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Acute and Chronic Musculoskeletal Injury in Para Sport: A Critical Review

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Synopsis

The many health benefits associated with sports participation are well-documented, and include reduced risk of lifestyle-related disease, improved mood, and enhanced quality of life. However, sport also carries an inherent risk of injury. Sport-related injury patterns among Para athletes have been described with increasing frequency since the 1980's. This critical review summarizes data from 47 fulltext manuscripts that describe musculoskeletal injuries in Para athletes. Seated Para athletes sustain upper extremity injuries more commonly, while ambulant Para athletes frequently sustain lower extremity injuries. The upper extremity, including shoulder, elbow, and wrist/hand, is the most commonly injured anatomical area in all Para athletes, unlike able-bodied athletes for whom lower extremity injuries predominate. Increased age and spinal cord injury may increase risk of upper extremity injury. Sprains, strains, blisters and lacerations are the most common injuries among Paralympians, and winter Paralympic sports carry higher risk of head injury, fracture and contusion, possibly due to the high-velocity elements. Male and female summer Paralympic athletes have similar overall injury rates, and Football 5-a-side, Para powerlifting, Goalball, Wheelchair fencing, and Wheelchair rugby are consistently the highest-risk sports. Para ice hockey, alpine skiing, and snowboarding are the highest-risk winter sports. Upper and lower extremity injury rates match in winter sport, unlike summer sport trends. Injury data for recreational and youth Para athletes are sparse. Summarizing current injury epidemiology data may help accelerate the development of injury prevention strategies and lifetime injury models for Para athletes.

Key Points (3-5):

1. Seated Para athletes sustain upper extremity injuries more commonly, while ambulant Para athletes frequently sustain lower extremity injuries.
2. The upper extremity is the most commonly injured anatomical area in all Para athletes, unlike able-bodied athletes for whom lower extremity injuries predominate, but minor soft tissue injuries are the most common injuries among Para athletes, similar to injury patterns observed among able-bodied athletes.
3. Football 5-a-side, Para powerlifting, Goalball, Wheelchair fencing, and Wheelchair rugby are consistently the highest-risk summer Paralympic sports while Para ice hockey, Para alpine skiing, and Para snowboarding are the highest-risk winter Paralympic sports.
4. Compared to elite Para athletes, recreational and youth Para athletes remain under-studied in the literature.

Key Words (5-8): Injury epidemiology, musculoskeletal injury, Paralympic sport, Para athlete, review

Introduction

Congenital and acquired disabilities increase baseline risk of lifestyle-related disease:[1] obesity and its attendant medical comorbidities are nearly four times higher among those with disabilities compared to the general population.[2,3] Physical activity and sport are thus important preventive health strategies for persons with impairment.[4] The term 'Para athlete' is the International Paralympic Committee's (IPC) general term for sportspersons with impairment, and signifies athletes who compete at all levels. Similarly, the term 'Para sport' encompasses both recreational and elite levels of competition. In contrast, the terms 'Paralympian' and 'Paralympic sport' connote the highest level of international competition, the Paralympic Games. Thus, Paralympians are a sub-set of Para athletes who have competed at the Paralympic Games. Over the past decade, sport for Para athletes has increased in popularity and visibility.[5,6] Like their able-bodied counterparts, Para athletes may enjoy the well-documented health benefits of increased physical activity.[1,7-13] Sport has a particularly positive impact on mental health indices for athletes with impairment, including life purpose, self-acceptance and autonomy, whilst it also reduces healthcare costs.[14,15]

All sports carry an inherent risk of injury and this is no different for Para sport.[16,17] Musculoskeletal injury epidemiology among Para athletes is similar to able-bodied sports injury patterns e.g. strains, sprains, contusions and lacerations are most common.[18-22] However, the biomechanics of Para athlete injury are Para sport specific and relate to impairment, level of competition, mechanism, anatomical area and equipment-specific factors.[23-28]

The aim of this critical review is to summarize current literature on the epidemiology of musculoskeletal injuries in Para athletes, and to discuss apparent research gaps.[29-31]

Methods

Five electronic databases were searched between May 31 and June 21, 2017, for relevant articles: Ovid Medline (1946 to June Week 2, 2017), Ovid Medline In Process & Other Non-Indexed Citations, Ovid Embase (1974 to 2017 June 15), Cumulative Index to Nursing and Allied Health (CINAHL) and Web of Science. Controlled vocabulary and free text terms were used. The Yale MeSH Analyzer (http://mesh.med.yale.edu) was used in the initial stages of strategy formulation to harvest controlled vocabulary and keyword terms from highly relevant, known articles. The search strategy for Ovid MEDLINE is documented in Appendix 1.

Inclusion criteria were (a) written in the English language; (b) published in a peer-reviewed journal or book between January 1975 and June 2017; (c) inclusive of athletes with impairment participating in recreational or elite Para sports; and (d) describe sports-related injury/injuries to the musculoskeletal system including acute traumatic and/or chronic overuse injury to the appendicular and/or axial skeleton. Exclusion criteria were (a) non-English; (b) non-inclusive of athletes with impairment; (c) focused on injury/pathology unrelated to sports; (d) review(s).

Prior to the removal of duplicate articles, the search yielded a total of 993 citations. This was reduced to 871 following the removal of duplicate records using the duplicate detection function

of EndNote X7. Citations with abstracts were ingested into Covidence, a screening and data extraction tool. Two screeners selected 174 records for fulltext review, of which 47 citations were selected based on predefined inclusion/exclusion criteria (see Figure 1).

A number of analyses utilized retrospective data within a cross-sectional study design. For example, a cohort of athletes competing at a single tournament may have been asked to report demographic data, describe their impairment(s), and recall past musculoskeletal injuries, in a single survey administered at a single point in time. In these instances, for the sake of consistency, we have designated these studies ‘cross-sectional,’ which refers to the study design. Table 1 summarizes study characteristics for all fulltext articles included in the review.

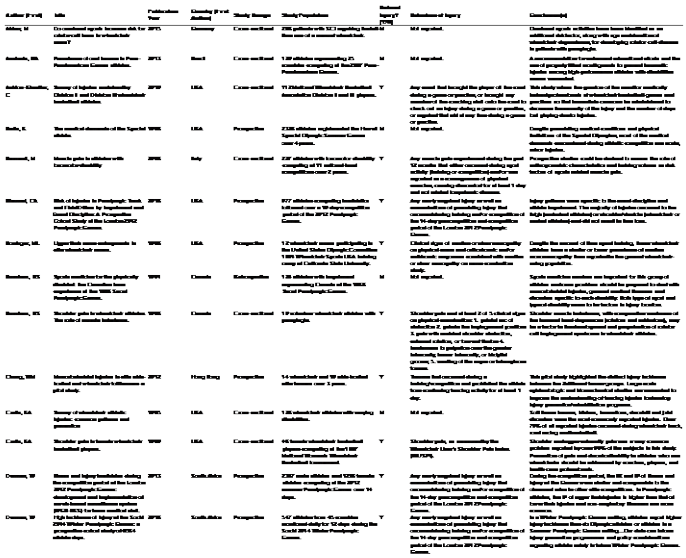

Table 1. Study Characteristics

Results

Summary of Search Results

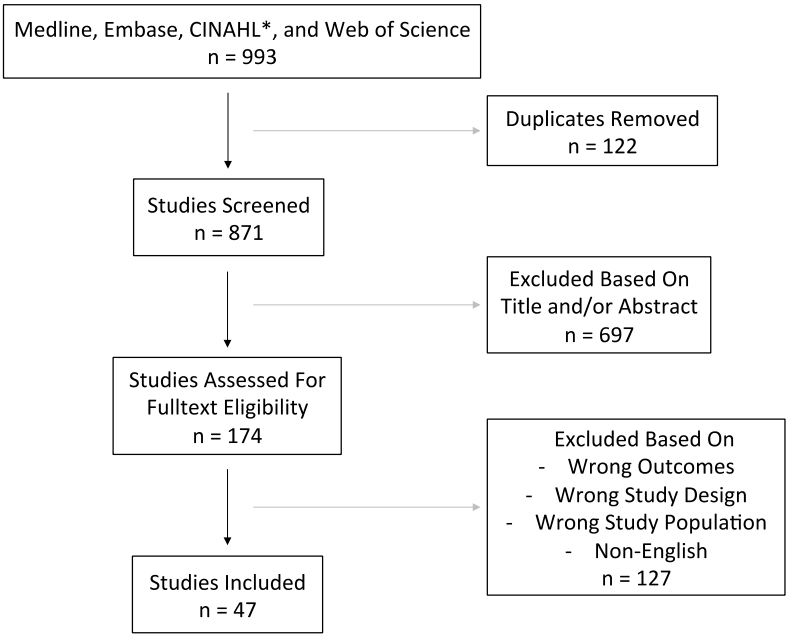

Figure 1. Summary of Search Results
*Cumulative Index to Nursing and Allied Health

Eligible Impairment Categories

Historically, the IPC organized athlete impairment categories in the same way a clinician might, by diagnosis: spinal cord related disability, cerebral palsy, amputee or limb deficiency, and visual impairment. Athletes with physical impairments not fitting these categories were classified as 'Les Autres' (the others Fr.). Athletes with an intellectual impairment were later included, as well.[32,33] Recently, the impairment classification system was revised; categories now reflect the impact of the impairment on sport-specific function and are summarized in Table 2.[34]

Impairment Category		Description
Physical Impairment		
	Impaired muscle power	Reduced force generated by muscles or muscle groups, such as muscles of one limb or the lower half of the body, as caused, for example, by spinal cord injuries, spina bifida or polio
	Impaired passive ROM	ROM in one or more joints is reduced permanently, for example due to arthrogryposis. Hypermobility of joints, joint instability, and acute conditions, such as arthritis, are not considered eligible impairments
	Limb deficiency	Total or partial absence of bones or joints as a consequence of trauma (e.g. car accident), illness (e.g. bone cancer) or congenital limb deficiency (e.g. dysmelia)
	Leg length difference	Bone shortening in one leg due to congenital deficiency or trauma
	Short stature	Reduced standing height due to abnormal dimensions of bones of upper and lower limbs or trunk, for example due to achondroplasia or growth hormone dysfunction
	Hypertonia	Abnormal increase in muscle tension and a reduced ability of a muscle to stretch, due to a neurological condition, such as cerebral palsy, brain injury or multiple sclerosis
	Ataxia	Lack of co-ordination of muscle movements due to a neurological condition, such as cerebral palsy, brain injury or multiple sclerosis
	Athetosis	Generally characterized by unbalanced, involuntary movements and a difficulty in maintaining a symmetrical posture, due to a neurological condition, such as cerebral palsy, brain injury or multiple sclerosis
Visual Impairment		Vision is impacted by either an impairment of the eye structure, optical nerves or optical pathways, or the visual cortex
Intellectual Impairment		A limitation in intellectual functioning and adaptive behavior as expressed in conceptual, social and practical adaptive skills, which originates before the age of 18

https://www.paralympic.org/classification

Table 2. International Paralympic Committee Eligible Impairment Categories

In the literature, sport-related injury patterns have been organized by impairment-type, sport, and/or season (summer versus winter), among other factors. This discussion will refer to updated impairment categories as often as possible, and will organize sport-related injury epidemiology by season.

General Injury Trends in Summer and Winter Para Sports

During both summer and winter sports, seated Para athletes generally sustain upper limb injuries more commonly, while ambulant Para athletes frequently sustain lower extremity injuries

(Figure 2).[26,29,35,36] The upper extremity, including the shoulder, elbow, and wrist/hand, is the most commonly injured anatomical area in all Para athletes,[19,26,29,37-39] unlike able-bodied athletes for whom lower extremity injuries predominate.[37] Increased age and spinal cord injury may increase the risk of upper extremity injury, generally, and shoulder muscle imbalance (comparative weakness of the shoulder rotators and adductors) may contribute to seated athletes' shoulder pathology.[31,40] Male and female summer Para athletes typically have similar overall injury rates[41] but certain sporting environments carry higher risk. In the summer Paralympic Games setting, Football 5-a-side, Para powerlifting, Goalball, Wheelchair fencing, and Wheelchair rugby consistently have high injury rates,[41,42] with Football 5-a-side carrying the highest overall risk (Figure 3).[42,43] Polish scientists have demonstrated that mandatory periodic health evaluations in the lead up to summer Paralympic Games may result in reduced overall injury rates, and improved performances.[44]

Figure 2. Seated Para athletes generally sustain upper limb injuries more commonly, while ambulant Para athletes frequently sustain lower extremity injuries.

Overall injury incidence rate (IR) at the Sochi 2014 winter Paralympic Games was two times higher than the IR at the London 2012 summer Paralympic Games.[45] While sprains, strains, blisters and lacerations are the most common injuries among all Paralympians,[19] winter Paralympic sports generally carry a higher risk of head injury, fracture, and contusion, possibly due to the high-velocity elements of competition.[45] Of note, high-velocity Para cycling (a summer sport) also poses this risk.[46-48] Para ice hockey (formerly called ice sledge hockey), Para alpine skiing, and Para snowboarding are particularly high-risk winter sports; Para alpine skiing/snowboarding has the highest injury risk (see Figure 3).[45]

As Webborn *et al.* have shown, certain injuries can be controlled by the introduction of sport-specific equipment regulations, discussed in more detail below.[49,50] Among all winter sports, upper extremity and lower extremity injury rates match, unlike summer sport injury trends.[45] Para cross country (previously called Nordic skiing/biathlon), and Wheelchair curling continue to have the lowest injury risk among winter Paralympic sports.[25,49] Certain identified sports will now be covered in greater detail.

Figure 3. Summer and winter Paralympic sports with the highest risk of injury.

Summer Sports

Athletics

Para athletics (track and field) is studied more than any other Para sport.[51] At all levels of competition including youth, soft tissue injuries including muscle contusions, skin abrasions, sunburn and decubitus ulcers are more common than ominous injuries such as fractures; and chronic overuse injuries are more common than acute traumatic injuries.[47,52-55] Premature return to sport may contribute to the chronicity of certain injuries.[47] Wheelchair track athletes may develop upper extremity mononeuropathies while amputee athletes may experience residual limb pain and injury.[23,56] Intellectually impaired athletes incur more injuries in track and field than

most other sports.[57] Visually impaired track athletes are at particularly high risk of chronic overuse lower extremity injury.[19,58] For example, Magno e Silva *et al.* have documented 78% overall injury prevalence and an incidence rate of 1.93 injuries per visually impaired track athlete over a typical competitive season, within an internationally competitive track and field team.[58]

At the London 2012 Paralympic Games, overall injury IR was 22.1 injuries per 1000 athlete days in Para athletics.[59] There was no significant difference in IR between track versus field athletes, but injury patterns were specific to event and impairment-type. In track events, ambulant athletes with cerebral palsy suffered a lower overall injury incidence rate (IR, 10.2; 95% CI, 4.2-16.2) compared to ambulant athletes in different impairment categories. Most injuries did not result in time loss from training or competition. Ambulant athletes experienced the greatest proportion of thigh injuries (16.4% of all injuries; IR, 4.0) predominantly on the track, and seated athletes experienced the greatest proportion of shoulder/clavicle injuries (19.3% of all injuries; IR, 3.4) predominantly in the field. Athletes in seated throwing events suffered a higher incidence of injury (IR, 23.7; 95% CI, 17.5-30.0) as compared to athletes in wheelchair racing events (IR, 10.6; 95% CI, 5.5-15.6).[59]

Football (5-a-side, 7-a-side, Intellectual Impairment, Amputee)

Football for athletes with visual impairment (5-a-side), hypertonia (7-a-side), intellectual impairment or amputation involves significant injury risk. Representative injury prevalence data is as follows: over 23 matches, injury prevalence among a cohort of national-level Brazilian players was 84.6%.[60] On the other hand, representative injury incidence data is as follows: at the

London 2012 Paralympic Games, Football 5-a-side had the highest IR of all 22 sports: 22.4 injuries/1000 athlete-days (injury incidence proportion 31.4 injuries per 100 athletes), while the IR for Football 7-a-side was only 10.4/1000 athlete-days (injury incidence proportion 14.6 injuries per 100 athletes).[43]

Collision- and foul-play-related, acute traumatic injuries tend to predominate in elite Football 5-a-side.[41,43,60] By anatomical area, lower limb (knee, then feet, ankle, thigh) followed by head, spine and upper limb are affected. Common diagnoses include contusion, sprain, tendinopathy and more recently, head injury.[42,61] High school Para athletes also experience the highest rates of injury playing football compared to other sports, and minor, collision-related lower extremity injuries predominate.[62] Finally, injury patterns and rates among footballers with limb amputations appear to be similar to those found among able-bodied footballers.[23]

Swimming

Chronic overuse injuries are more common than acute traumatic injuries among elite Para swimmers, and there do not seem to be significant differences between injury patterns or rates based on gender or classification category.[63] The highest proportion of injuries occurs in the trunk, upper extremity (predominantly shoulder) thoracic and lumbar spine regions. Muscle pain/spasm and tendinopathy are common diagnoses. Spinal cord injury or amputation, rather than limb deficiency, visual impairment, or other impairment may be associated with increased risk of muscle pain/spasm.[63,64]

Sitting Volleyball

Chronic overuse injuries are more common than acute traumatic injuries in sitting volleyball players. In a large cohort of prospectively studied elite players, chronic low back pain, then acute wrist and finger sprain, and chronic rotator cuff pathology were the most common sports-related musculoskeletal injuries, in order. Older players with longer duration of disability were disproportionately more affected by injury.[65]

Para Powerlifting

At the 2016 Rio Paralympic Games, nearly 20% of Para powerlifters reported an injury, predominantly in the upper extremity/shoulder.[42] Furthermore, at the 2012 London Paralympic Games, Para powerlifters had the second highest overall IR, after Football 5-a-side: 33.3 injuries/1000 athlete days (injury incidence proportion, 23.3 per 100 Para powerlifters). The majority of injuries were chronic overuse, and the shoulder/clavicle was the most injured anatomical area. Most injuries occurred during the competition period, there were no significant differences in injury pattern or rate by gender, and athletes in heavier weight classes were at higher injury risk.[66]

Wheelchair Fencing

Among a cohort of elite wheelchair fencers, 73.8% experienced upper extremity injury, 32.5% of which were elbow strain and 15.8% of which were shoulder strain. Those with poor trunk control

had increased risk of injury compared to fencers with good trunk control (4.9/1000 hours versus 3.0/1000 hours, no p value reported).[67]

Para Cycling

Literature on Para cycling injury epidemiology is sparse and includes a German-language cohort study.[48]

Overhead Summer Para Sports

Participation in overhead Para sports such as wheelchair basketball and tennis is a risk factor for upper extremity tendon, ligament, bursa, and muscle pathology, including rotator cuff (RTC) disease.[19,41,52,68-71] Additional risk factors include advanced age, presence/duration of manual wheelchair dependence, and possibly, playing surface(s).[64,69,72] Overuse upper extremity injuries are associated with repetitive motions while acute injuries are due to high-force physical contact.[73,74] Comparing a large cohort of amateur wheelchair basketball players to a cohort of non-athlete wheelchair users, Akbar *et al.* showed a 2.09 relative risk of RTC injury (95% confidence interval, 1.68-2.59; $P<0.001$).[69]

Concussion was recently described in 6% of a large cohort of adult recreational wheelchair basketball athletes.[75] Sacral and ischial deep tissue injuries (DTI) are also common in seated overhead summer Para athletes, particularly among spinally injured players as opposed to players with musculoskeletal disease.[76,77]

Para Sailing and Rowing

Overuse rib stress injury was reported in a single Croatian Para athlete, and authors speculate that this unique injury is potentially due to complete reliance on the upper extremity and torso in certain classes of high-level spinally injured rowers, in addition to high force transmission through certain areas of the body during rowing.[78-80]

Winter Sports

Para Skiing/Snowboarding

There is no significant difference in overall injury rate between skiers with and without impairment, but patterns of injury differ.[81-84] Among able-bodied skiiers, beginners are at higher risk of injury compared to advanced skiiers. This association is reversed in Para skiiers: elite, high-velocity skiiers (either seated or standing) suffer increased injury rates and severity compared to novice, relatively low-velocity skiiers.[82,84]

Upper and lower extremity injuries seem to occur in equal proportion, and for seated Para skiiers (i.e. those using sit-skis), upper extremity injuries seem most common.[25,85-87] Nordic Para skiiers have a significantly lower risk of injury compared to Alpine.[25,87]

Para Ice Hockey (formerly called IPC Ice Sledge Hockey)

There is a similar injury incidence proportion among male and female Para Ice Hockey players at the Paralympic Games. Overuse upper extremity and spine injuries predominate, and importantly, the frequency of relatively catastrophic injuries has been reduced over time. Between the 2002 and 2010 winter Paralympic Games, the rates of lower limb fracture in Para ice hockey dropped from 33% to 2.5% after the introduction of the regulation change on protective equipment and sledge height.[49] This illustrates the positive impact data-driven policy changes can have on athlete health, particularly in high-risk sports like Para ice hockey. Additional safety strategies including hand protection, and training programs to reduce intentional head-contact may be of additional benefit in this sport.[88]

Discussion

The lifetime injury model

To promote health through lifelong sport and physical activity, an accurate model of long-term injury risk, a so-called *Lifetime Injury Model*, is needed for Para athletes at various stages of their careers.[31] For reference, injury risk during and after sport has been described for able-bodied sportspeople e.g. increased risk of lower extremity osteoarthritis in former soccer players.[89] Understanding long-term injury risk is especially important for Para athletes who tend to be older than able-bodied athletes, have non-modifiable functional impairments, and among whom younger, recreational athletes are less frequently studied.[26,90]

Sports injury surveillance programs can help generate data needed for a *Lifetime Injury Model*.[91] The comprehensive, Web-based Injury and Illness Surveillance Survey (WEB-IISS) for example, is currently used to prospectively capture injury and illness data at Paralympic Games (WEB-IISS data has been referenced frequently in this review).[37] While some injury patterns can be garnered from Paralympic data, lifetime consequences of injury remain unclear. As national and international Para sport federations create their own surveillance protocols and gather longitudinal, sport- and country-specific data, a better understanding of injury patterns in both recreational and elite Para sport can be achieved.[90] Furthermore, internal and external factors such as age, skill, training intensity and volume, impairment, and secondary gain influence injury risk at the developmental, elite and post-playing phases of a Para athletes' life.[92] As the specific components of this *Lifetime Injury Model* become clear, coaches, athletes, and clinicians can help mitigate those risks.[92-96] Injury research in both recreational and elite Para sport may benefit from the use of technology similar to WEB-IISS, longitudinal study design, focus on youth and recreational Para athletes, and the use of standardized multinational protocols.

Conclusion

Methodology, definition of injury, population, and study size varied in the 47 studies reviewed, which made it challenging to pool data. Still, it is clear that the literature on musculoskeletal injury epidemiology in Para athletes is growing: nearly 40% of the analyses reviewed were published within the last five years. While rates of musculoskeletal injury are similar for athletes with and without impairment, injury patterns differ, and injuries have magnified functional consequences for Para athletes.[81,97-99] Prevention is therefore paramount in this population of

athletes. Fortunately, as described, injury prevention can be achieved by integrating epidemiological data into evidence-based policy changes that protect athlete health during their competitive years.[49] Furthermore, using such data to drive lifetime injury modeling can protect Para athlete health over the life course.

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Appendix 1. Ovid MEDLINE Search Strategy

1. paralympic.mp. or exp Sports for Persons with Disabilities/ or adapted sport*.mp. or para sport*.mp. or athletes with impairment.mp. or adaptive sport*.mp. or para athlet*.mp. or paraathlet*.mp. para olympic*.mp. or exp Disabled Persons/ or handicapped athlet*.mp. or paralyzed athlet*.mp. or paralysed athlet*.mp. or disabled athlet*.mp. or disabled player*.mp. or physically challenged athlet*.mp. or handicapped sport*.mp. or disabled wheeler*.mp. or (handicapped adj3 sport*).mp.
2. (wheelchair* adj2 (sport* or tennis or basketball or rugby or fencing)).mp.
3. (para adj2 (cycling or canoeing or triathalon* or rowing or tennis or archery or shooting)).mp.
4. (para adj3 (powerlift* or equestrian* or taekwondo or dance* or swim* or snowboard* or sail* or skii* or judo)).mp.
5. (exp Disabled Persons/ or wheelchair*.mp. or exp wheelchairs/) and (exp Sports/ or Athletes/ or Sports medicine/)
6. 1 or 2 or 3 or 4 or 5
7. overuse injur*.mp. or Athletic Injuries/ or exp Cumulative Trauma Disorders/ or exp "Wounds and Injuries"/ or sport* injur*.mp. or athletic injur*.mp.
8. 7 and 8