 26,0% of wheelchair athletes Most injuries to upper limb in wheelchair athletes Most injuries to lower limb in visually impaired athletes Sports with most injuries: Athletics 51,2% Powerlifting 18,3% Tendinopathy 28,2% Muscle strain 19,1% Muscle spams 16,8% DOMS 16,8%	Included 25 days of data (11 days before, 12 days during and 2 days after the tournament) Reported the method of treatment Reported the type of injury	Included non-athletes such as delegates, employees and volunteers in the data Only included individuals seen in Paralympic Village Polyclinic Physiotherapy Department Distinction between "chronic" and "overuse" injuries

CP, cerebral palsy; IR, incidence rate; IP, incidence proportion; ODA, other disabled athletes; SCI, spinal cord injury; US, United States; USA, United states of America.
Summer Paralympic Sports: archery, boccia, cycling, equestrian, football 5-a-side and 7-a-side, goalball, judo, powerlifting, rowing, sailing, seated volleyball, shooting, swimming, track and field, wheelchair fencing, wheelchair basketball, wheelchair tennis, and wheelchair rugby.
Winter Paralympic Sports: alpine skiing, biathlon, cross-country skiing, ice sledge hockey and wheelchair curling.

Table 2-1. Summary of literature on injuries in athletes with impairments

Author, year, Study design	Population	Sport	Impairment categories	Injury definition	Notable results	Strengths	Weaknesses
Sobieka 2005 Retrospective review of medical records	114 Polish athletes participating at the 2000 Summer Paralympic Games	All Summer Paralympic sports	Visual impairment Amputation Spinal cord injury Cerebral palsy Intellectual Impairment	Not reported	Injuries to the motor system (46,5%) most frequent reason to seek medical attention followed by common colds (32%)	Reported on injuries and medical conditions	Lack of injury definition and categorization of type, sight and severity of injury
Finley & Rodgers 2004 **Retrospective questionnaire**	52 manual wheelchair users (26 athletes, 26 non- athletes) recruited from community athletic leagues, the Mid-Atlantic Wheelchair Games, community support groups, and personal contacts	Wheelchair basketball Football Tennis Softball Road racing Hand cycling Track and field	Spinal Cord Injury Spina Bifida Amputation Cerebral Palsy Multiple Sclerosis Other	Not reported	28% reported current shoulder pain 32% reported shoulder pain since onset of impairment Longer duration of wheelchair use significant predictor of shoulder pain	Comparison between athletes and non-athletes with impairment Well-defined clinical assessment	Self-reported injuries Sports-specific and impairment-specific injuries not reported
Bernardi *et al* 2003 **Retrospective questionnaire**	227 of 567 athletes with locomotor impairments (randomly selected) participating in selected National sports events during 1 year	Swimming Track and field Basketball "Others"	Cerebral palsy Spinal cord injury Amputees “Les autres”	Any muscle pain experienced during the past 12 months that either occurred during sport activity (training/competition) and/or as consequence of physical exercise, causing discomfort for at least 1 day, not related to systemic disease	Overall prevalence of 50,7% Shoulder involved in 56% Spinal cord injury, amputation, increased training volume and increased BMI associated with injury	1 year prevalence of injury reported	Selection of sporting events may not be representative of the disabled athlete population Questionnaire-based study Injury specific to sports-related muscle pain
Curtis & Black 1999 **Retrospective questionnaire**	46 of 94 athletes (48,9%) participating at the 1997 USA National Women's Wheelchair Basketball Tournament	Wheelchair basketball	Wheelchair athletes	The Wheelchair User's Shoulder Pain Index	72% reported shoulder pain since wheelchair use compared 52% reported recurrent shoulder pain 70% reported hand and/or elbow pain since wheelchair use 48% sought medical attention for shoulder pain	Standardized pain score used	Selection bias Self-reported injuries

CP, cerebral palsy; IR, incidence rate; IP, incidence proportion; ODA, other disabled athletes; SCI, spinal cord injury; US, United States; USA, United states of America.
Summer Paralympic Sports: archery, boccia, cycling, equestrian, football 5-a-side and 7-a-side, goalball, judo, powerlifting, rowing, sailing, seated volleyball, shooting, swimming, track and field, wheelchair fencing, wheelchair basketball, wheelchair tennis, and wheelchair rugby.
Winter Paralympic Sports: alpine skiing, biathlon, cross-country skiing, ice sledge hockey and wheelchair curling.

Table 2-1. Summary of literature on injuries in athletes with impairments

Author, year, Study design	Population	Sport	Impairment categories	Injury definition	Notable results	Strengths	Weaknesses
Taylor & Williams 1995 **Retrospective questionnaire**	53 members (±58%) of the British Wheelchair Racing Association	Wheelchair racing	Wheelchair athletes	Pain in any part of the body that affected or prevented the athlete from training or competing for at least 1 day	72% reported injury in the past year Acute injuries 16% Chronic injuries 52% Other/unclassified 33% Most injuries involved the hand and wrist (27%) and the shoulder (25%) 71% of injuries prevented training Median days lost = 14 Medical attention sought in 45%	Severity of injuries reported as time lost from sport	Self-reported injuries
Reynolds *et al* 1994 **Retrospective review of medical records**	205 British athletes attending the 1992 Summer Paralympic Games	All Summer Paralympic sports	IPC impairments: Ataxia Athetosis Hypertonia Leg length discrepancy Limb deficiency Impaired muscle power Impaired passive range of movement Intellectual impairment Short stature Visual impairment	Not reported	Serious injury/illness rare Injuries most commonly involved spine (28%), shoulder (9%) and hand (6%) Highest proportion of injuries in: Volleyball (90%) Track & field (80%) Judo (80%) Basketball (79%) Powerlifting (75%)	Injury and medical illness data reported	Impairment-specific data not reported Inadequate record keep and under-reporting of injuries noted
Ferrara *et al* 1992a **Retrospective questionnaire**	426 athletes participating in the 1989 national competition of the National Wheelchair Athletic Association, US Association for Blind Athletes and US Cerebral Palsy Athletic Association	Track & field Powerlifting Swimming	Wheelchair athletes Visual impairment Cerebral palsy	Any trauma to the athlete that occurred during a training or competition session that caused the athlete to modify, limit or stop participation for 1 day or more	Acute injuries 45.9% Chronic/overuse injuries 54,1% Upper limb injuries in 44,3% Shoulder most common injury in wheelchair athletes	Large study	Self-reported injuries

CP, cerebral palsy; IR, incidence rate; IP, incidence proportion; ODA, other disabled athletes; SCI, spinal cord injury; US, United States; USA, United states of America.
Summer Paralympic Sports: archery, boccia, cycling, equestrian, football 5-a-side and 7-a-side, goalball, judo, powerlifting, rowing, sailing, seated volleyball, shooting, swimming, track and field, wheelchair fencing, wheelchair basketball, wheelchair tennis, and wheelchair rugby.
Winter Paralympic Sports: alpine skiing, biathlon, cross-country skiing, ice sledge hockey and wheelchair curling.

Table 2-1. Summary of literature on injuries in athletes with impairments

Author, year, Study design	Population	Sport	Impairment categories	Injury definition	Notable results	Strengths	Weaknesses
Ferrara *et al* 1992b **Retrospective questionnaire**	68 of the 125 athletes (54%) participating in the 1989 National Handicapped Sports and the US Association for Blind Athletes Winter National Games	Skiing	Amputation Spinal cord injury Visual impairment Spina bifida Multiple sclerosis Muscular dystrophy	Any trauma to the athlete that occurred during a training or competition session that caused the athlete to modify, limit or stop participation for 1 day or more	Acute injuries 40% Overuse injuries 60% 51% upper extremity injuries Shoulder most frequently involved anatomical area (30% of chronic and 25% of acute injuries)	Characteristics of individual training strategies reported	Self-reported injuries Only 40% of reported injuries were medically evaluated
Burnham *et al* 1991 **Retrospective review of medical records**	151 Canadian athletes participating in the 1988 Summer Paralympic Games	All Summer Paralympic sports	IPC impairments: Ataxia Athetosis Hypertonia Leg length discrepancy Limb deficiency Impaired muscle power Impaired passive range of movement Intellectual impairment Short stature Visual impairment	Not reported	82% of Canadian athletes received medical attention Acute injuries 49% Overuse injuries 51% Shoulder most common anatomical region injured Rotator cuff impingement syndrome most common diagnosis (21,4%) Upper limb injuries more prevalent in “arm-dominant sports” Lower limb injuries more prevalent in “leg-dominant sports”	Injury and medical illness data reported Biomechanical factors involved in rotator cuff impingement syndrome discussed	Retrospective study
McCormack *et al* 1991 **Retrospective questionnaire**	90 Canadian wheelchair athletes	Wheelchair sports	Spinal cord injury Amputation Cerebral palsy Spina bifida Neurological and congenital disorders	Trauma that occurred during training or competing in wheelchair sports	3,8 injuries per athlete reported 30,9% in basketball 30,6% in track and field 12,1% in road racing Upper limb most commonly involved 21,3% hand injuries 16,7% shoulder injuries	Training load reported and discussed	Self-reported injuries Only trauma-related injuries reported Inclusion of minor ailments such as blisters may overestimate injury rate

CP, cerebral palsy; IR, incidence rate; IP, incidence proportion; ODA, other disabled athletes; SCI, spinal cord injury; US, United States; USA, United states of America.
Summer Paralympic Sports: archery, boccia, cycling, equestrian, football 5-a-side and 7-a-side, goalball, judo, powerlifting, rowing, sailing, seated volleyball, shooting, swimming, track and field, wheelchair fencing, wheelchair basketball, wheelchair tennis, and wheelchair rugby.
Winter Paralympic Sports: alpine skiing, biathlon, cross-country skiing, ice sledge hockey and wheelchair curling.

Table 2-1. Summary of literature on injuries in athletes with impairments

Author, year, Study design	Population	Sport	Impairment categories	Injury definition	Notable results	Strengths	Weaknesses
Ferrara & Davis 1990 **Retrospective questionnaire**	19 of the 65 athletes invited to the National Wheelchair Athletic Association elite training camp	Track and field Shooting Swimming Table tennis	Wheelchair athletes	Anything the athlete expressed concern about and (a) caused a loss of participation due to an injury or illness, or (b) an injury in which a fracture, dislocation, or subluxation occurred and the athlete was able to continue participation	2,6 injuries per athlete over 1 year reported Acute injuries 65% Chronic injuries 23% 58% upper limb injuries, especially shoulder and wrist Highest proportion of injuries in track and field (80%) and swimming (20%) 12,2% reported that they did not seek medical attention Direct impact most common mechanisms of injury Severity of injuries: 57% minor (≤7 days) significant (8-21 days) 32% major (>22 days)	Severity of injuries in terms of time lost reported	Small study Self-reported injuries
Curtis & Dillon 1985 **Retrospective questionnaire**	128 of over 1200 athletes with impairments	Wheelchair sports	Spinal cord injury Congenital disorders Polio Amputation Neuromuscular disorders	Not reported	Injury prevalence 72% Highest proportion of injuries in Track and field (30%) Basketball (24%) Roadracing (22%) Soft tissue injuries (strains, sprains, tendonitis) frequently reported at shoulders, elbows, wrists and hands	Injury-specific methods of prevention recommended	Self-reported injuries low response rate (±10%)
McCormick 1985 **Retrospective questionnaire**	60 of 68 athletes participating at the 1983 Northeast Regional Handicapped Skiing Championship, New Hampshire	Alpine skiing	Amputation Visual impairment Polio	Not reported	2 injuries per 1000 skier-days 27% of athletes reported injury Knee injuries most common (17%)	Design of equipment discussed as methods of injury prevention	"Skier-days" calculated from assumption that athletes skied 21 times per year for 9 years Self-reported injuries

CP, cerebral palsy; IR, incidence rate; IP, incidence proportion; ODA, other disabled athletes; SCI, spinal cord injury; US, United States; USA, United states of America.
Summer Paralympic Sports: archery, boccia, cycling, equestrian, football 5-a-side and 7-a-side, goalball, judo, powerlifting, rowing, sailing, seated volleyball, shooting, swimming, track and field, wheelchair fencing, wheelchair basketball, wheelchair tennis, and wheelchair rugby.
Winter Paralympic Sports: alpine skiing, biathlon, cross-country skiing, ice sledge hockey and wheelchair curling.

Table 2-1. Summary of literature on injuries in athletes with impairments

Author, year, Study design	Population	Sport	Impairment categories	Injury definition	Notable results	Strengths	Weaknesses
Jackson & Fredrickson 1976 Retrospective review	184 athletes at the 1976 Olympiad for the Physically Disabled	Paralympic sports not specified	Wheelchair Amputation Visual impairment	Not reported	Disabled athletes slightly more vulnerable to stress and fatigue than able-bodied athletes	First report on injuries in Paralympic athletes	

CP, cerebral palsy; IR, incidence rate; IP, incidence proportion; ODA, other disabled athletes; SCI, spinal cord injury; US, United States; USA, United states of America.
Summer Paralympic Sports: archery, boccia, cycling, equestrian, football 5-a-side and 7-a-side, goalball, judo, powerlifting, rowing, sailing, seated volleyball, shooting, swimming, track and field, wheelchair fencing, wheelchair basketball, wheelchair tennis, and wheelchair rugby.
Winter Paralympic Sports: alpine skiing, biathlon, cross-country skiing, ice sledge hockey and wheelchair curling.

Chapter 3

Incidence and risk factors associated with upper limb injuries in athletes participating at the London 2012 Paralympic Games

3.1. Introduction

Participation in sports for individuals with impairments has benefits that ultimately translate into improved quality of life. Growing numbers of participants in these sports necessitates and facilitates effective surveillance research that is aimed at better understanding the injury patterns in order to develop injury prevention strategies. Effective injury prevention strategies are more important for the athlete with impairment than for any other athlete, since an injury may not only cause time away from sport, but also a marked incapacity to cope with activities of daily living.

For the first time a comprehensive injury and illness surveillance study was conducted at the London 2012 Paralympic Games using novel data capture technology. (Derman *et al*, 2013). During this study it was shown that the upper limb was the predominant anatomical region injured in Paralympic athletes in contrast to studies that have demonstrated the predominance of lower limb injuries in able-bodied athletes (June *et al*, 2009, Webborn & van de Vliet, 2012; Jacobsson *et al*, 2013; Willick *et al*, 2013; Derman *et al*, 2013).

The available literature on injury patterns in athletes with impairments is deficient, but improving. Prospective epidemiological data has become more available in recent times, especially since the introduction of standardized injury surveillance systems. In athletes with impairments, the upper limb, and more specifically, the shoulder, has been implicated as the main anatomical site of injury in numerous studies. The sports with the highest reported frequency of

injuries include athletics, powerlifting, football 5-a-side, wheelchair-based sports, swimming, judo and goalball (Curtis & Dillon, 1985; Ferrara & Davis, 1990; McCormack *et al*, 1991; Reynolds *et al*, 1994; Taylor & Williams, 1995; Curtis & Black, 1999; Nyland *et al*, 2000; Athanasopoulos *et al*, 2009; Patatoukas *et al*, 2011; Chung *et al*, 2012; Magno e Silva *et al*, 2013, Willick *et al*, 2013).

There has been a lack of standardization of upper limb injury definitions and determinants of severity; however, the methodologies in more recent studies have improved (Webborn *et al*, 2012; Magno e Silva *et al*, 2013; Willick *et al*, 2013; Derman *et al*, 2013). The literature is still markedly deficient in the identification of risk factors associated with upper limb injuries in athletes with impairments. Furthermore, there is a paucity of data on the clinical features, investigation and treatment of injuries, and prevention strategies for these athletes.

To our knowledge, no studies thus far have comprehensively described the incidence of upper limb injuries in all impairment categories of Paralympic athletes. Furthermore, the relationship between potential risk factors such as age, gender, type of impairment, and sports category has not been reported. Finally, the mechanisms, severity and duration of upper limb injuries in athletes with impairments have not been reported.

3.2. Objectives of the study

There were two main objective of this study:

1. To document the incidence and risk factors associated with upper limb injuries in athletes participating in the London 2012 Paralympic Games.
2. To describe the mechanisms, severity, requirement for special investigations and duration of upper limb injuries in athletes with impairments.

The results from these two phases of the study will provide the initial framework for future research aimed at designing and implementing upper limb injury prevention strategies in these athletes.

3.3. Method

3.3.1. Study design

This study forms a component of the large prospective cohort study conducted over the 14 day period of the London 2012 Paralympic Games and was coordinated through the International Paralympic Committee (IPC) Medical Committee. The study design of this large prospective study has been previously been described in detail (Derman *et al*, 2013)**.**

The study was conducted in two phases. In Phase 1 data were collected to document the incidence and risk factors associated with upper limb injuries in athletes participating in the London 2012 Paralympic Games. In Phase 2, data were collected to describe the mechanisms, severity, requirement from special investigations and the duration of upper limb injuries in athletes with impairments.

3.2.2. Data sources

In this study, three data sources were used (Derman *et al*, 2013). The first data source was a comprehensive database of athletes provided by the IPC containing accreditation number, sports code, country code, age and gender. The second data source was from medical encounters (illness and injury) at both the Paralympic Village polyclinic and at the sports venues. These data were captured through an electronic medical data capture system (EMDCS; ATOS, France) that was utilized in previous Olympic and Paralympic Games. Sports physicians and medical staff from the London Organization Committee of the Olympic and Paralympic Games (LOCOG) were requested to enter all these data via the ATOS system (Derman *et al*, 2013).

The third data source was medical information that was recorded by medical staff whilst providing care to their own teams. Previously this data has been collected by completion of forms. However, during the London 2012 Paralympic Games a novel electronic web-based injury and illness surveillance system (WEB-IISS, Derman *et al*, 2013) was used to collect data via desktop

computer interface, laptop computer, tablet or smart phone. Some unique features of this WEB-IISS system included: 1) personalized login and password for designated team medical staff members to ensure accurate daily reporting, 2) security, 3) automated email reminders if staff members did not update the records for the day, and 4) administrator access to facilitate daily computation of data collected and analysis of team compliance. Data fields included: professional designation (e.g. team physician or radiologist), athlete accreditation number, gender, type of impairment, location of medical facility, new or recurrent injury, time loss or medical attention only, acute, chronic, or acute on chronic injury, mechanism of injury, stage of the games during injury, use of protective equipment, severity, investigations performed, anatomical region of injury, and final diagnosis.

Information from all three databases were utilized for data collection of Phase 1 of the study. However, as more detailed medical information on the mechanisms, severity, investigations and duration of upper limb injuries in athletes with impairments was only available on the WEB-IISS system, this data source was used to collect additional medical information on upper limb injuries in a sub-group of athletes for Phase 2 of this study.

3.3.3. Study participants

3.3.3a. Phase 1

During the London 2012 Paralympic Games 164 countries and 4 176 athletes participated, of which 4 countries elected not to participate in the data collection (Derman *et al*, 2013). Injury data from participants in Phase 1 of the study was obtained from 3 565 athletes representing 160 of the 164 particpating countries utilizing medical data sources 2 (EMDCS) and 3 (WEB-IISS) (Table 3.1a.) (Derman *et al*, 2013).

Table 3.1a: Medical data sources and study participants for Phase 1 of the study

	Data source 2: Medical data from EMDCS	*Data source 3: Medical data from WEB-IISS*	*Phase 1 Data sources (EMDCS and WEB-IISS)*
NPCs (n)	82	78	160
Athletes (n)	236	3 329	3 565
Athlete days (Pre-competition period)	708	9 987	10 695
Athlete days (Competition period)	2 596	36 619	39 215
Athlete days (Total period)	3 304	46 606	49 910

NPC, National Paralympic Committee; EMDCS, electronic medical data capturing system used by the polyclinic and sporting venue medical staff; WEB-IISS, web based injury and illness surveillance system.

3.3.3b. Phase 2:

In Phase 2 of the study, detailed additional medical data on the mechanisms, severity, requirement for special investigations and duration of upper limb injuries in athletes with impairments was only available on the WEB-ISS system. Therefore, only medical data source 3 was used for Phase 2 of this study (Table 2.2.). As a result, the study participants for Phase 2 of the study were from 78 countries and consisted of 3 329 athletes (80% of total number of athletes at the tournament) (Table 3.1b.).

Table 3.1b: Medical data source and study participants for Phase 2 of the study

	Phase 2 medical data source (WEB-IISS)
NPCs (n)	78
Athletes (n)	3 329
Athlete days (Pre-competition period)	9 987
Athlete days (Competition period)	36 619
Athlete days (Total period)	46 606

NPC, National Paralympic Committee; EMDCS, electronic medical data capturing system used by the polyclinic and sporting venue medical staff; WEB-IISS, web based injury and illness surveillance system.

3.3.4. Inclusion and exclusion criteria

All medical encounters whereby athletes presented with complaints or injuries pertaining to the upper limb (from and the including the shoulder girdle to and including the digits of the hand) were included in the analysis (Phase 1 and 2). A medical encounter was defined as any athlete who received medical attention regardless of the consequences with respect to absence from competition or training.

3.3.5. Location of the research

The data were collected at the London 2012 Paralympic Games during over a 14-day period (a 3 day precompetition and an 11 day competition period).

3.4. Definitions of Injury and Severity

For the present study the same definitions for acute, acute on chronic and chronic injuries were used as that defined in the large prospective cohort study of which this study forms a part (Willick *et al*, 2013)**.**

- **Injury**: Any sport-related musculoskeletal complaint that resulted in an athlete seeking medical attention.
- **Acute injury**: Any injury that started at a single, identifiable point in time (e.g. wrist pain following a fall).
- **Acute on chronic injury**: Any injury that an athlete had prior to the London 2012 Paralympic Games, with subsequent exacerbation of the same symptoms during the period of the Games (e.g. rotator cuff impingement syndrome with acute exacerbation of pain).
- **Chronic (overuse) injury**: Any injury that did not have a single, identifiable onset (e.g. chronic rotator cuff injury).

The severity of acute injuries was classified according to the amount of time that the injury prevented the athlete from participating in sport:

- **Slight**: 0 – 1 day of time lost from sport
- **Minimal**: 2 – 3 days of time lost from sport
- **Mild**: 4 – 7 days of time lost from sport
- **Moderate**: 8 – 28 days of time lost from sport
- **Severe**: More than 28 days of time lost from sport

The severity of chronic injuries was graded according to presence of pain and the extent to which this interfered with training or competition as follows:

- **Grade 0**: Does not affect training
- **Grade 1**: Pain occurs after training
- **Grade 2**: Pain occurs during training or competition
- **Grade 3**: Pain occurs during training or competition and interferes with sport
- **Grade 4**: Pain is severe enough to prevent participation in training or Competition

3.5. Definitions of categories of impairment

For the purposes of this study, athletes were classified into 4 major categories of impairment, namely:

- **Amputation/limb deficiency** – Total or partial absence of the bones or joints of a limb
- **Spinal Cord injury** – Impairment in the spinal cord resulting in loss or abnormal movement of a limb or limbs
- **Visual impairment** – Impaired vision by either an impairment of the eye structure, optical nerves or optical pathways, or visual cortex of the central brain
- **Other** – Athletes with impairments that are not classifiable in the above categories, such as intellectual impairment

3.6. Research ethics approval

Ethics approval for the study was obtained from both the University of Brighton (FREGS/ES/12/11, Appendix A) and the University of Cape Town Health Sciences Research Ethics Committee (HREC/REF 436/2012, Appendix B). All the athletes consented to the utilization of their medical data for research purposes prior to the Paralympic Games.

3.7. Statistical analysis of data

The data were analysed using standard analysis methods. Standard descriptive statistical analysis was conducted and included: numbers, means, proportions/percentages, and incidence (where applicable). Incidence proportion (IP) was defined as the number of injuries per 100 athletes during the study period. Incidence rate (IR) was defined as the number of injuries per 1000 athlete days for the study period. The 95% confidence interval (CI) is reported and was used to determine significant differneces in the incidence data.

3.8. Results

3.8.1. Upper limb injuries

3.8.1.1. Upper limb injuries - Phase 1

In the study period, a total of 258 upper limb injuries were recorded from the combined WEB-ISS and the EMDCS data sources (Table 3.2.). This included 112 shoulder injuries, 74 upper arm, forearm or elbow injuries, and 72 wrist or hand injuries. These injuries were studied in detail in Phase 1 of this investigation.

3.8.1.2. Upper limb injuries - Phase 2

Additional medical information for Phase 2 of the investigation on a sub-group of the upper limb injuries could only be obtained from the WEB-ISS system. Therefore, in Phase 2 of the investigation, a sub-group of 183 upper limb injuries were studied (Table 3.2.) of which 80 were shoulder injuries, 49 were upper arm, forearm or elbow injuries, and 54 were wrist injuries.

Table 3.2: Upper limb injuries for Phase 1 and Phase 2 of the study (Data are presented as number and %)

	*All upper limb injuries (EMDCS and WEB-IISS sources) **	*Upper limb injuries (WEB-IISS source) ***	*Upper limb injuries (EMDCS source)*
All upper limb injuries	258 (100%)	183 (100%)	75 (100%)
Shoulder	112 (43.4%)	80 (43.7%)	32 (42.7%)
Upper arm, forearm or elbow	74 (28.7%)	49 (26.8%)	25 (33.3%)
Wrist or hand	72 (27.9%)	54 (29.5%)	18 (24.0%)

* Data used in Phase 1 of the investigation

** Data used in Phase 2 of the investigation

3.8.2. Phase 1: Incidence and risk factors associated with upper limb injuries

3.8.2.1. Incidence of all upper limb injuries and by main anatomical region

As the total number of upper limb injuries in the combined EMDCS and WEB-IISS systems (data sources 2 and 3) was 258, the overall incidence proportion (IP) of upper limb injuries per 100 athletes was 7,2, with and an incidence rate (IR) of 5,2 upper limb injuries per 1000 athlete days (**Table 3.3**). Shoulder injuries occurred more frequently than injury to any other anatomical region of the upper limb with a significantly higher IP of 3,1 (95% CI 2,6 – 3,7) and IR of 2,2/1000 athlete days (95% CI 1,85 – 2,7). This was followed by injuries of the wrist and hand with an IP of 2,0 (95% CI 1,6 – 2,5) and an IR of 1,4/1000 athlete days (95% CI 1,1 – 1,82)**.** Injuries involving the upper arm and forearm were grouped together with elbow injuries as the number of injuries in these areas was to small for individual analysis. The injuries in these regions are therefore grouped for the remainder of the data analysis.

Table 3.3: Incidence of all upper limb Injuries and by anatomical region

Anatomical region	Number of injuries	IP	Standard error	95% CI	IR	95% CI
Shoulder	112	3,1	0,3	2,6 – 3,7	2,2	1,85 – 2,7
Upper arm	13	0,4	0,1	0,2 – 0,6	0,3	0,1 – 0,4
Elbow	56	1,6	0,2	1,2 – 2,0	1,1	0,8 – 1,5
Forearm	5	0,1	0,1	0,0 – 0,3	0,1	0,0 – 0,2
Wrist & hand	72	2,0	0,2	1,6 – 2,5	1,4	1,1 – 1,82
All upper limb	258	7,2	0,4	6,4 – 8,1	5,2	4,6 – 5,8

CI, confidence interval
IP, incidence proportion (%)
IR, incidence rate (injuries/1000 athlete days)

3.8.2.2. Incidence of upper limb injuries by sex

An analysis of the sex distribution of injuries revealed that all upper limb injuries were encountered significantly more frequently in males (IR 10,8/1000 athlete days, 95% CI 9,0 – 12,1) in comparison to females (IR 4,7/1000 athlete days, 95% CI 3,7 – 5,8). Similarly, shoulder injuries and injuries of the wrist and hand were significantly more frequent in males compared with females with IR of 4,6/100 athlete days and 3,2/1000 athlete days versus 1,9/1000 athlete days and 1,1/1000 athlete days respectively (**Table 3.4a** and **Table 3.4b**) (**Figure 3.1**). Although a higher IR of injuries in the group consisting of upper arm, forearm and elbow injuries was also seen in males in comparison to females (2,6/1000 athlete days versus 1,7/1000 athlete days), the difference was not statistically significant.

Table 3.4a: Injuries by anatomical region in females

	Females		
Anatomical region	**Number of injuries**	**IR**	**95% CI**
Shoulder	33	1,9	1,3 – 2,7
Upper arm/Forearm/elbow	29	1,7	1,1 – 2,4
Wrist & hand	18	1,1	0,6 – 1,7
All upper limb	80	4,7	3,7 – 5,8

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

Table 3.4b: Injuries by anatomical region in males

	Males		
Anatomical region	**Number of injuries**	**IR**	**95% CI**
Shoulder	79,0	4,6	3,7 – 5,8
Upper arm/Forearm/elbow	45,0	2,6	1,9 – 3,5
Wrist & hand	54,0	3,2	2,4 – 4,1
All upper limb	178,0	10,4	9,0 – 12,1

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

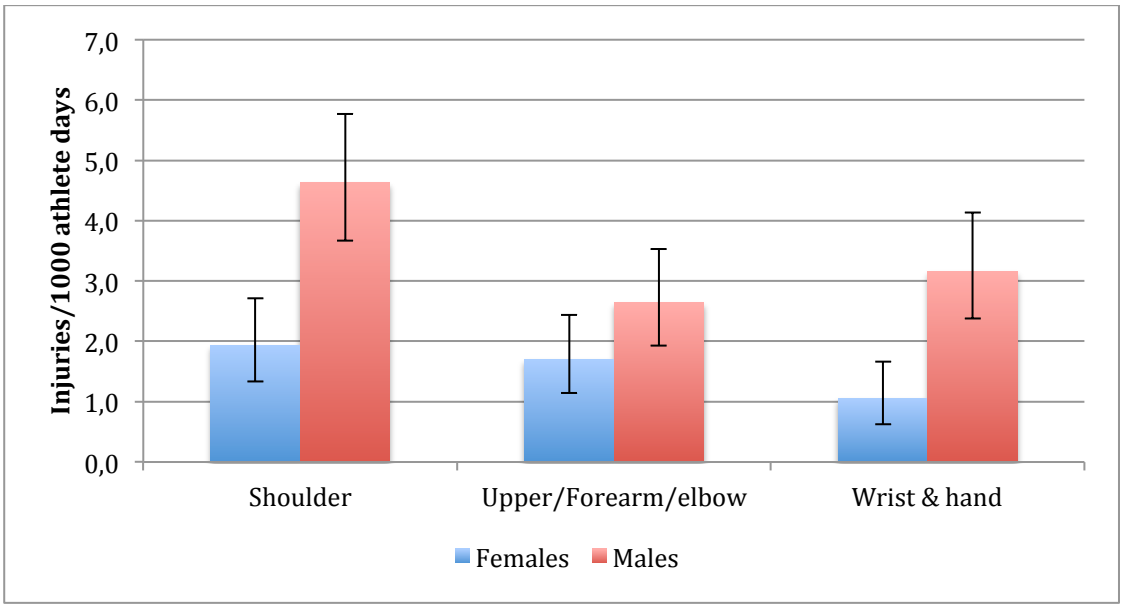

Figure 3.1: Incidence rate of upper limb injuries by sex (per 1000 athlete days)

3.8.2.3. Incidence of upper limb injuries by age groups

The participants were grouped into age categories (as per prior definitions by Derman *et al*, 2013) as follows: 13-25 years, 26-34 years and 35-67 years. Shoulder injuries showed an increasing incidence with age. The 35-67 year age group showed an IR of 2,8/1000 athlete days (95% CI 2,05 – 3,7), significantly higher than the IR of 1,3/1000 athlete days (95% CI 0,8 – 2,01) recorded in the 13-25 years age group. However, the IR of injuries of the wrist and hand were similar across all age groups, as were injuries of the upper arm/forearm and elbow (see **Tables 3.5a, 3.5b, 3.5c, Figure 3.2**).

Table 3.5a: Injuries by anatomical region in the 13-25 years age group

Anatomical region	Age 13-25 years		
	Number of injuries	IR	95% CI
Shoulder	21	1,3	0,8 – 2,0
Upper/Forearm/elbow	14	0,9	0,5 – 1,5
Wrist & hand	24	1,5	1,0 – 2,2
All upper limb	59	3,7	2,8 – 4,8

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

Table 3.5b: Injuries by anatomical region in the 26-34 years age group

Anatomical region	Age 26-34 years		
	Number of injuries	IR	95% CI
Shoulder	45,0	2,6	1,9 – 3,4
Upper/Forearm/elbow	31,0	1,8	1,2 – 2,5
Wrist & hand	26,0	1,5	1,0 – 2,2
All upper limb	102,0	5,8	4,8 – 7,1

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

Table 3.5c: Injuries by anatomical region in the 35-67 years age group

Anatomical region	Age 35-67 years		
	Number of injuries	IR	95% CI
Shoulder	46,0	2,8	2,0 – 3,7
Upper/Forearm/elbow	29,0	1,8	1,2 – 2,5
Wrist & hand	22,0	1,3	0,8 – 2,0
All upper limb	97,0	5,9	4,8 – 7,2

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

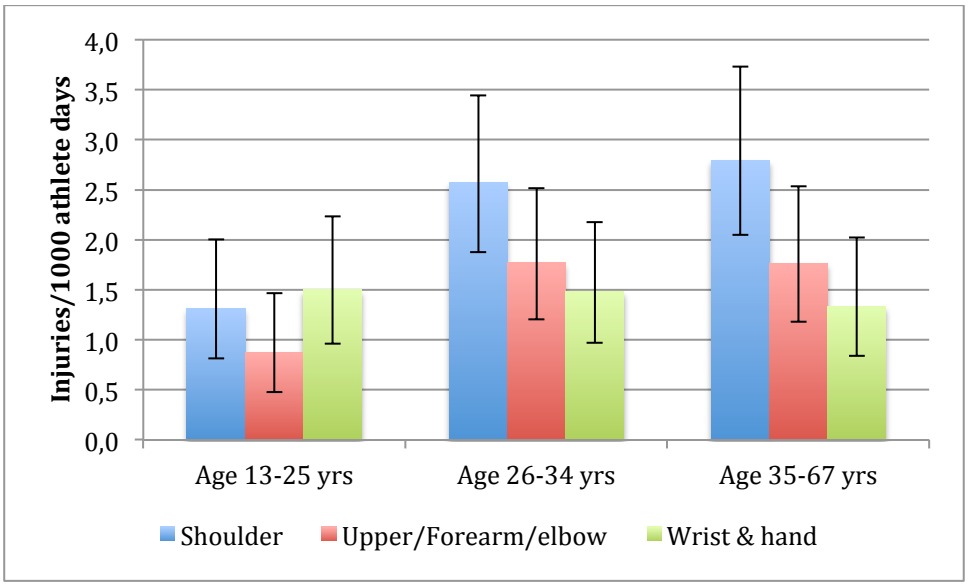

Figure 3.2: Incidence rate of upper limb injuries by age group (injuries per 1000 athlete days)

3.8.2.4. Incidence of injuries by type of injury (acute, acute on chronic and chronic)

The incidence of upper limb injuries was analyzed by type of injury (acute, acute on chronic and chronic) in the anatomical region of injury.

Overall, there was a higher IR of acute injuries (2,2/1000 athlete days, 95% CI 1,8 – 2,6) and chronic injuries (2,1/1000 athlete days; 95% CI 1,7 – 2,5) compared with acute on chronic injuries (IR 0,9 and 95% CI 0,7 – 1,2). Notably, chronic shoulder injuries were the most frequently encountered chronic injury with a significantly higher IR rate of 1,1/1000 athlete days (95% CI 0,8 – 1,5) compared with chronic injuries in any other individual anatomical region. Although acute injuries of the wrist and hand were the most frequently encountered acute injuries (IR 1,0/1000 athlete days, 95% CI 0,8 – 1,3), this incidence was not significantly different from acute injuries in other anatomical regions (**Tables 3.6a, 3.6b, 3.6c and Figure 3.3**).

Table 3.6a: Acute injuries by anatomical region

Anatomical region	Acute		
	Number of injuries	IR	95% CI
Shoulder	32	0,6	0,4 – 0,9
Upper/Forearm/elbow	25	0,5	0,3 – 0,7
Wrist & hand	51	1,0	0,8 – 1,3
Total	108	2,2	1,8 – 2,6

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

Table 3.6b: Acute on chronic injuries by anatomical region

Anatomical region	Acute on chronic		
	Number of injuries	IR	95% CI
Shoulder	24	0,5	0,3 – 0,7
Upper/Forearm/elbow	13	0,3	0,1 – 0,4
Wrist & hand	9	0,2	0,1 – 0,3
Total	46	0,9	0,7 – 1,2

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

Table 3.6c: Chronic injuries by anatomical region

Anatomical region	Chronic		
	Number of injuries	IR	95% CI
Shoulder	56	1,1	0,8 – 1,5
Upper/Forearm/elbow	36	0,7	0,5 – 1,0
Wrist & hand	12	0,2	0,1 – 0,4
Total	104	2,1	1,7 – 2,5

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

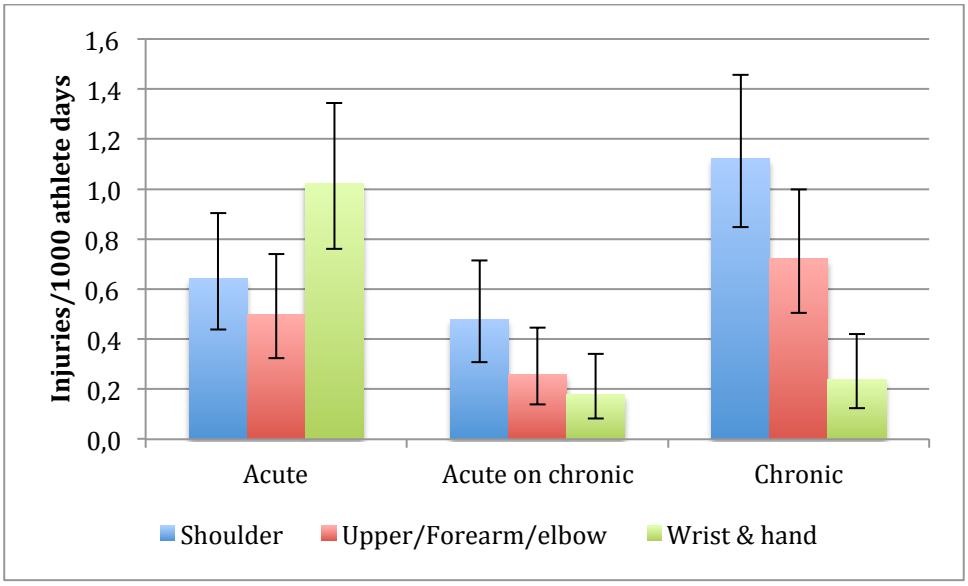

Figure 3.3: Onset of injury – acute, acute on chronic, and chronic (upper limb injuries per 1000 athlete days)

3.8.2.6. Incidence of type of injury (acute, acute on chronic and chronic) by sex and age

The incidence of upper limb injuries was analyzed by type of injury (acute, acute on chronic and chronic) and by sex and the age groups of the participants.

In males, there was a higher IR of acute wrist and hand injuries (1,1/1000 athlete days, 95% CI 0,8 – 1,6), compared with chronic wrist and hand injuries and any other acute injury of the upper limb. Similarly, the IR of chronic shoulder injuries (1,3/1000 athlete days, 95% CI 0,9 – 1,8) was a higher compared with acute shoulder injuries and any other chronic injury of the upper limb (**Tables 3.7a, 3.7b**, **3.7c** and **Figure 3.4**).

Table 3.7a: Acute injuries by anatomical region in males

Males

Anatomical region	Acute		
	Number of injuries	IR	95% CI
Shoulder	22	0,7	0,4 – 1,0
Upper/Forearm/elbow	15	0,5	0,3 – 0,8
Wrist & hand	37	1,1	0,8 – 1,6
Total	74	2,3	1,8 – 2,8

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

Table 3.7b: Acute on chronic injuries by anatomical region in males

Males

Anatomical region	Acute on chronic		
	Number of injuries	IR	95% CI
Shoulder	14	0,4	0,2 – 0,7
Upper/Forearm/elbow	9	0,3	0,1 – 0,5
Wrist & hand	7	0,2	0,1 – 0,4
Total	30	0,9	0,6 – 1,3

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

Table 3.7c: Chronic injuries by anatomical region in males

Males

Anatomical region	Chronic		
	Number of injuries	IR	95% CI
Shoulder	43	1,3	0,9 – 1,8
Upper/Forearm/elbow	21	0,6	0,4 – 1,0
Wrist & hand	10	0,3	0,1 – 0,6
Total	74	2,3	1,8 – 2,8

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

In females, acute and chronic wrist and hand injuries showed incidence rates of 0,8/1000 athlete days and 0,1/1000 athlete days respectively, and acute and chronic shoulder injuries showed incidence rates of 0,6/1000 athlete days and 0,8/1000 athlete days respectively. The number of injuries encountered was low and these differences were not statistically significant. The subgroup including upper arm, forearm and elbow injuries showed an IR of chronic injuries of 0,9/1000 athlete days (95% CI 0,5 – 1,5, **Tables 3.8a**, **3.8b, 3.8c, Figure 3.4, Figure 3.5**). Also, the comparison of IR of these injuries between male and female revealed no statistically significant difference at a 95% confidence level.

Table 3.8a: Acute injuries by anatomical region in females

Females

	Acute		
Anatomical region	**Number of injuries**	**IR**	**95% CI**
Shoulder	10	0,6	0,3 – 1,1
Upper/Forearm/elbow	10	0,6	0,3 – 1,1
Wrist & hand	14	0,8	0,4 – 1,4
Total	34	2,0	1,4 – 2,8

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

Table 3.8b: Acute on chronic injuries by anatomical region in females

Females

	Acute on chronic		
Anatomical region	**Number of injuries**	**IR**	**95% CI**
Shoulder	10	0,6	0,3 – 1,1
Upper/Forearm/elbow	4	0,2	0,1 – 0,6
Wrist & hand	2	0,1	–
Total	16	0,9	0,5 – 1,5

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

Table 3.8c: Chronic injuries by anatomical region in females

Females

Anatomical region	Chronic		
	Number of injuries	IR	95% CI
Shoulder	13	0,8	0,4 – 1,3
Upper/Forearm/elbow	15	0,9	0,5 – 1,5
Wrist & hand	2	0,1	–
Total	30	1,8	1,2 – 2,5

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

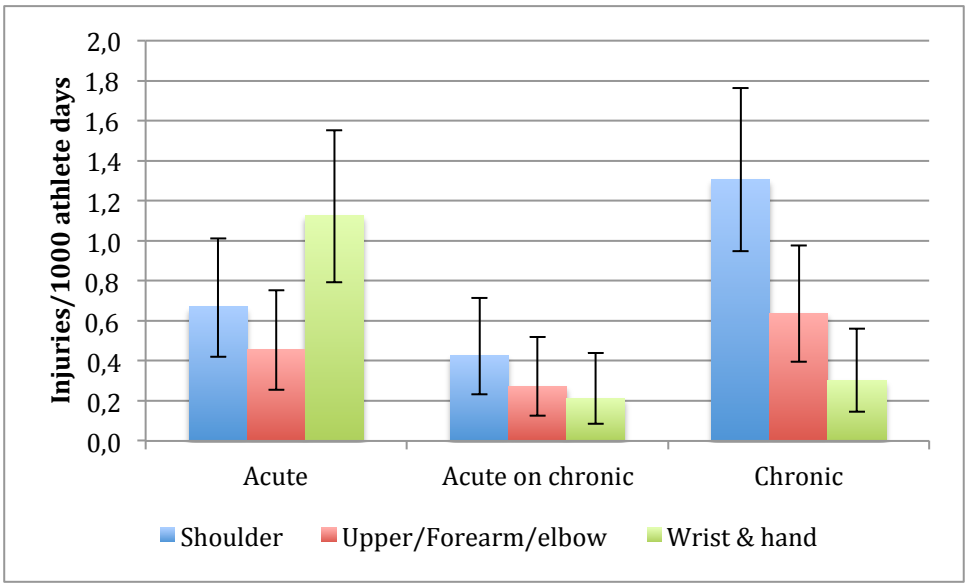

Figure 3.4: Onset of injuries in males (injuries per 1000 athlete days)

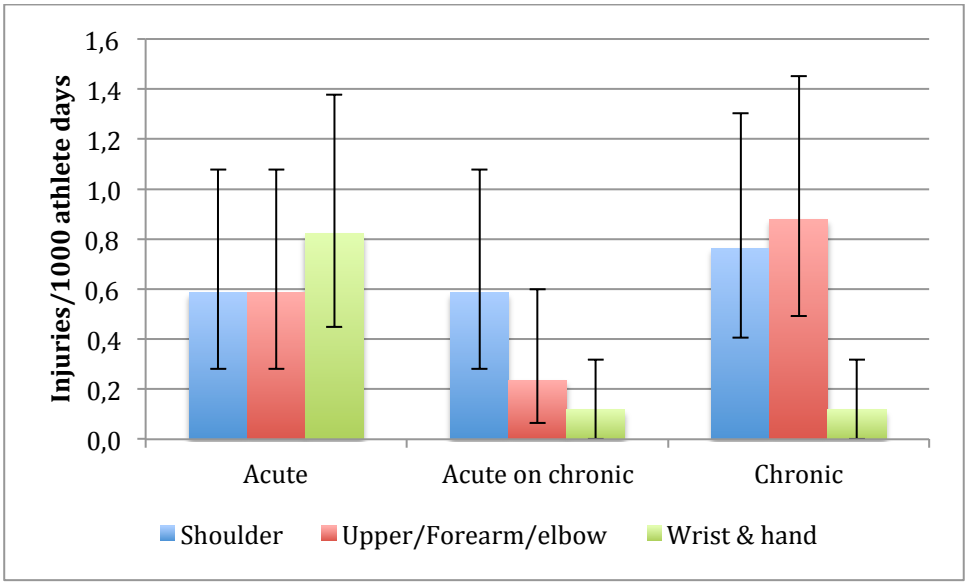

Figure 3.5: Onset of injuries in females (injuries per 1000 athlete days)

The analysis of the onset of upper limb injuries in terms of age groups is summarized in **Figure**s **3.6a**, **3.6b** and **3.6c**. In the 13-25 years age group, the IR of acute injuries of the wrist and hand (1,3; 95% CI 0,8 – 1,9) was higher compared with chronic injuries of the wrist and hand (IR 0,3/1000 athlete days, 95% CI 0,1 – 0,6) and any other acute upper limb injuries (**Figure 3.6a**). In the 26-34 years age group, the IR of chronic shoulder injuries (1,3/1000 athlete days, 95% CI 0,8 – 1,9) was higher than any other chronic injury (**Figure 3.6b**). In the 35-67 years age group, the IR of chronic shoulder injuries (1,3/1000 athlete days, 95% CI 0,8 – 2,0) was higher than the incidence of any other chronic injury (**Figure 3.6c**).

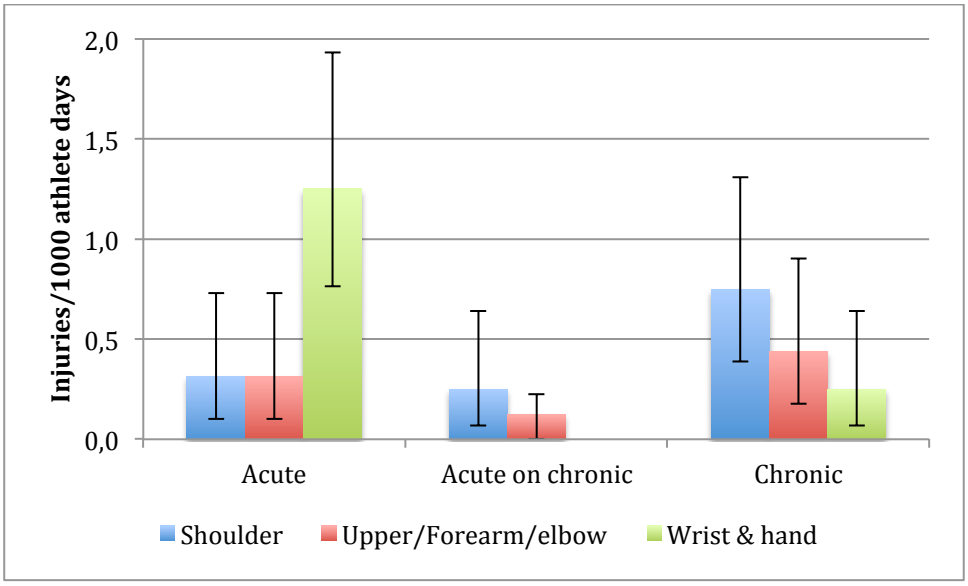

Figure 3.6a: Onset of injury in the 13-25 years age group (injuries per 1000 athlete days)

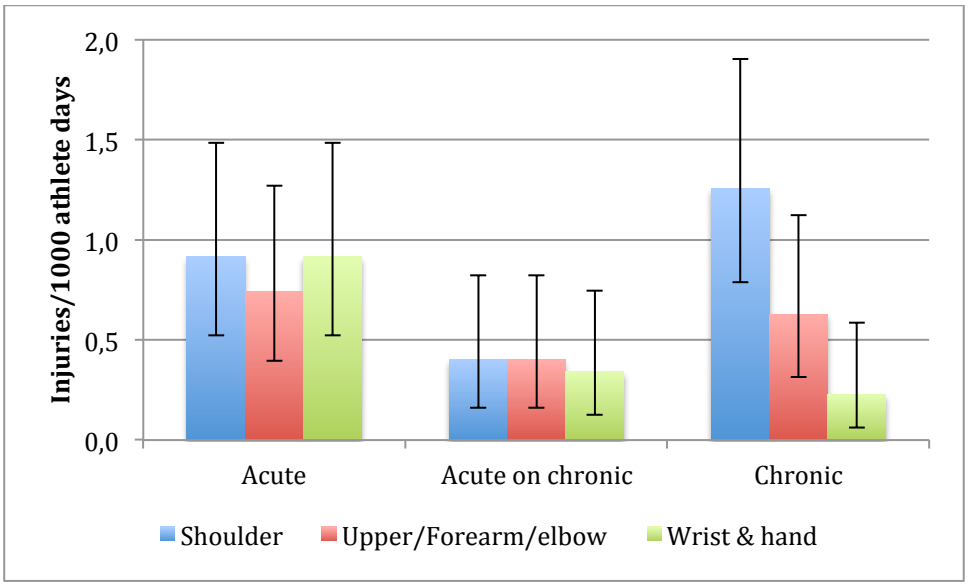

Figure 3.6b: Onset of injury in the 26-34 years age group (injuries per 1000 athlete days)

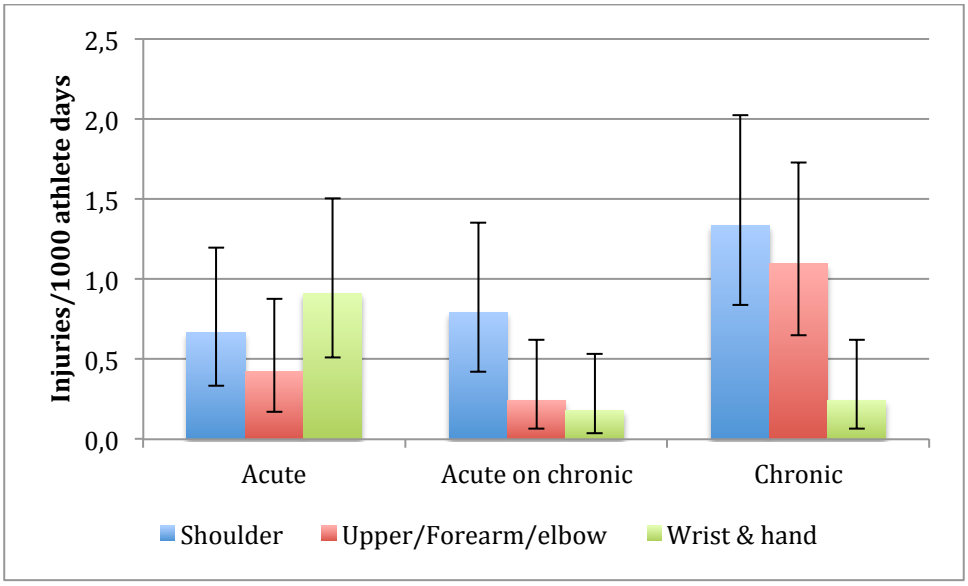

Figure 3.6c: Onset of injury in the 35-67 years age group (injuries per 1000 athlete days)

In summary, there was a high incidence of chronic shoulder injuries and the highest incidence was in older age groups. Acute injuries of the wrist and hand were the second most frequently encountered upper limb injury and were more common in the younger age group. There were no significant differences in the incidence of upper limb injuries between males and females in terms of onset of injury and age category.

3.8.2.7. Incidence of upper limb injuries in different sports

The 7 sports with the highest incidence of upper limb injuries have been included in this analysis, namely athletics, swimming, powerlifting, table tennis, wheelchair basketball, goalball and judo. These sports collectively represent 172 of the total 258 upper limb injuries encountered (67%). The remaining sports will not be reported here, as the number of injuries in each anatomical region according to sport category is too low to make a meaningful comparison.

The highest incidence of upper limb injuries was recorded in powerlifting, judo, goalball and wheelchair basketball (**Table 3.9a**, **Figure 3.7.**). The IR of shoulder injuries was 8,8/1000 athlete days (95% CI 5,4 – 13,5) in powerlifting, 5,0/1000 athlete days (95% CI 2,1 – 9,8) in judo, 2,8/1000 athlete days (95% CI

1,2 – 5,6) in wheelchair basketball, and 2,7/1000 athlete days (95% CI 1,6 – 4,2) in swimming

The incidence of upper arm, forearm and elbow injuries was 1,6 (95% CI 1,0 – 2,4) in athletics and 0,7 (95% CI 0,4 – 1,3) in powerlifting. Injuries to this anatomical region were infrequently encountered in other sports (**Table 3.9b**).

The incidence of injuries of the wrist and hand was 3,9 (95% CI 1,4 – 8,5) in goalball, 3,2 (95% CI 1,5 – 6,0) in wheelchair basketball, and 2,8 (95% CI 1,3 – 5,4) in table tennis (**Table 3.9c**).

Table 3.9a: Incidence of shoulder injuries by sport

Sport	Shoulder		
	Number of injuries	IR	95% CI
Athletics	22	1,6	1,0 – 2,4
Swimming	19	2,7	1,6 – 4,2
Powerlifting	20	8,8	5,4 – 13,5
Table tennis	6	1,9	0,7 – 4,1
Wheelchair basketball	8	2,8	1,2 – 5,6
Goalball	1		
Judo	8	5,0	2,1 – 9,8

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

Table 3.9b: Incidence of upper/forearm/elbow injuries by sport

Sport	Upper/forearm/elbow		
	Number of injuries	IR	95% CI
Athletics	22	1,6	1,0 – 2,4
Swimming	4	0,3	0,1 – 0,7
Powerlifting	10	0,7	0,4 – 1,3
Table tennis	4	0,3	0,1 – 0,7
Wheelchair basketball	2	0,1	
Goalball	2	0,1	
Judo	0		

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

Table 3.9c: Incidence of wrist and hand injuries by sport

Sport	Wrist & hand		
	Number of injuries	IR	95% CI
Athletics	10	0,7	0,4 – 1,3
Swimming	8	1,1	0,5 – 2,3
Powerlifting	1		
Table tennis	9	2,8	1,3 – 5,4
Wheelchair basketball	9	3,2	1,5 – 6,0
Goalball	6	3,9	1,4 – 8,5
Judo	1		

CI, confidence interval
IR, incidence rate (injuries/1000 athlete days)

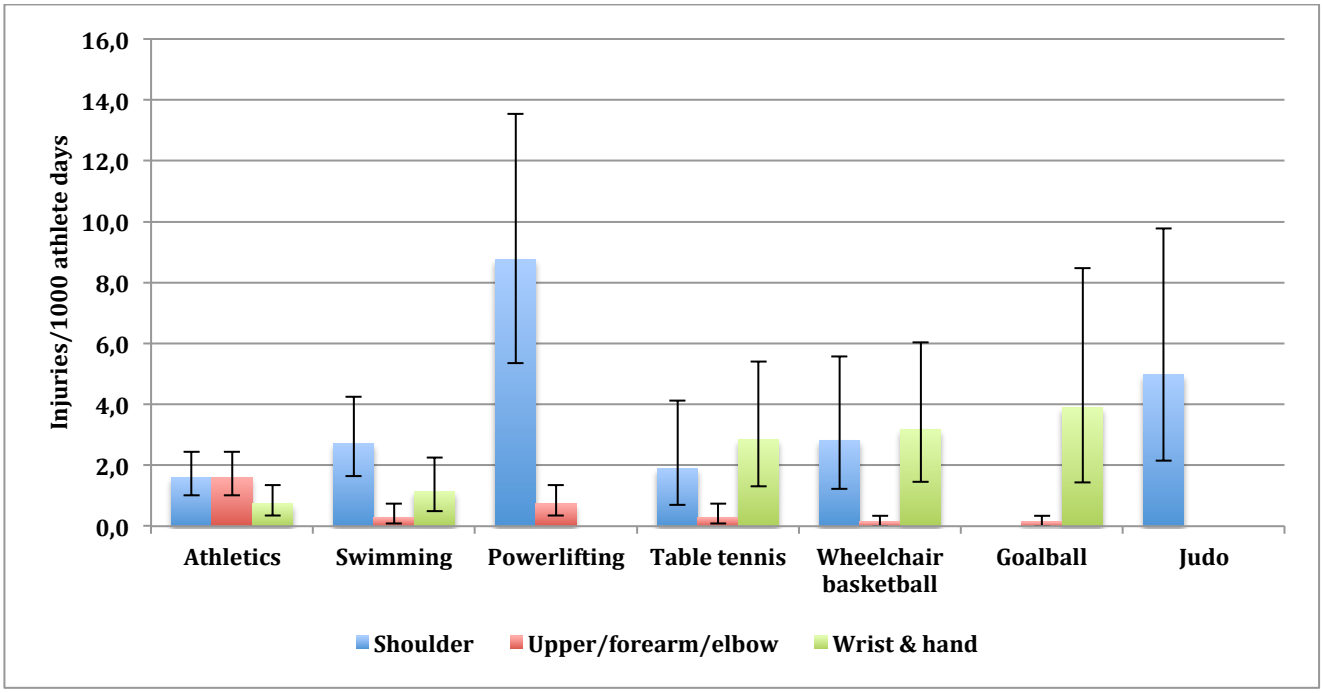

Figure 3.7: Distribution of upper limb injuries by sport (incidence per 1000 athlete days)

3.8.2.8. Upper limb injuries in the pre-games vs. the games period

Although all injury data were collected during the 3-day pre-competition and 11-day competition period of the Paralympic Games (as defined by Derman *et al*, 2013), a substantial proportion of injuries were pre-existing. Non-sport-related and sport-related shoulder injuries occurring prior to the Paralympic Games represented 6,3% and 22,9% of all shoulder injuries. Similarly, non-sport-related and sports-related injuries to the upper arm, forearm and elbow sustained prior to the Games constituted 12,1% and 15,2% of injuries to this region; and non-sport-related injuries and sport-related injuries to the wrist and hand sustained prior to the Games constituted 8,5% and 10,6% of injuries to this anatomical region.

During the total period of the Paralympic Games 31,3% of shoulder injuries, 30,3% of upper arm, forearm and elbow injuries and 25,5% of injuries of the wrist and hand were sustained during the pre-games period in comparison to 33,4%, 36,4% and 42,6% of injuries to each of the above anatomical regions sustained during the competition period. Notably, a small proportion of injuries of

the shoulder (4,2%), upper arm, forearm and elbow (6,1%) and wrist and hand (12,8%) were sustained during the Paralympic Games but were not sport-related (see **Figure 3.8.**). It is important to note that an athlete may not be actively competing during the pre-competition or part of the competition periods of the Games, but may be engaging in training, or non-sport related activities.

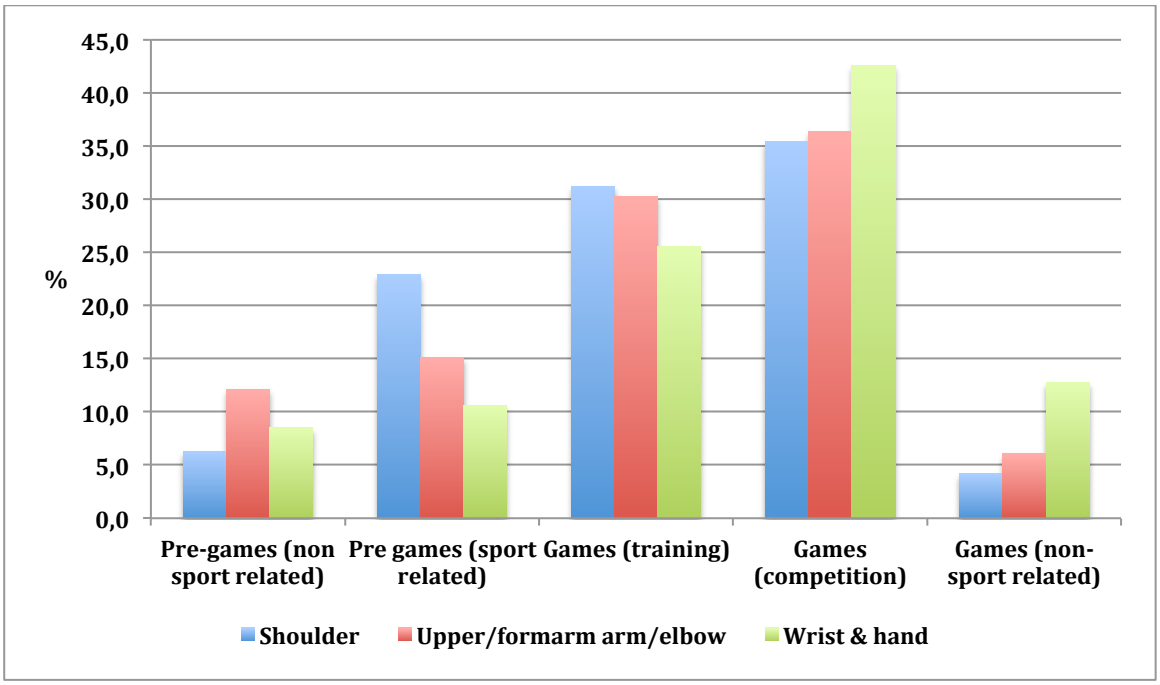

Figure 3.8: Timing of injury by proportion of injuries in each anatomical region (% of upper limb injuries)

3.8.2.9. Severity of upper limb injuries

a. Acute and acute on chronic injuries

The majority of acute and acute on chronic injuries recorded in each anatomical region were classified as medical attention injuries. However, 31,3% of shoulder injuries were time loss injuries (caused the athlete more than 1 day of time lost from sport). This is higher than the 6,1% recorded for upper arm, forearm and elbow injuries, and 12,5% for wrist and hand injuries (**Figure 3.9a**). The severity of time loss injuries (days lost due to injury) is reported in **Figure 3.9b**. These data show that 6,3% of shoulder injuries were classified as “severe”, (more than

28 days lost from sport), while no other injuries were recorded as “severe”; 6,3% of injuries to the wrist and hand were “moderate” (8–28 days lost from sport); and injuries to the upper arm, forearm and elbow were either “minimal” or “slight” (3 days or less lost from sport).

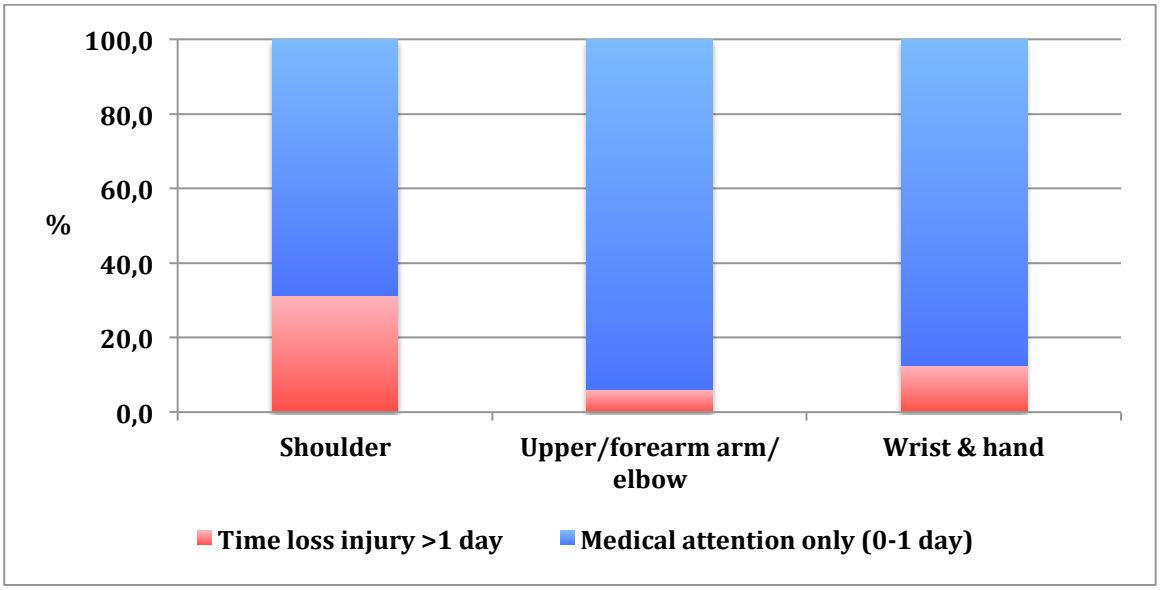

Figure 3.9a: Proportion of injuries resulting in time lost from sport (% of upper limb injuries)

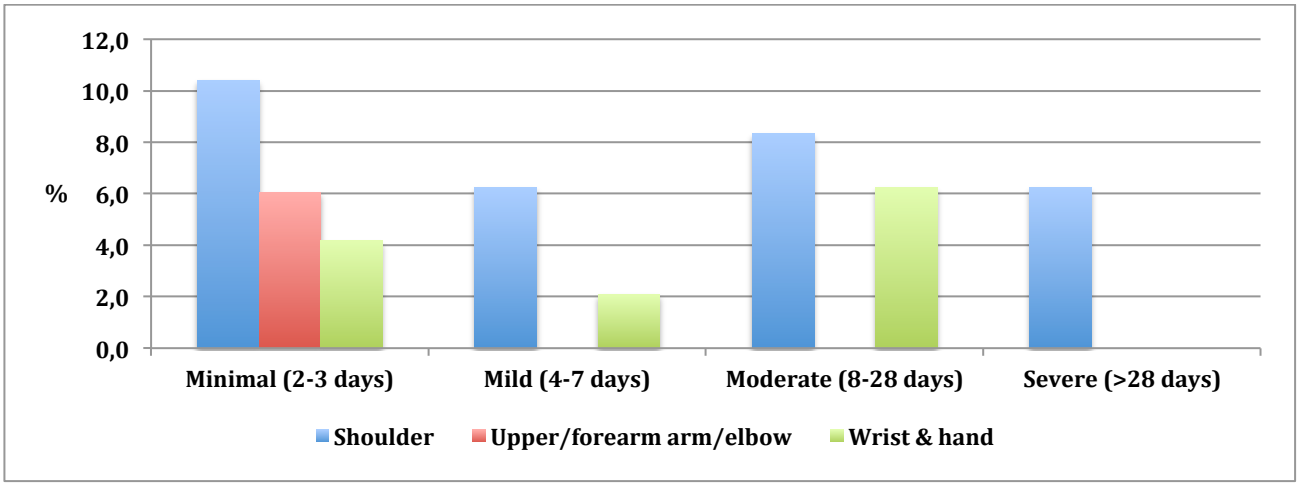

Figure 3.9b: Severity of time loss injuries in terms of time lost from sport (% of upper limb injuries)

b. Chronic injuries

The injury severity (Grade 0-4) was recorded in the 54 of the 104 (52%) chronic upper limb injuries. The proportion (%) of chronic upper limb injuries by severity in the different anatomical regions of the upper limb is depicted in **Figure 3.9c**. Chronic shoulder injuries were recorded as grade 0 in 6,3% of injuries, grade 1 in 50% of injuries, grade 2 in 15,6% of injuries and grade 3 in 3,1% of injuries. Injuries of the wrist and hand showed a bimodal distribution of severity with 33,1% recorded as grade 0, 16,7% as grade 2 and 50,0% as grade 3. There was no predictable distribution of injuries of the upper arm, forearm and elbow.

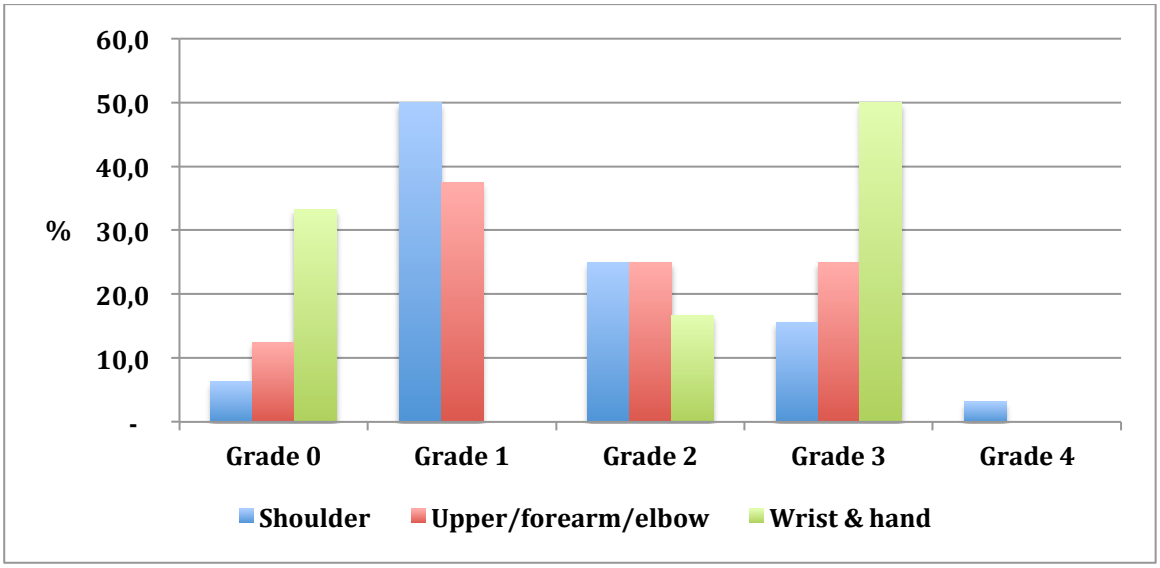

Figure 3.9c: Severity of chronic upper limb injuries (% of upper limb injuries)

3.8.3. Phase 2: Sub-group of upper limb injuries (n=183) by final diagnosis of injury (chronic injuries only), impairment category, requirement for special investigations for injuries, and the mechanisms of injury

3.8.3.1. Details of the final diagnosis in the sub-group (n=54) of athletes with chronic upper limb injuries

Data regarding the final diagnosis was only available in 54 of the 104 chronic upper limb injuries (51,9%). No data on the final diagnosis was available for the acute and acute on chronic injuries. Rotator cuff impingement syndrome (24,1%), lateral epicondylopathy (20,4%), and chronic rotator cuff injury (14,8%) were the most frequently diagnosed chronic upper limb injuries (**Figure 3.10**).

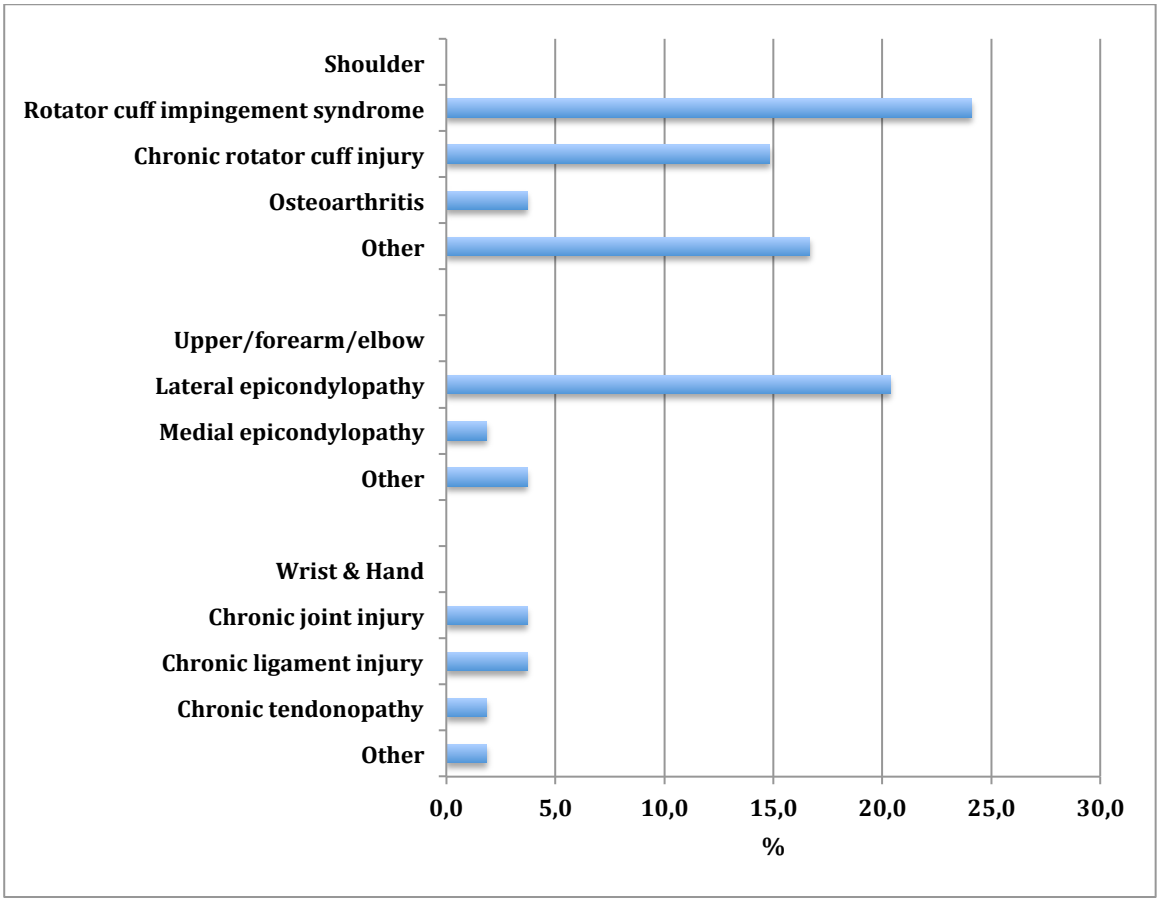

Figure 3.10: Final diagnosis of chronic upper limb injuries (n=54) (data expressed as % of chronic upper limb injuries)

3.8.3.2. Upper limb injuries (n=183) related to category of impairment

The analysis of the distribution of the sub-group of upper limb injuries according to impairment categories **(Figure 3.11)** revealed that 35,0% of shoulder injuries were in athletes with amputation/limb deficiency, and 33,8% were in athletes with spinal cord injury. There were similar proportions of shoulder injuries and injuries of the wrist and hand in athletes with visual impairment.

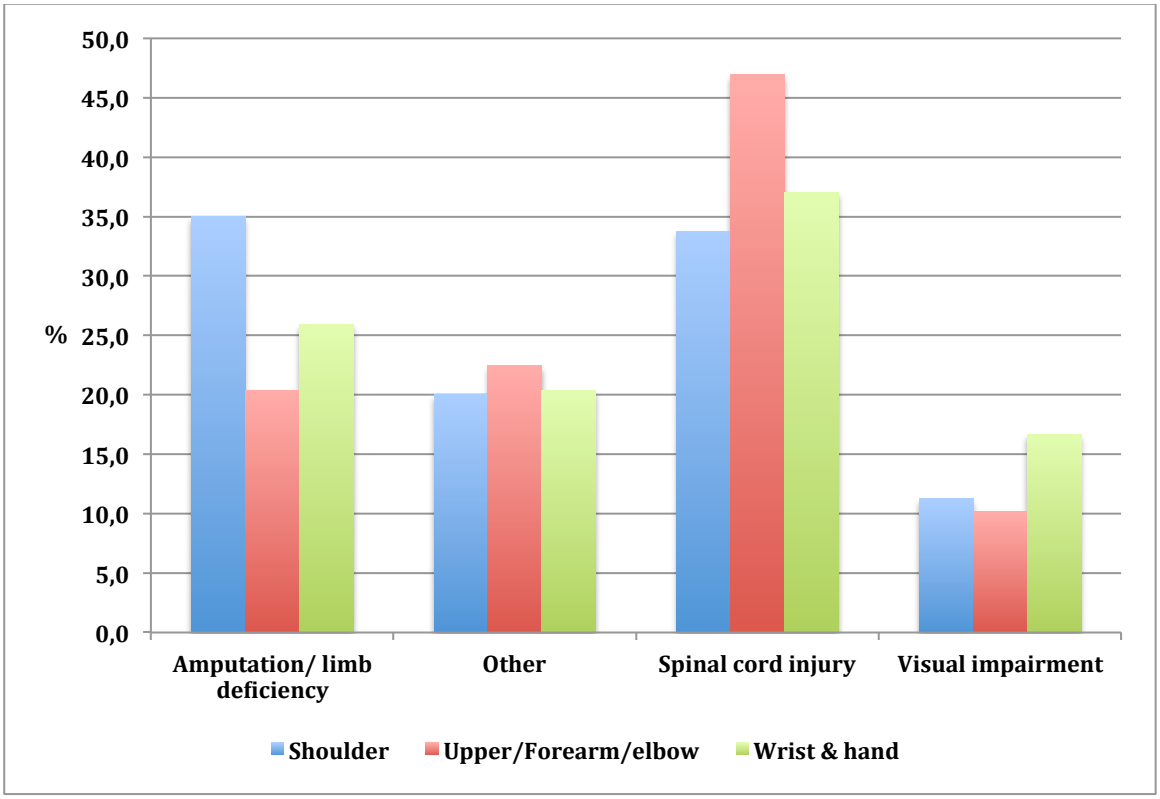

Figure 3.11: Distribution of upper limb injuries by categories of impairment (% of upper limb injuries)

3.8.3.3. The requirement for special investigations in the sub-group (n=183) of upper limb injuries according to the IPC

Fifty percent of shoulder injuries in the sub-group required special investigations, while 20% of injuries of the upper arm, forearm and elbow and 20% of injuries of the wrist and hand required special investigations (**Figure 3.12a**). The choice of

investigations is represented in **Figure 3.12b** and includes X-rays, ultrasound and MRI in the majority of athletes.

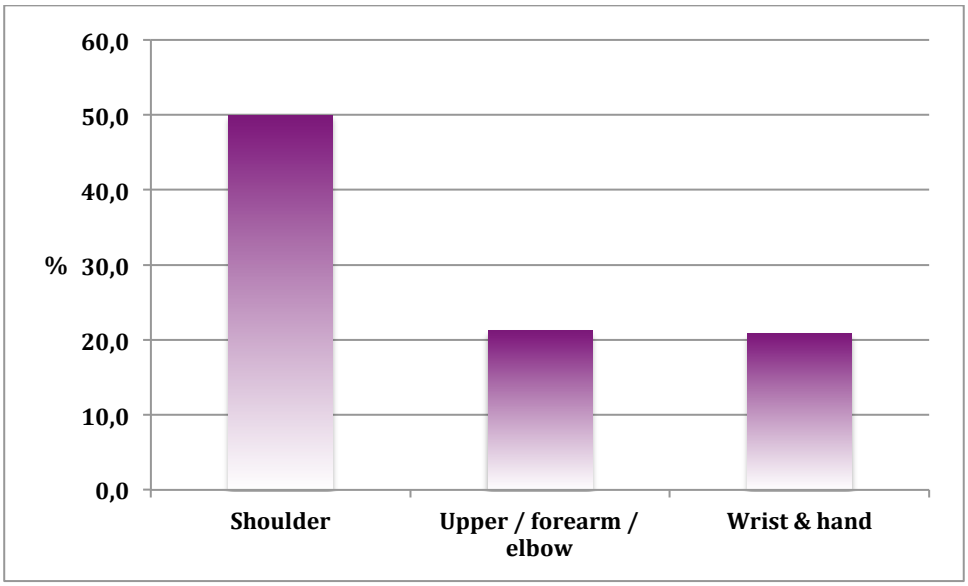

Figure 3.12a: Proportion of injuries requiring special investigations (% of upper limb injuries)

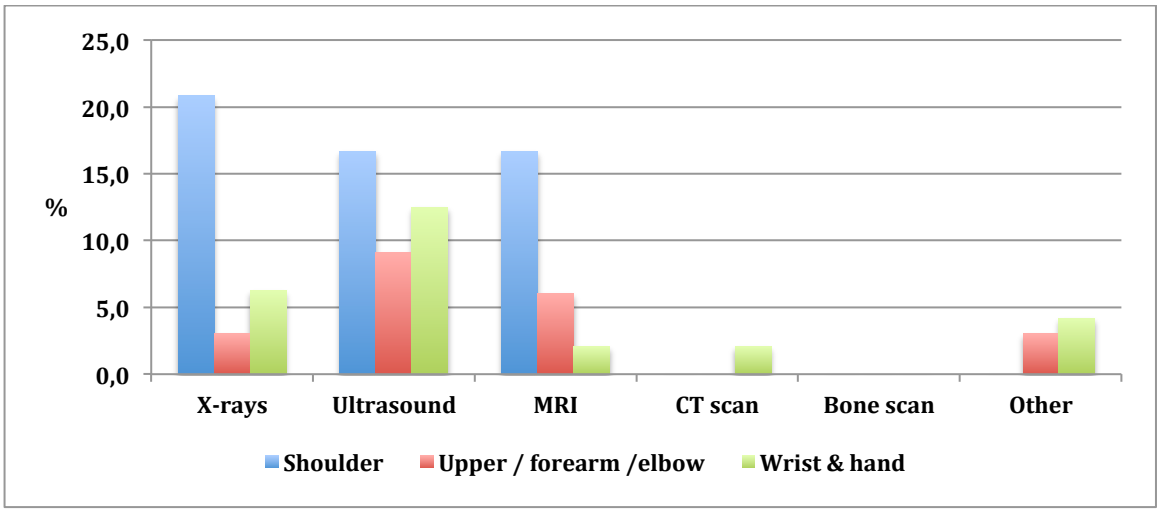

Figure 3.12b: Distribution of special investigations (% of injury to each anatomical region)

3.8.3.4. Mechanism of injury in the sub-group (n=154) of upper limb injuries

Information regarding the mechanism of injury was recorded in 129 of the 154 cases (83,8%) of acute and acute on chronic injuries and is illustrated in **Figure 3.13**.

Shoulder injuries were associated with an intrinsic mechanism in 60,4%, extrinsic mechanism in 20,8% and “Other” mechanism in 18,8% of cases. Similarly, injuries to the upper arm, forearm and elbow were associated with an intrinsic mechanism in 63,6%, an extrinsic mechanism in 18,2% and “Other” mechanism in 18,2% of cases. Injuries to the wrist and hand were associated with an intrinsic mechanism in 45,8%, an extrinsic mechanism in 33,3% and “Other” mechanism in 20,8% of cases.

The distribution of specific intrinsic and extrinsic mechanisms of injury is represented in **Tables 3.10a** and **3.10b**. Notably, wheelchair propulsion and falls constituted the majority of identifiable intrinsic mechanisms; however, a large proportion of injuries were classified as “Other intrinsic” mechanisms (**Table 3.10a**).

The most frequently associated extrinsic mechanisms of injury in athletes with injuries to each anatomical region of the upper limb were contact with another athlete and being struck by sports equipment (**Table 3.10b**).

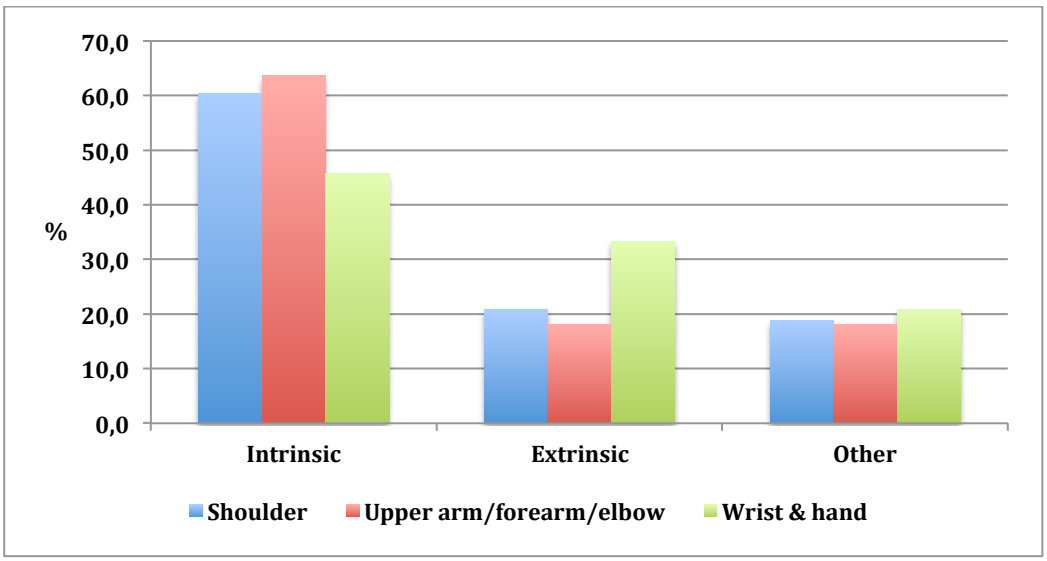

Figure 3.13: Distribution of mechanisms of injury in acute and acute on chronic injuries (% of upper limb injuries)

Table 3.10a: Mechanism of injury - intrinsic

Anatomical region	Running		Pushing wheelchair		Fall - no contact		Other intrinsic	
	n	%	*n*	%	*n*	%	*n*	%
Shoulder	0		4	8,3	6	12,5	19	39,6
Upper arm/forearm/elbow	0		6	18,2	4	12,1	11	33,3
Wrist & hand	1	2,1	10	20,8	3	6,3	8	16,7

Table 3.10b: Mechanism of injury – extrinsic

Anatomical region	Contact with athlete		Struck by ball		Struck by wheelchair		Struck by equipment		Equipment failure	
	n	%	n	%	n	%	n	%	n	%
Shoulder	5	10,4	0		0		3	6,3	2	4,2
Upper/forearm/elbow	2	6,1	0		0		3	9,1	0	0,0
Wrist & hand	4	8,3	5	10,4	3	6,3	3	6,3	0	0,0

3.9. Discussion

3.9.1. Phase 1: Incidence and risk factors associated with upper limb injuries in athletes with impairments

The main findings of Phase 1 of the study were that 1) there were significantly more shoulder injuries in these athletes compared with elbow, wrist or hand injuries, 2) male athletes had a significantly higher incidence of upper limb injuries compared with female athletes, 3) older athletes (> 35 years) had a higher incidence of upper limb injuries, 4) shoulder injuries were mostly chronic injuries, while wrist and hand injuries were of an acute nature, 5) there was an increased proportion of injuries in the competition vs. the pre-competition period, 6) more severe injuries, resulting in greater time loss from sport, occurred in the shoulder, and 7) sports with the highest incidence of upper limb injuries were powerlifting, judo, goalball and wheelchair basketball.

3.9.1.1. Incidence of upper limb injuries

The total number of injuries reported in this cohort of Paralympic athletes was 633 (17,8/100 athletes). This IP is 38% greater than that reported in the athletes participating in the London 2012 Summer Olympic Games (12,9/100 athletes) (Engebretsen *et al*, 2013), and 85% greater than that reported in the athletes participating in the Beijing 2008 Summer Olympic Games (9,6/100 athletes).

Importantly, the anatomical regions most frequently injured also differs – the ratio of upper limb to lower limb injuries in the athletes participating at the London 2012 Paralympic Games was 1,5:1 (7,2/100 athletes: 4,7/100 athletes) (Willick *et al*, 2013), which is five fold greater than the ratio of upper limb to lower limb injuries reported in the athletes participating at the Beijing 2008 Summer Olympic Games of 0,3:1 (2/100 athletes : 5,5/100 athletes) (Junge *et al*, 2009). These findings are also consistent with the higher proportion of injuries reported in the shoulder, elbow, wrist and hand in comparison to other anatomical regions in questionnaire-based studies (Curtis and Dillon, 1985; Ferrara and Davis, 1990; McCormack *et al*, 1991; Ferrara *et al*, 1992a; Ferrara *et al*, 1992b; Taylor and

Williams, 1995; Bernardi *et al*, 2003), retrospective reviews (Burnham *et al*, 1991; Athanasopoulos, 2009), as well as prospective studies (Nyland *et al*, 2000; Ferrara *et al*, 2000; Webborn *et al*, 2006; Webborn *et al*, 2012; Chung *et al*, 2012, Magno e Silva *et al*, 2013a, Derman *et al*, 2013; Willick *et al*, 2013).

3.9.1.2. Upper limb injuries by sex

The significantly increased incidence of upper limb injuries in males in comparison to females in this cohort needs further exploration. Possible confounding variables in this population may include age, sport, and impairment category. We are not aware of any studies that have reported a comparison of the incidence of upper limb injuries in male and female athletes with impairments and the literature is not consistent in demonstrated a male or female preponderance of upper limb injuries. However, various studies have identified gender differences in a variety of able-bodied athletes as well as manual wheelchair users. Greenwald et al (1996) found that males had a higher incidence of impact shoulder injuries than females in alpine skiing. Powell and Barber-Foss (2000) showed a significantly higher injury rate per 100 players in females participating in softball and soccer. Sallis *et al* (2001) found significantly higher incidence of reported injuries in female swimmers and waterpolo players aged 18-20 years. Gutierrez et al (2007) found higher levels of shoulder pain in female manual wheelchair users than their male counterparts. Greater upper body strength in males and the subsequent increased acceleration and deceleration forces placing greater stress on the rotator cuff has been proposed as a reason for increased rates of shoulder injuries in male pitchers (Krajnik *et al*, 2010). Increased range of motion in females has been suggested as a possible reason for higher reported shoulder injury rates in female manual wheelchair users (Wessels *et al*, 2013). The influence of sex hormones on connective tissue has been extensively investigated. Morphological differences in male versus female anterior cruciate ligaments as well as the impact of cyclical hormonal changes has been linked to the increased risk of these injuries in female athletes (Wotjys *et al*, 2002; Lipps *et al*, 2012). The use of anabolic steroids (nandrolone decanoate) has been shown to be detrimental to rotator cuff healing in rabbit

models (Papaspiliopoulos *et al*, 2010). Further analysis is required to determine whether gender is an independent risk factor for upper limb injuries in this population group.

3.9.1.3. Upper limb injuries by age categories

The increasing incidence of shoulder injuries with increasing age is an important finding that is consisting with current literature that demonstrates evidence for increasing rotator cuff pathology with age in the general public (Tashjian, 2012). It has been suggested that rotator cuff pathology may occur as a degenerative process, which increases with age, and is exacerbated by micro or macrotrauma (Tashjian, 2012). This is supported by population-based imaging studies and cadaver-based studies that have demonstrated increased prevalence of rotator cuff tears in older people, even in the absence of symptoms (Lehman *et al*, 1995; Sher *et al*, 1995; Templehof *et al*, 1999; Yamaguchi *et al*, 2006; Yamamoto *et al*, 2010). It is not clear from this study whether older athletes have competed for longer than the younger athletes, which may, in part, explain the increasing incidence of overuse shoulder injuries, and is a variable that should be documented in future studies. The clinical importance of shoulder injuries later in life should also be considered. We are not aware of any studies that have evaluated the long-term sequelae of shoulder injuries in athletes with impairments. However, rotator cuff arthropathy, which may be the result of progressive rotator cuff pathology, is well described in the general population and consists of rotator cuff insufficiency, degenerative changes of the glenohumeral joint, and superior migration of the humeral head (Jensen *et al*, 1999; Ecklund *et al*, 2007). Shoulder function in these individuals is often poor, and the management thereof is challenging and still evolving (Ecklund *et al*, 2007).

3.9.1.4. Type of upper limb injury (acute, acute on chronic, and chronic)

The analysis of the type (by onset) of injury in this cohort demonstrated that chronic shoulder injuries and acute wrist and hand injuries were most frequently encountered. This was made more evident when the age group of the athletes was considered, as chronic shoulder injuries were more frequently observed in

the 35-67 years age group than the 13-25 years age group, and wrist and hand injuries were more frequently observed in the 13-25 years age group than the 35-67 years age group. There is no overall consensus with regards to the frequency of acute versus chronic injuries (Chapter 2). However, the onset of injury appeared to be determined by other factors such as impairment category, and sport (Magno e Silva *et al*, 2013b; 2013c; Webborn *et al*, 2006).

3.9.1.5. Upper limb injuries in the pre-competition and competition period

The distribution of injuries in terms of pre-competition and competition showed an increasing proportion of injuries in the competition period. It is important to note, however, that the athletes are not without risk during training, as well as outside of sporting activities. A substantial proportion of injuries sustained by athletes in this cohort were either “Pre-Games” or “Non-sport related”, highlighting the need to audit training strategies employed, as well as the reasons for sustaining injuries at the Games that are not related to sports participation.

3.9.1.6. Upper limb injuries by severity of injury (time loss from sport)

The majority of injuries in this cohort were medical attention injuries (no loss from training or competition). However, 1 in 3 shoulder injuries caused time away from sport. Furthermore, the more severe upper limb injuries (>28 days away from sport) occurred in the shoulder. It is important to note the severity scale of injuries relied on the estimation of time off sport by the attending physician, which may not have represented the true quantity of time lost from participation. For example, the attending physician may have seen the athlete on day 13 of the 14 day period of the Paralympic Games and prescribed 4 weeks of rest from sporting activity, but would not have validated whether this rest period was adhered to or necessary.

3.9.1.7. Upper limb injuries by sport category

The sports with the highest incidence of upper limb injuries were powerlifting, judo, goalball and wheelchair basketball, and this is in keeping with previously published data (Curtis and Dillon, 1985; McCormack *et al*, 1991; Reynolds *et al*,

1994; Nyland *et al*, 2000; Athanasopoulos, 2009, Willick *et al*, 2013). Athletes participating in these sports, and indeed the technical aspects of the sports themselves, should be the focus of further studies aimed at identifying potential areas for reducing the risk of upper limb injuries.

3.9.2. Phase 2: Upper limb injuries by final diagnosis of injury (chronic injuries only), impairment category, requirement for special investigations for injuries, and the mechanisms of injury

The main findings of Phase 2 of the study were that 1) rotator cuff pathology was the most common specific diagnosis in chronic shoulder injuries, while lateral epicondylopathy was the most common specific diagnosis in chronic elbow injuries, 2) 35,0% of shoulder injuries were most common in athletes with amputation/limb deficiency (35,0%) and in athletes with spinal cord injury 33,8%, 3) 50% of shoulder injuries required special investigations, mostly MRI and ultrasound, 4) the majority of upper limb injuries were attributed to an intrinsic mechanism of injury, but the most frequently associated extrinsic mechanisms of injury in athletes with injuries to each anatomical region of the upper limb were contact with another athlete and being struck by sports equipment.

3.9.2.1. Specific diagnosis of chronic upper limb injuries

Rotator cuff-related pathology was the most frequently reported cause of chronic upper limb injuries in the athletes participating at the London 2012 Paralympic Games. In previous studies, it has been shown that rotator cuff disorders are the most common cause of shoulder related disability in the general population (Chakravarty & Webley, 1993), and are frequently implicated in injuries sustained by upper limb dominant sports such as swimming (Rupp et al, 1995), kayaking (Rupp *et al*, 2004) and throwing sports (Jost *et al*, 2005). It has also been shown that there is a 10-fold increase in the prevalence of rotator cuff pathology in paraplegic individuals in comparison to age and sex-matched controls, confirmed on MRI (Akbhar *et al*, 2010). It follows that these injuries should be prioritized in terms of injury prevention strategies.

3.9.2.2. Upper limb injuries in relation to category of impairment

The categories of impairment that displayed the highest proportion of upper limb injuries included the spinal cord injury and the amputation/limb deficiency groups. These categories likely represent the groups of athletes that depend on the upper limb the most for activities of daily living, and participate in upper limb dominant sports. This is also in keeping with previous reports of increased rates of injuries in wheelchair athletes (Athanasopoulos *et al*, 2009), and in particular, the increased risk of shoulder injuries in wheelchair athletes (Ferrara *et al*, 1992a).

3.9.2.3. Requirement for special investigations of upper limb injuries

Injuries of the elbow, wrist and hand required investigation in 1 in 5 athletes, whereas half of the shoulder injuries required further investigation. The majority of which included X-rays, ultrasound and MRI. The most frequent clinical diagnosis made by the attending physician in this cohort was rotator cuff impingement syndrome, followed by lateral epicondylopathy, and chronic rotator cuff injury. To the author's knowledge, there is no standardized protocol for the investigation of upper limb injuries at the Paralympic Games, and numerous studies discussed in Chapter 2 have reported injuries without the diagnosis confirmed on imaging. However, the importance of imaging, especially in diagnosis of shoulder injuries, is well recognized (Anderson, Brennan, & Mittal, 2012). Radiographs are the recommended first imaging modality to obtain and may reveal anatomical features that predispose the individual to rotator cuff pathology, such as a prominent or "hooked" acromion (Anderson, Brennan & Mittal, 2012). Ultrasound is a valuable, dynamic imaging modality that is portable and inexpensive to perform; however it is highly operator dependent and does not permit subsequent review of the images adequately (Anderson, Brennan & Mittal, 2012). Magnetic resonance imaging (MRI) provides the best overall evaluation of the shoulder, with the addition of an arthrogram is helpful when attempting to evaluate the labrum, and is far less operator dependent than ultrasound (Anderson, Brennan & Mittal, 2012). For athletes in whom MRI is contraindicated, a computerized tomography (CT) arthrogram is valuable

alternative for assessing the rotator cuff, labrum and skeletal structures (Anderson, Brennan & Mittal, 2012). Investigation for lateral epicondylopathy is seldom necessary and can be reserved for atypical clinical findings.

3.9.2.4. Mechanisms of upper limb injuries

The mechanisms for injury are not well researched in athletes with impairments. However, there is some literature on athletes participating in “overhead” and “throwing” sports such as baseball, tennis, swimming and volleyball, which have highlighted the importance of balanced scapulothoracic rhythm and an efficient, sports-specific kinetic chain activation sequence in injury prevention (Lintner, Noonan, & Ben Kibler, 2008). Increasing age, smoking, hypercholesterolemia, and family history have been shown to increase the risk of rotator cuff pathology (Tashjian, 2012). Although these may seem to be chronic diseases of lifestyle, not in keeping with the profile of an athlete, it is important to recognize that every effort to prevent shoulder injuries should be made for athletes with impairments, and, therefore, screening for the above risk factors should be mandatory.

In this cohort, the majority of acute and acute on chronic injuries in each anatomical region of the upper limb were associated with an intrinsic mechanism. This data must be interpreted with caution, since the definition of “intrinsic” and “extrinsic” mechanism did not seem to be clear enough to the attending physician and a substantial number of risk factors were recorded as “other”.

3.9.3. Strengths and limitations of this study

3.9.3.1. Strengths of the study

The main strength of this study is that it is the largest, prospective study to date reporting on upper limb injuries in Paralympic athletes. In addition, in Phase 1 injury rates were reported as injuries per 100 athletes (incidence proportion) and number of injuries per 1000 athlete days (incidence rate) where applicable. There was a high level of compliance to the WEB-IIS system, which was able to capture injury data in more detail than has been possible in previous tournaments. Therefore in Phase 2 of the study, novel data on upper limb injuries could be

reported. Groups of athletes at risk of injury were identified, which will provide some guidance for future research and areas in need of injury prevention strategies.

3.9.3.2. Limitations of the study

The injury severity was graded according to time lost from participation in sport, which was subjectively evaluated by the attending physician at the time of logging the injury. This may not accurately reflect the actual time lost from participation. The definition of intrinsic and extrinsic risk factors appeared to be unclear to a substantial number of physicians and health care providers and did not provide useful information regarding the groups of athletes at risk of injury. The final diagnostic information was not available for acute and acute on chronic injuries. Also, in Phase 2 of the study, only smaller sub-groups of athletes could be studied and it was not possible to validate the final diagnosis by reviewing case history, special investigations and treatment response.

3.10. Summary and conclusion

To date this is the largest study evaluating upper limb injuries at the Paralympic Games. The shoulder is the anatomical region most frequently implicated in upper limb injuries and causes the greatest time lost from sport. Older athletes were at increased risk of chronic shoulder injuries; younger athletes were at increased risk of acute wrist and hand injuries; males, athletes with spinal cord injury or amputation/limb deficiency and athletes participating in powerlifting, judo, goalball or wheelchair basketball were at increased risk of upper limb injuries. This information can be used to target the athletes at risk for further elucidation of the injuries they sustain. Pre-Games assessment, accurate, definitive diagnosis during the Games and the introduction of a standardised score for shoulder function will assist in providing improved diagnostic and injury severity information in future studies. It is hoped that the knowledge gained from this study will provide the initial framework for future research aimed at injury prevention strategies in this population of athletes.

Chapter 4

Summary and recommendations for future studies

The Paralympic Games provides athletes with impairments with the opportunity to accomplish remarkable feats and test the limits of human physiology. These athletes, however, are at greater risk of loss of function than their able-bodied counterparts if they sustain an injury. It is, therefore, imperative that every effort is made to prevent injuries in this group of athletes. In this dissertation, the available literature on upper limb injuries in athletes with impairments was reviewed. Despite large inadequacies, there is a trend to improved quality and quantity of data on the injuries that these athletes sustain.

In the original research component of this dissertation, it has been demonstrated that older athletes are at increased risk of chronic shoulder injuries; younger athletes are at increased risk of acute wrist and hand injuries; males athletes, athletes with spinal cord injury or amputation/limb deficiency and athletes participating in powerlifting, judo, goalball or wheelchair basketball are at increased risk of upper limb injuries. This information will provide guidance for future studies aimed at preventing injuries in the groups of athletes at risk of upper limb injuries.

In future studies, the following are recommended:

1. The upper arm, elbow and forearm should be ungrouped in the data analysis to allow for more meaningful comparison of anatomical regions. Injuries to these 3 anatomical regions are dissimilar and grouping them together will not assist in guiding us in the prevention of injuries in these regions. Also, this grouping has prevented the demonstration of statistical significance in some variables.

2. The final diagnosis needs to be recorded accurately. This may require a pre-Games assessment of the high-risk groups of athletes (for example shoulder assessment in powerlifting, judo and swimming) as well as appropriate use of diagnostic aids such as X-rays, ultrasound and MRI during the Games.
3. Grading chronic injuries according to reproducible/internationally accepted grading method should be considered. The “time loss” grading system is not practical for the physician who will not be able to determine the true duration of time lost from sport for moderate and major injuries. At the next Games, the assessment of shoulder injury may include the use of the Disabilities of the Arm, Shoulder and Hand (“DASH”) score, developed and validated by the Institute for Work and Health and the American Academy of Orthopaedic Surgeons.
4. Impairment categories used for research need to be considered carefully, as large number of IPC categories may make comparisons difficult. Relevant risk factors for upper limb injury need to be evaluated and the definition of intrinsic and extrinsic needs clarification.
5. It is recommended that an attempt be made to better understand the pathophysiological aspects of injury in these athletes. This should start with a literature review on the current theories regarding mechanism of shoulder injuries, and potential risk factors. Classifying risk factors as “intrinsic” or “extrinsic” does not appear to assist in the identification athletes at risk of these injuries.

Finally, it is recommended that the study design for injury surveillance at the next Paralympic Games incorporates the following elements:

1. Prospective data collection using the WEB-IISS
2. Improved participation from all delegations in injury surveillance.
3. The introduction of a standardized upper limb injury severity or impairment score, such as the “DASH” score.
4. Pre-Games surveillance of the shoulder for all athletes in high risk groups, namely, athletes aged 35-67 years, males athletes, athletes with spinal cord injury or amputation/limb deficiency and athletes participating in

powerlifting, judo, goalball or wheelchair sports. This surveillance should be conducted by clinical examination, X-rays and ultrasound.

5. A protocol for the investigation of upper limb injuries during the Games.
6. Injury rates should be reported as number of injuries per 1000 athlete days and number of injuries per 100 athletes.

“The best and most beautiful things in the world cannot be seen or even touched - they must be felt with the heart.”

Helen Keller

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Appendix A - Research Ethics approval
University of Brighton

University of Brighton

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26 August 2011

Dear Dr Webborn

Faculty of Education and Sport Research Ethics and Governance Committee

Study Title: **'Ongoing surveillance of sport injuries and illnesses in Paralympic athletes during the Paralympic Games, starting with the Paralympic Summer Games in London 2012': Principal investigator, Dr. Josep Oriol Martinez.**

Ref: FREGC/ES/12/11

The Faculty of Education and Sport Research Ethics and Governance Committee reviewed the above research proposal at its meeting held on 25 May 2011.

Ethical Opinion

No ethical objections were raised by members of the Committee. The Committee agreed that the research proposed could be considered low-risk, being primarily an audit, with no medical procedures or active interventions proposed. The FREGC asked that the investigating team ensure that protocols are in place for the secure storage and use of data collected during the course of the research.

Yours sincerely

Matthew Warne
Quality Assurance Administrator & Secretary to the FREGC

cc Professor Jo Doust
Head of Chelsea School, UoB and Chair of the FREGC

Appendix B - Research Ethics approval
University of Cape Town

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences
Human Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
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Telephone [021] 406 6338 • **Facsimile** [021] 406 6411
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17 September 2013

HREC REF: 565/2013

Dr M Roussot
c/o Prof M Schwellnus
Division of Orthopaedic Surgery
H-49, OMB

Dear Dr Roussot

PROJECT TITLE: UPPER LIMB INJURIES AT THE LONDON 2012 PARALYMPIC GAMES (linked to 436/2012)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year till the 30th September 2014

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/research/humanethics/forms)

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the HREC. REF in all your correspondence.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN ETHICS
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP) and Declaration of Helsinki guidelines.
The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

L Samuels

17 November 2014

Dear Dr Blauwet and Dr Ramagole

Thank you for the time and effort spent on reviewing my dissertation titled: Upper limb injuries in athletes participating in the London 2012 Paralympic Games. I have included all of your recommendations, as summarized in the table below. Also, thank you for the kind remarks on the quality of the dissertation. I have been fortunate to participate in this research and to have such dedicated supervisors.

Sincerely,

Signed by candidate

Dr Mark Roussot

Template for submission of dissertation corrections/revisions

Candidate:	Mark Roussot
Degree:	MPhil (Sport and Exercise Medicine)
Department:	Human Biology
Title:	Upper limb injuries in athletes participating in the London 2012 Paralympic Games
Supervisors:	Prof Martin Schwellnus and Prof Wayne Derman

Examiner 1 – Dr Cheri Blauwet

	Original dissertation		**Corrected/Revised dissertation**	
1	Comment 1, Ch 1, Page 8, 2nd paragraph	I would recommend avoiding citing reviews (which site original articles) rather than the orginal references themselves. A good example of this is Page 8, 2nd paragraph, in which the Pepper and Willick article is referenced to support the point of physical, psychological, and social benefits of participation. I would prefer to to see here some of the references from the original papers which support this statement.	Now on pg 8, 2nd paragraph	Furthermore, the physical, psychological and social benefits of participating in sports and recreational activities have been well described in individuals with impairment (Bakalim, 1969; Yekutiel *et al*, 1989; Wetterhahn et al, 2002; Yazicioglu *et al*, 2007; Pepper & Willick, 2009) and these benefits have been shown to translate to improvements in quality of life, reduced risk of illness and a decrease in the utilization of hospital resources (Webborn & van de Vliet, 2012; Fernhall *et al*, 2008; Stevens *et al*, 2008; Stotts, 1986).
2	Comment 2, Ch1, page 10, 1st paragraph	On page 10, 1st paragraph, would reference the IOC injury surveillance articles noting the predominance of lower limb injuries in athletes without impairments (as you do later in the dissertation).	Now on pg 10, 1st paragraph	High quality injury surveillance is required to determine the incidence and severity of injuries in athletes with impairments and thereby forms an important, initial step in the development of sports injury prevention strategies (Webborn & van de Vliet, 2012,

				Junge *et al*, 2008; Junge *et al*, 2004; Derman *et al*, 2013). For the first time, comprehensive injury and illness surveillance was conducted at the London 2012 Paralympic Games using novel data capture technology (Willick *et al*, 2013, Derman *et al*, 2013). From this surveillance, it was shown that the upper limb is the predominant anatomical region injured in Paralympic athletes and this is in contrast to previous findings of the predominance of lower limb injuries in athletes without impairment (Junge *et al*, 2009; Webborn & van de Vliet, 2012; Jacobsson *et al*, 2013).
3	Comment 4, page 15, 2nd paragraph	Given that the Ferrara 2000 study seems quite good (prospective, lingitudinal), I would like to know more about how this data was collected. Via medical encounter forms? Athlete self-report?	Now on Pg 15, 2nd paragraph	In one of the first prospective cohort studies, it was reported that 12,8% of all injuries sustained by 1,360 US athletes with impairments participating in the 1990 World Games and Championships, 1991 US Paralympic Trials, 1992 Paralympic Games, 1994 World Athletics Championship, and the 1996 Paralympic Games involved the shoulder (Ferrara *et al*, 2000). The only other anatomical region implicated in injury more frequently than the shoulder in this study, was the thorax/spine (13,3% of injuries). In this study, team medical staff recorded medical encounters and a reportable injury was defined as any injury/illness that was evaluated by the US Medical Staff during these competitions (Ferrara *et al*, 2000).
4	Page 17, 3rd paragraph	Would also reference the IOC surveillance articles noting predominance of lower limb injuries in athletes without impairment	Now page 17 3rd paragraph	In this study, the overall incidence of injury and illness was reported in 3,565 of the 4,176 athletes at the Games (85,4%) and 49,910

				athlete-days of exposure. The results showed that Paralympic athletes sustain 12,7 injuries per 1000 athlete days and 13,2 illnesses per 1000 athlete days (Derman *et al*, 2013). Most injuries were acute and the highest incidence rate was seen in upper limb injuries. Injuries were further described in relation to sport, anatomical region and onset, reporting the highest incidence rates of injury in the shoulder (2,3/1000 athlete days) followed by the wrist and hand (1,4/1000 athlete days), elbow (1,1/1000 athlete days) and knee (1,0/1000 athlete days) (Willick *et al*, 2013). This demonstrates a predominance of upper limb injuries in Paralympic athletes in contrast to the predominance of lower limb injuries that has been reported in able-bodied athletes (Junge *et al*, 2009; Webborn & van de Vliet, 2012; Jacobsson *et al*, 2013). While these studies represent the largest injury surveillance conducted at the Paralympic Games thus far, there are still limitations: under-reporting of injuries is still possible; and the WEB-IISS was not the only system used to collect data, which necessitated collation of databases and deletion of duplicates.
5	Page 18	For Magno e Silva papers, would note where there injuries were UE vs LE, or not specified.	Now on pg 16, 3rd paragraph	In three separates publications, injuries encountered in 40 Brazilian track and field athletes (2013a), 13 male Brazilian football 5-a-side athletes (2013b), and 28 Brazilian swimmers (2013c) all with visual impairment and participating in a number of tournaments

				were reported (Magno e Silva *et al*.) The results of these cohort studies showed that shoulder injuries were the most common site of injury in the visually impaired swimmers (29,3% of all injuries in this group) (Magno e Silva *et al*, 2013a), while the lower limb was most frequently injured in football 5-a-side athletes (80% of injuries in this group) (Magno e Silva *et al*, 2013b) and in track and field athletes (87% of injuries in this group) (Magno e Silva *et al*, 2013c). AND Now on page 18 - 19	AND **2.3.3 Onset (acute, chronic or acute on chronic) of upper limb injuries in athletes with impairments** **2.3.3.1. Introduction** The majority of the studies reviewed were able to report the frequency of acute and chronic injuries encountered and some included acute on chronic injuries. Few of the studies, however, defined the terms acute, acute on chronic, and chronic injuries, and **no studies reported the onset upper limb injuries specifically**. **2.3.3.2. Acute injuries** Acute injuries were reported as most common in 7 studies with proportions as high as 80% overall in football 5-a-side for visually impaired Brazilian athletes (Magno e Silva *et al*, 2013b) and incidence rate as high as 6,6 injuries per 1000 athlete days reported in the

				2012 Summer Paralympic Games (Derman *et al*, 2013). Of note, only 5,7% of all injuries in the Brazilian football 5-a-side cohort involved the upper limb (Magno e Silva *et al*, 2013b). **2.3.3.3. Chronic injuries** Chronic injuries were reported as most common in a further 7 studies with proportions as high as 80% in visually impaired Brazilian Paralympic swimmers where the authors also reported that 34% of all injuries in this cohort involved the upper limb (Magno e Silva *et al*, 2013a). Webborn *et al* (2006) reported that 83,3% of chronic injuries involved the upper limb in a cohort of 416 athletes participating in the 2002 Winter Paralympic Games. **2.3.3.4. Acute on Chronic** The proportion of acute on chronic injuries encountered in all sports at the 2010 Winter Paralympic Games was 0,8% (Webborn *et al*, 2012), and the overall incidence rate of 2,2 injuries per 100 athlete days was reported at the London 2012 Paralympic Games (Derman *et al*, 2013). **2.3.3.5. Summary: Onset of upper limb injuries in athletes with impairments** There are no studies where the onset of **upper limb injuries** in terms of incidence rate with adequate definitions of "acute", "chronic" and "acute on chronic" injuries has been reported.
6	Page 22, 3rd paragraph	Would state "reproduced these findings" rather than "confirmed this"	Now of pg 22, 3rd paragraph	**2.3.5.6. Summary: Upper limb injuries in athletes with impairments related to type of**

				sport There is a paucity of literature reporting specifically on the incidence of upper limb injuries in relation to type of sport. The sports most frequently implicated include athletics, wheelchair sports, swimming, goalball, powerlifting and judo. A large, prospective cohort of 3,565 athletes at the London 2012 Paralympic Games has recently reproduced these findings.
7	Page 25, 5th paragraph	Would state "may" rather than "appear to" given that this is data from only 1 study	Now on pg 26 1st paragraph and pg 26, 1st paragraph	Prospective epidemiological data on injuries in athletes with impairments has become more abundant in recent times, especially since the introduction of standardized injury surveillance systems. The upper limb, and more specifically, the shoulder, has been implicated as the anatomical site of injury in numerous studies. The sports with the highest reported frequency of injuries are athletics, powerlifting, football 5-a-side, wheelchair-based sports, swimming, judo and goalball. Collisions with another athlete, the ground or sport equipment may be the most frequent cause of injuries.
8	Page 38, 2nd paragraph	Similar to prior comments, would reference the IOC injury surveillance articles noting predominance of lower limb injuries in athletes without impairment	Now on pg 38, 2nd paragraph	For the first time a comprehensive injury and illness surveillance study was conducted at the London 2012 Paralympic Games using novel data capture technology. (Derman *et al*, 2013). During this study it was shown that the upper limb was the predominant anatomical region injured in Paralympic athletes in contrast to studies that have demonstrated the predominance of lower limb injuries in

				able-bodied athletes (Junge *et al*, 2009, Webborn & van de Vliet, 2012; Jacobsson *et al*, 2013; Willick *et al*, 2013; Derman *et al*, 2013).
9	Page 39, 2nd paragraph	Would reference the first sentence of this paragraph, noting which studies have showed improved methodology	Now on pg 39, 2nd paragraph	There has been a lack of standardization of upper limb injury definitions and determinants of severity; however, the methodologies in more recent studies have improved (Webborn *et al*, 2012; Magno e Silva *et al*, 2013; Willick *et al*, 2013; Derman *et al*, 2013). The literature is still markedly deficient in the identification of risk factors associated with upper limb injuries in athletes with impairments. Furthermore, there is a paucity of data on the clinical features, investigation and treatment of injuries, and prevention strategies for these athletes.
10	Page 43, 1st paragraph	Would take this opportunity in the paragraph on inclusion/exclusion criteria to define what you mean by "upper limb". This becomes more apparent later in the manuscript (shoulder and distal) however readers will want this information right up front in the methodology	Now on pg 43, 1st paragraph	All medical encounters whereby athletes presented with complaints or injuries pertaining to the upper limb (from and the including the shoulder girdle to and including the digits of the hand) were included in the analysis (Phase 1 and 2). A medical encounter was defined as any athlete who received medical attention regardless of the consequences with respect to absence from competition or training.
11	Page 43	Would recommend changing the title to "Definitions of Injury and Severity," which is more clear.	Now on pg 43	**3.4. Definitions of Injury and Severity**
12	Page 45, 1st paragraph	What do you mean by "as deemed appropriate?"	No on page 45, 3rd paragraph	**3.7. Statistical analysis of data** The data were analysed using standard analysis methods. Standard descriptive statistical analysis was conducted and

				included: numbers, means, proportions/percentages, and incidence (where applicable). Incidence proportion (IP) was defined as the number of injuries per 100 athletes during the study period. Incidence rate (IR) was defined as the number of injuries per 1000 athlete days for the study period. The 95% confidence interval (CI) is reported and was used to determine significant differences in the incidence data.
13	Page 49, 1st paragraph	Would state why these age groups were used. Easiest way would be to state, "As per prior definitions, the participants were grouped…" And then reference the Derman BJSM paper that desribes the Paralympic ISS methodology	No on pg 49, 1st paragrph	**3.8.2.3. Incidence of upper limb injuries by age groups** The participants were grouped into age categories (as per prior definitions by Derman *et al*, 2013) as follows: 13-25 years, 26-34 years and 35-67 years. Shoulder injuries showed an increasing incidence with age. The 35-67 year age group showed an IR of 2,8/1000 athlete days (95% CI 2,05 – 3,7), significantly higher than the IR of 1,3/1000 athlete days (95% CI 0,8 – 2,01) recorded in the 13-25 years age group. However, the IR of injuries of the wrist and hand were similar across all age groups, as were injuries of the upper arm/forearm and elbow (see Tables 3.5a, 3.5b, 3.5c, Figure 3.2).
14	Page 53, 1st paragraph	This states that the IR of of chronic shoulder injuries was significantly higher than acute shoulder and any other chronic. The CI's have .1 overlap here. Are you still counting that as significant? If so – may want to say in the methodology section what you are defining as significant/not significant	No on page 53, 1st paragraph	**3.8.2.6. Incidence of type of injury (acute, acute on chronic and chronic) by sex and age** The incidence of upper limb injuries was analyzed by type of injury (acute, acute on chronic and chronic) and by sex and the age groups of the participants. In males, there was a higher IR of acute wrist

				and hand injuries (1,1/1000 athlete days, 95% CI 0,8 – 1,6), compared with chronic wrist and hand injuries and any other acute injury of the upper limb. Similarly, the IR of chronic shoulder injuries (1,3/1000 athlete days, 95% CI 0,9 – 1,8) was a higher compared with acute shoulder injuries and any other chronic injury of the upper limb (Tables 3.7a, 3.7b, 3.7c and Figure 3.4).
15	Page 62, 1st paragraph	You note data collection in the pre-competition vs. competition period. Have these terms previously been defined would be worth adding this to methodology so that it is clear here. Important to note that and athlete may not be actively competing and yet still be in "competition period" for the purpose of this study (ex: marathoner who has no events until the last day of the Games).	Now on pg 62, 2nd paragraph	During the total period of the Paralympic Games 31,3% of shoulder injuries, 30,3% of upper arm, forearm and elbow injuries and 25,5% of injuries of the wrist and hand were sustained during the pre-games period in comparison to 33,4%, 36,4% and 42,6% of injuries to each of the above anatomical regions sustained during the competition period. Notably, a small proportion of injuries of the shoulder (4,2%), upper arm, forearm and elbow (6,1%) and wrist and hand (12,8%) were sustained during the Paralympic Games but were not sport-related (see Figure 3.8.). It is important to note that an athlete may not be actively competing during the pre-competition or part of the competition periods of the Games, but may be engaging in training, or non-sport related activities.
16	Page 67, 1st paragraph	May want to consider changing the phrase "IPC impairment categories" given that you are then presenting a table that has various disabilities such as amputation, SCI, VI, which are n ot the official IPC impairment categories but rather more broad disability categories	Now on pg 67, 1st paragraph	**3.8.3.2. Upper limb injuries (n=183) related to category of impairment according to the IPC** The analysis of the distribution of the sub-group of upper limb injuries according to impairment categories (Figure 3.11) revealed

				that 35,0% of shoulder injuries were in athletes with amputation/limb deficiency, and 33,8% were in athletes with spinal cord injury. There were similar proportions of shoulder injuries and injuries of the wrist and hand in athletes with visual impairment.
17	Page 67, figure 3.11	Text notes that there was an "equal proportion of shoulder injuries and injuries to the wrist/hand in athletes with VI" – however the bars on the table do not match	Now on pg 67, figure 3.11	*See text above*
18	Page 76, 2nd paragraph	Section regarding MR arthrogram – would re-consider making such a definitive statement regarding use of arthrogram given that for some pathologies it will be helpful whereas for others it will not provide additional insight. One idea would be to change to "MRI provides the best overall evaluation of the shoulder, with use of an arthrogram additionally helpful when attempting to evaluate the labrum."	Now on pg 76, 2nd paragraph	Magnetic resonance imaging (MRI) provides the best overall evaluation of the shoulder, with the addition of an arthrogram is helpful when attempting to evaluate the labrum, and is far less operator dependent than ultrasound (Anderson, Brennan & Mittal, 2012).
19	Page 78, 2nd paragraph	Recommend adjusting to "physicians and health care providers" given that non-MD medical staff could also log encounters in London.	Now on pg 78, 2nd paragraph	**3.9.3.2. Limitations of the study** The injury severity was graded according to time lost from participation in sport, which was subjectively evaluated by the attending physician at the time of logging the injury. This may not accurately reflect the actual time lost from participation. The definition of intrinsic and extrinsic risk factors appeared to be unclear to a substantial number of physicians and health care providers and did not provide useful information regarding the groups of athletes at risk of injury. The final diagnostic information was not available for acute and acute on chronic injuries. Also, in Phase 2 of the study, only smaller sub-groups of athletes could be studied and it was not possible to validate the final diagnosis by

				reviewing case history, special investigations and treatment response.
20		Overall very good – moderate ampount of typos as noted below. Otherwise clearly written and easy to follow.		*Typos corrected as instructed.*

Examiner 2 – Dr DA Ramagole

	Original dissertation		**Corrected/Revised dissertation**	
1	Comment d), pg 10 and 13	Presentation is excellent. The graphical presentations are also very neatle done, and accurate. There are just a few grammatical erros in Page 10 sentence 4, and Pge 13 on phrasing of paragraphs 2 and 3. The sentances need small corrections.	No on pg 10 and 13	*Thank you for these comments. Grammitical errors corrected as suggested, and in accordance with comments from Dr Blauwet.*

Student signature: _____ **Date:** _____