Peripheral Nervous System Injuries in Sport and Recreation
A Systematic Review

Cory Toth, Stephen McNeil and Thomas Feasby
1 Department of Clinical Neurosciences, University of Calgary, Calgary, Alberta, Canada
2 Department of Medicine, University of Alberta and Capital Health, Edmonton, Alberta, Canada

Contents
Abstract ....................................................................................718
1. Cervical Radiculopathy .................................................................719
2. Spinal Accessory Nerve (at the Lateral Neck) ............................719
3. Brachial Plexus ........................................................................719
4. ‘Stinger’ ................................................................................723
5. Thoracic Outlet Syndrome .........................................................724
6. Long Thoracic Nerve ................................................................724
7. Thoracodorsal Neuropathy .........................................................724
8. Dorsocapular Nerve ................................................................725
9. Suprascapular Nerve ................................................................725
10. Medial Pectoral Neuropathy ......................................................726
11. Axillary Nerve (at the Shoulder) .............................................726
12. Median Nerve ........................................................................727
12.1 Entrapment at Pronator Teres ..............................................727
12.2 Entrapment Within the Carpal Tunnel at the Wrist .................727
12.3 Entrapment Within the Palm of the Palmar Branch .............728
13. Ulnar Nerve ........................................................................728
13.1 At the Elbow in the Cubital Tunnel .......................................728
13.2 In the Forearm at Flexor Carpi Ulnaris .................................729
13.3 At the Wrist in Guyon’s Canal ............................................729
13.4 In the Palm at the Deep Motor Branch .................................729
14. Musculocutaneous Nerve .........................................................730
15. Lateral Antebrachial Cutaneous Neuropathy ..........................730
16. Radial Nerve ........................................................................730
16.1 At the Spiral Groove .............................................................730
17. Posterior Interosseous Neuropathy .........................................730
18. Superficial Radial Nerve ...........................................................731
19. Digital Nerves (at the Fingers) ...............................................731
20. Lumbar Radiculopathy .............................................................731
21. Pudendal Nerve ....................................................................731
22. Iliohypogastric Nerve ...............................................................732
23. Sciatic Nerve .......................................................................732
24. Femoral Nerve ....................................................................732
25. Lateral Femoral Cutaneous Nerve .........................................733
26. Obturator Nerve ....................................................................733
27. Posterior Cutaneous Nerve of the Thigh .................................733
Many sports are associated with a variety of peripheral nervous system (PNS) injuries specific to that sport. A systematic review of sport-specific PNS injuries has not been attempted previously, and will assist in the understanding of morbidities and mortality associated with particular sporting activities, either professional or amateur. A systematic review of the literature using PubMed (1965–2003) was performed examining all known sports and a range of possible PNS injuries attributable to that sport. Numerous sporting activities (53) were found to have associated PNS injuries. The sports most commonly reported with injuries were football, hockey, soccer, baseball, and winter activities. There are a number of sporting activities with injuries unique to the individual sport. This review should be of assistance for the neurologist, neurosurgeon, orthopaedic surgeon, physiatrist, sports medicine doctor, athletic trainer and general physician in contact with athletes possessing neurological injuries.

Neurological injuries are varied and numerous depending on the nature of the sporting activity, age of the participants, and intensity of play. The type of sport may vary from recreational games such as lawn darts, or spectator sports such as professional football. The physician may be confronted with symptoms and signs reflecting injury to a number of neurological levels, including the peripheral nerve, spinal roots and brachial plexus. Recognition of specific injury and its relationship to a specific sporting activity may assist the physician with the rapidity of diagnosis and possible therapy.

We have performed a systematic review of the scientific peer-reviewed literature in order to obtain an exhaustive description of injuries to the peripheral nervous system (PNS) associated with specific sporting activities. Injuries have been categorised by anatomical location of peripheral nerve injury. Whenever possible, comments about pathogenesis and prognosis have been included, as well as recommendations for diagnostic and therapeutic interventions for specific sports-related injury. The numerous peripheral nerve injuries attributable to each sport have been listed.

A MEDLINE search was performed using the website of the National Library of Medicine (‘PubMed’) to examine the literature for all possible scientific papers discussing sports and neurological injuries published between the years of 1966–2003. MeSH search terms and non-MeSH terms used included all combinations as listed in table I. All abstracts found using these MeSH terms were examined. Articles were included for consideration in this review if they met the following criteria: (i) papers describing a series of injuries or a single case report of injury, including those of a neurological basis, within one sport or activity; and (ii) papers...
describing one particular form of peripheral nerve injury within a group of sports.

Whenever possible, full publications were obtained in place of abstracts. References found within the obtained papers, which met the above criteria, were also used to obtain further relevant papers, textbooks, or scientific presentations for data to be used within this review. In situations where the association between a sporting activity and injury was questionable, the article was not included within this review. Categorisation was performed by each individual sport or activity. Injuries of the PNS are organised by sport within table II, and are organised anatomically in table III.

A total of 270 abstracts were found using the defined search criteria. Examination of references within the initially found manuscripts revealed an additional 92 articles to be obtained. The final reference list consisted of 139 papers or books. References were obtained in full in 68% of cases, and abstracts were used in remaining cases where the journal could not be located or was in a foreign language, resulting in the abstract being used for information. Sporting activities associated with peripheral nerve injury are listed in alphabetical order, specific by sport, within this article. The majority of the references located were of individual case reports, or of a small series of similar injuries within one sporting activity. In all cases, emphasis was placed upon those cases where electrophysiological evidence of a nerve lesion was demonstrated. Figures 1–7 demonstrate the PNS and the lesion sites where particular sports have been associated with peripheral nerve injury. This article outlines the results of our MEDLINE search by listing injuries to the central nervous system (CNS) by peripheral nerve lesion beginning in the upper extremities in a proximal to distant gradient.

1. Cervical Radiculopathy

Although controversial, the ‘stinger’ (described in sections 3 and 4) is believed by some authors to be due to a transient C5 or C6 radiculopathy,[1] while others believe it to be due to dysfunction of the upper trunk of the brachial plexus.[2,3] Football players are subject to more persistent cervical radiculoplexopathies including upper trunk brachial plexopathies.[4,5] However, cervical radiculopathy is probably underreported, as no other associations with sporting activities can be located in the literature.

2. Spinal Accessory Nerve (at the Lateral Neck)

Although the martial arts have been associated with numerous injuries, neurological injuries occur in an unusual manner secondary to direct blows leading to a presumed nerve contusion, including a mononeuropathy affecting the spinal accessory nerve.[6]

3. Brachial Plexus

The brachial plexus is most often at risk due to traumatic injuries, although traction can also lead to brachial plexopathy. Football is perhaps the most common sporting activity associated with brachial plexus injury (figure 1).
Table II. Peripheral nervous system injuries by sport

<table>
<thead>
<tr>
<th>Sport</th>
<th>Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archery</td>
<td>Digital nerve compression; median neuropathy at wrist; median neuropathy at pronator teres; long thoracic nerve palsy</td>
</tr>
<tr>
<td>Arm wrestling</td>
<td>Radial nerve palsy</td>
</tr>
<tr>
<td>Auto racing</td>
<td>Brachial plexopathy; sciatic neuropathy; peroneal neuropathy</td>
</tr>
<tr>
<td>Ballet dancing</td>
<td>Suprascapular neuropathy; femoral neuropathy; peroneal neuropathy; sural neuropathy; dorsal cutaneous neuropathy; Morton’s neuroma</td>
</tr>
<tr>
<td>Baseball</td>
<td>Suprascapular neuropathy; radial neuropathy; ulnar neuropathy; median neuropathy at pronator teres; thoracic outlet syndrome; axillary neuropathy with quadrilateral space syndrome; digital neuropathy at thumb; brachial plexopathy (‘pitcher’s arm’)</td>
</tr>
<tr>
<td>Basketball</td>
<td>Suprascapular neuropathy; stinger; median neuropathy at the wrist (wheelchair athletes); ulnar neuropathy at the wrist (wheelchair athletes)</td>
</tr>
<tr>
<td>Bicycling</td>
<td>Ulnar neuropathy at Guyon’s canal; ulnar neuropathy at the elbow; median neuropathy at wrist; pudendal neuropathy; posterior cutaneous nerve of the thigh neuropathy; sciatic nerve palsies (unicyclists)</td>
</tr>
<tr>
<td>Bodybuilding and weightlifting</td>
<td>Ulnar neuropathy at the deep motor branch; ulnar neuropathy at flexor carpi ulnaris; ulnar neuropathy at the deep palmar branch; ulnar neuropathy at the elbow; posterior interosseous neuropathy; medial pectoral neuropathy; suprascapular neuropathy; median neuropathy at the wrist; long thoracic neuropathy; lateral antebrachial cutaneous neuropathy; musculocutaneous neuropathy; femoral neuropathy; thoracodorsal neuropathy; dorsocapular neuropathy; stinger; rectus abdominis syndrome with rhabdomyolysis</td>
</tr>
<tr>
<td>Bowling</td>
<td>Digital neuropathy of the thumb</td>
</tr>
<tr>
<td>Boxing</td>
<td>Stinger</td>
</tr>
<tr>
<td>Cheerleading</td>
<td>Digital neuropathy; median neuropathy at the palmar branch</td>
</tr>
<tr>
<td>Football</td>
<td>Stinger; upper trunk brachial plexopathy; radiculopathy of C5, C6, L5 or S1 roots; axillary neuropathy with or without dislocated shoulder; suprascapular neuropathy; ulnar neuropathy at the elbow; median neuropathy at the wrist; long thoracic neuropathy; radial neuropathy; thoracic outlet syndrome; iliohypogastric neuropathy; peroneal neuropathy with knee dislocation; sciatic nerve (hamstring syndrome)</td>
</tr>
<tr>
<td>Frisbee</td>
<td>Posterior interosseous neuropathy</td>
</tr>
<tr>
<td>Golf</td>
<td>Median neuropathy distal to wrist; carpal tunnel syndrome; ulnar neuropathy at flexor carpi ulnaris</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>Posterior interosseous neuropathy; lateral femoral cutaneous neuropathy; femoral neuropathy</td>
</tr>
<tr>
<td>Handball</td>
<td>Handball goalie’s elbow</td>
</tr>
<tr>
<td>Hockey</td>
<td>Stinger; axillary neuropathy; tibial neuropathy due to tarsal tunnel syndrome; peroneal neuropathy</td>
</tr>
<tr>
<td>In-line skating, rollerskating and skateboarding</td>
<td>Superficial peroneal neuropathy</td>
</tr>
<tr>
<td>Judo, karate and kickboxing</td>
<td>Morton’s neuroma of a plantar nerve; ulnar neuropathy at trauma site; axillary neuropathy at trauma site; spinal accessory neuropathy at trauma site; long thoracic neuropathy at trauma site; peroneal neuropathy at trauma site</td>
</tr>
<tr>
<td>Mountain climbing, hiking</td>
<td>Tarsal tunnel syndrome; rucksack paralysis – brachial plexopathy (upper and middle trunks); suprascapular neuropathy; axillary neuropathy; long thoracic neuropathy</td>
</tr>
<tr>
<td>Rugby and Australian rules football</td>
<td>Axillary neuropathy; obturator neuropathy</td>
</tr>
<tr>
<td>Running</td>
<td>Peroneal neuropathy; lateral femoral cutaneous neuropathy; tibial neuropathy at the tarsal tunnel; posterior tibial neuropathy; Morton’s neuroma of a plantar nerve; interdigital neuropathies; plantar neuropathies; calcaneal neuropathy; sural neuropathy; superficial peroneal neuropathy; saphenous neuropathy; rhabdomyolysis</td>
</tr>
<tr>
<td>Scuba diving</td>
<td>Lateral femoral cutaneous neuropathy</td>
</tr>
<tr>
<td>Shooting</td>
<td>Long thoracic neuropathy</td>
</tr>
</tbody>
</table>

Continued next page
football is an aggressive sport with significant physical contact and high risk of injury, particularly to the brachial plexus. In most studies, football is reported as the sport most likely to be associated with injury, serious injury, as well as neurological injury. The injury rate for football in collegiate-level athletes is estimated at 1.5 per 100 athlete exposures in games as well as practices. High-school football is no different in that football was also associated with the highest injury rate per 100 player-seasons (3.66). As would be expected, contact with another player was the most frequent method of injury in football.

The majority of injuries affecting the nervous system appear to be CNS in nature, but brachial plexus injuries appear to be the most common PNS injury. In Canadian varsity football players, brachial plexus injuries were the third most common specific diagnosis in football injuries, while the incidence at two University centres was 49% of all injuries. The incidence of plexus injury has been reported to be as high as 2.2 cases per 100 players. Football players can be subject to more persistent upper trunk brachial plexopathies.

In racecar drivers, the brachial plexus is at risk of injury due to the tight fastening by seatbelts of arm to helmet to prevent centrifugal force for auto drivers.

The notion of a ‘pitcher’s arm’ on electrodiagnostic testing can make evaluation of potential nerve disorders in the baseball pitcher difficult. Asymptomatic professional and amateur baseball pitchers have had reduced sensory nerve action potentials in the throwing arm, although this did not appear to impact player performance. The authors reporting the phenomenon of ‘pitcher’s arm’ speculated on this being a repetitive use syndrome affecting the brachial plexus, although this remains unclear.

Injury rates amongst mountain climbers are low, estimated at two cases per 1000 climbers. PNS injuries are uncommon in mountain climbers and hikers, but exist. The use of a backpack by hikers has been associated with a unique condition called rucksack paralysis, a syndrome leading to injury of the brachial plexus at the upper and middle trunks. Traction upon the brachial plexus is the probable aetiology, and one predisposing factor for this condition is the use of a pack without waist support. Often, there are paraesthesias, but no pain. Electrophysiology may demonstrate conduction block or axonal loss in particular patients with rucksack paralysis, with axonal loss suggesting a poorer prognosis for recovery.

PNS injuries due to snowmobiling include brachial plexus injuries in 4.8% of snowmobile accident victims. A complete brachial plexopathy is seen in 67% of snowmobile accidents with brachial plexus injury, often associated with orthopaedic shoulder injury. Supraclavicular injuries were more common and more severe than infraclavicular injuries.
Table III. Injuries of the peripheral nervous system due to sport organised by anatomical location

<table>
<thead>
<tr>
<th>Nerve/Neuropathy</th>
<th>Sports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital nerves</td>
<td>Archery; baseball; bowling; cheerleading; tennis</td>
</tr>
<tr>
<td>Median nerve</td>
<td>Archery; baseball (wheelchair); bicycling; bodybuilding/weightlifting; football; golf; wrestling</td>
</tr>
<tr>
<td>wrist</td>
<td>Archery; basketball (wheelchair); bicycling; bodybuilding/weightlifting; football; golf; wrestling</td>
</tr>
<tr>
<td>palmar branch</td>
<td>Cheerleading; golf</td>
</tr>
<tr>
<td>pronator teres</td>
<td>Archery; baseball</td>
</tr>
<tr>
<td>Ulnar nerve</td>
<td>Baseball; bicycling; bodybuilding/weightlifting; judo, karate and kickboxing; cross-country skiing; wrestling</td>
</tr>
<tr>
<td>at the elbow</td>
<td>Baseball; bicycling; bodybuilding/weightlifting; judo, karate and kickboxing; cross-country skiing; snowmobiling</td>
</tr>
<tr>
<td>at the wrist</td>
<td>Basketball (wheelchair); bicycling; football; cross-country skiing; snowmobiling</td>
</tr>
<tr>
<td>at flexor carpi ulnaris</td>
<td>Bodybuilding/weightlifting; golf</td>
</tr>
<tr>
<td>at the deep motor branch</td>
<td>Bodybuilding/weightlifting</td>
</tr>
<tr>
<td>Radial nerve</td>
<td>Arm wrestling; baseball; football; tennis/weightlifting</td>
</tr>
<tr>
<td>Posterior interosseous neuropathy</td>
<td>Bodybuilding/weightlifting; frisbee; gymnastics; tennis/weightlifting</td>
</tr>
<tr>
<td>Superficial radial nerve</td>
<td>Tennis/weightlifting</td>
</tr>
<tr>
<td>Axillary nerve</td>
<td>Baseball; football; hiking; judo, karate and kickboxing; rugby; volleyball; wrestling</td>
</tr>
<tr>
<td>Spinal accessory nerve</td>
<td>Judo, karate and kickboxing</td>
</tr>
<tr>
<td>Musculocutaneous nerve</td>
<td>Bodybuilding/weightlifting</td>
</tr>
<tr>
<td>Lateral antebrachial cutaneous neuropathy</td>
<td>Bodybuilding/weightlifting; tennis</td>
</tr>
<tr>
<td>Thoracic outlet syndrome</td>
<td>Baseball; football; swimming; tennis</td>
</tr>
<tr>
<td>Long thoracic nerve</td>
<td>Archery; bodybuilding/weightlifting; football; judo, karate and kickboxing; hiking; shooting; tennis/weightlifting; volleyball; wrestling</td>
</tr>
<tr>
<td>Thoracodorsal neuropathy</td>
<td>Bodybuilding/weightlifting</td>
</tr>
<tr>
<td>Dorsocapular nerve</td>
<td>Bodybuilding/weightlifting</td>
</tr>
<tr>
<td>Suprascapular nerve</td>
<td>Ballet dancing; baseball; basketball; bodybuilding/weightlifting; football; hiking; tennis/weightlifting; volleyball; wrestling</td>
</tr>
<tr>
<td>Medial pectoral neuropathy</td>
<td>Bodybuilding/weightlifting</td>
</tr>
<tr>
<td>Brachial plexus</td>
<td>Auto racing; baseball; football (upper trunk); hiking (upper, middle trunks); snowmobiling; wrestling</td>
</tr>
<tr>
<td>Sling</td>
<td>Basketball; bodybuilding/weightlifting; boxing; football; hockey; wrestling</td>
</tr>
<tr>
<td>Cervical radiculopathy</td>
<td>Football</td>
</tr>
<tr>
<td>Femoral nerve</td>
<td>Ballet dancing; bodybuilding/weightlifting; gymnastics; cross-country skiing</td>
</tr>
<tr>
<td>Obturator nerve</td>
<td>Rugby/Australian rules football</td>
</tr>
<tr>
<td>Peroneal nerve</td>
<td>Auto racing; ballet dancing; football; hockey; judo karate and kickboxing; running; soccer; surfing</td>
</tr>
<tr>
<td>Pudendal nerve</td>
<td>Bicycling</td>
</tr>
<tr>
<td>Iliohypogastric nerve</td>
<td>Football</td>
</tr>
<tr>
<td>Sciatic nerve</td>
<td>Auto racing; bicycling; football (hamstring syndrome)</td>
</tr>
<tr>
<td>Superficial peroneal nerve</td>
<td>Running</td>
</tr>
<tr>
<td>Interdigital nerves of foot</td>
<td>Running</td>
</tr>
<tr>
<td>Tibial nerve</td>
<td>Hockey; hiking; running</td>
</tr>
<tr>
<td>at tarsal tunnel</td>
<td>Ballet dancing; running</td>
</tr>
<tr>
<td>Sural nerve</td>
<td>Ballet dancing; running</td>
</tr>
<tr>
<td>Lateral femoral cutaneous nerve</td>
<td>Gymnastics; running; scuba diving</td>
</tr>
<tr>
<td>Posterior cutaneous nerve of the thigh</td>
<td>Bicycling</td>
</tr>
<tr>
<td>Superficial peroneal nerve</td>
<td>Rollerskating; running</td>
</tr>
</tbody>
</table>

**Continued next page**
Table III. Contd

<table>
<thead>
<tr>
<th>Nerve or Condition</th>
<th>Sport/Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saphenous nerve</td>
<td>Surfing; running</td>
</tr>
<tr>
<td>Dorsal cutaneous nerve of foot</td>
<td>Ballet dancing</td>
</tr>
<tr>
<td>Lumbar radiculopathy</td>
<td>Football</td>
</tr>
<tr>
<td>Morton’s neuroma of plantar nerve</td>
<td>Ballet dancing; judo, karate and kickboxing; running</td>
</tr>
<tr>
<td>Plantar nerves of feet</td>
<td>Running</td>
</tr>
<tr>
<td>Calcaneal neuropathy</td>
<td>Running</td>
</tr>
<tr>
<td>Rhabdomyolysis</td>
<td>Bodybuilding/weightlifting; running</td>
</tr>
</tbody>
</table>

4. ‘Stinger’

Initially called a nerve pinch syndrome, this phenomenon is now colloquially termed a ‘stinger’, or ‘burner’. The basis of the stinger is controversial, with some authors advocating C5 or C6 radiculopathy,[1] while others believe it to be due to dysfunction of the upper trunk of the brachial plexus.[2,3] In most cases, the stinger presents acutely after trauma to the shoulder region. The stinger comprises approximately 36% of all neurological upper extremity injuries related to football.[5] Patients note pain and paraesthesias shooting down the arm into a few of the fingers, associated with transient weakness and prompt recovery over minutes. Rarely, weakness may persist for several months,[21] suggesting upper trunk brachial plexus axonotmesis, which has been documented by electromyography.[10] Electromyography and nerve root stimulation studies may find abnormality in 12% of players with such injuries.[2] Electromyographic abnormalities in such injuries best correlate with the presence of weakness at 72 hours post-injury.[22]

Amateur wrestling is an aggressive sport with frequent CNS injury, and injury rates in wrestling are second only to football amongst high-school competitors, with an injury rate of 1.58 per 100 player-seasons.[8] Brachial plexus injury is relatively common in wrestling compared with other sports, and tends to occur with holds that force the opposing wrestler’s head in a direction opposite to one shoulder, such as with a full- or half-Nelson hold.[20]

Fig. 1. Anatomy and lesions by sport affecting the brachial plexus and its branches. N = nerve.
A stinger has rarely been seen in basketball players. Brachial plexus injuries are rare in the bodybuilder, but stingers have rarely been reported in weightlifters.

Boxing has become a controversial sport due to the high risk of injury, long-term sequelae, and occurrence of death during competition. Most boxing injuries are the result of CNS trauma. The lone peripheral nerve injury is one usually seen in football players, the ‘burner’ or ‘stinger’, which is rarely reported. The most common ice hockey injuries to affect the nervous system are concussions and spinal cord injuries, while PNS injuries are less common. Although more common in football players, the ‘stinger’ has also been rarely reported in hockey players. Stingers also account for 37% of all head and neck injuries in competitive wrestlers.

5. Thoracic Outlet Syndrome

The controversial and rare entity of thoracic outlet syndrome has been previously reported in baseball pitchers. In one case, thoracic outlet syndrome has presented as numbness in the fingers of the throwing hand of a college baseball player, with compression of the neurovascular bundle demonstrated using magnetic resonance angiography with arm held in abduction. Thoracic outlet syndrome has also been reported in the throwing shoulder of football quarterbacks and rarely in the dominant arm of tennis players. In swimmers, thoracic outlet syndrome may occur in association with hypertrophied pectoralis minor muscles.

6. Long Thoracic Nerve

A number of sports have been associated with a palsy of the long thoracic nerve, either related to a repetitive swinging motion, local trauma, or muscular hypertrophy. The use of a bow in archery has been associated with development of an isolated long thoracic nerve palsy, likely due to repeated drawing of the bow and possible hypertrophy of shoulder and periscapular muscles. Measures that may improve archery safety include using a lightweight bow, conditioning of forearm flexor muscles, and modifications in the mechanism of drawing the bowstring. A single report of a long thoracic neuropathy has been reported in a world-class marksman, probably due to positional stress during repetitive shooting postures while holding the gun.

Bodybuilding has been associated with a number of entrapment neuropathies secondary to repetitive motions or excessive muscle bulk, sometimes associated with anabolic steroid use. Often, the nature of the mononeuropathies in the bodybuilder or weightlifter is unique. Repetitive movements at the shoulder as well as relative muscular hypertrophy in bodybuilders may lead to compression of the long thoracic nerve. In one patient, the use of anabolic steroids may have been associated with excessive muscular hypertrophy of the shoulder and flank region muscles; resting of the affected region led to some improvement with return of serratus anterior bulk.

Local trauma to the shoulder and axillary region while blocking or tackling has been associated with long thoracic neuropathy in football players. Local trauma in the martial arts may have also been associated a long thoracic neuropathy due to nerve contusion. Peripheral nerve injury in wrestlers may occur with excessive shoulder manipulation, which can lead to long thoracic neuropathy.

Rucksack paralysis in backpacking hikers, normally associated with a brachial plexopathy, has also been associated with an isolated long thoracic neuropathy. Traction upon the shoulder is a possible aetiology with a predisposing factor being the use of a pack without waist support.

Long thoracic neuropathy is rarely reported in the tennis player. An isolated mononeuropathy of the long thoracic nerve may occur in the dominant arm of younger volleyball players, perhaps related to excessive repetitive shoulder movements of the serving arm.

7. Thoracodorsal Neuropathy

A thoracodorsal mononeuropathy occurred in a bodybuilder who was using anabolic steroids, with both clinical and electrophysiological findings that...
improved with resting of the affected region and were associated with return of latissimus dorsi bulk.\textsuperscript{[37,38]} Entrapment of the nerve by hypertrophied subscapularis muscle may have been the cause of this palsy.

8. Dorsoscapular Nerve

Unilateral weakness of the rhomboid muscles has occurred in a bodybuilder using anabolic steroids, with suspected entrapment of the dorsoscapular nerve by muscular hypertrophy.\textsuperscript{[38]} possibly of the scalenus anterior and medius muscles.

9. Suprascapular Nerve

The suprascapular nerve is subject to injury within a number of sports, with mechanisms varying from repetitive throwing or swinging motions of a shoulder, direct trauma, to traction injury. Perhaps the most frequently associated sport with suprascapular nerve palsy is volleyball. Volleyball is one of the safest competitive and recreational sports played by high-school and collegiate athletes. The injury rate is only 0.14 per 100 volleyball players-seasons for high school student participants, the lowest of ten sports examined in one study.\textsuperscript{[8]} PNS injuries due to volleyball are frequently reported. One frequent form of mononeuropathy is an isolated entrapment of the suprascapular nerve at the spinoglenoid notch, presenting with painless weakness of dominant arm external rotation with evidence of infraspinitus atrophy on examination.\textsuperscript{[39,40]} This neuropathy only occurs with the serving, or dominant, arm.\textsuperscript{[38]} In one study of international-level volleyball players, the overall prevalence of suprascapular neuropathy was surprisingly found to range from 33% to 45% based on clinical and electrophysiological examination.\textsuperscript{[41,42]} Up to 12% of volleyball players may have subclinical suprascapular neuropathy.\textsuperscript{[39]} Electrolymography in these cases discloses denervation and loss of motor units restricted to the infraspinitus muscle with the suprascapinatus and other shoulder muscles found to be normal.\textsuperscript{[40]} A possible association between increased range of motion of the shoulder joint and presence of isolated suprascapular neuropathy has been suggested.\textsuperscript{[43]} Alternatively, the medial tendinous margin between the infraspinitus and supraspinatus muscles may impinge against the lateral edge of the scapular spine, leading to compression of the infraspinatus branch of the suprascapular nerve.\textsuperscript{[44]} Favouring the latter theory is the favourable response of elite volleyball players to a spinoglenoid notchplasty procedure.\textsuperscript{[44]} With a probable similar mechanism, suprascapular neuropathy has also been reported in tennis players, with compression at the suprascapular or supraglenoid notches, as well as with a ganglion cyst.\textsuperscript{[45,46]}

Although injuries in baseball are typically acute, such as with the most frequent mechanism of baseball-related injury, being hit by the ball (62% of acute injuries),\textsuperscript{[35]} local nerve lesions are relatively common in baseball players as well. Many of the peripheral nerve injuries occur during the act of pitching. During the biomechanics of throwing the baseball, the humerus is whipped with a maximum torque of nearly 1600Nm.\textsuperscript{[47]} This degree of torque requires significant muscular force and places great stress upon musculoskeletal and nervous elements. Suprascapular nerve injuries presenting as shoulder pain accompanied by weakness of shoulder abduction and external rotation can occur in a pitching arm.\textsuperscript{[48,49]} Entrapment of the suprascapular nerve in pitchers may occur at the suprascapular or spinoglenoid notches.\textsuperscript{[50]} Often, suprascapular nerve injury can mimic a rotator cuff tear. Although not reported with suprascapular nerve injuries in the baseball player, the presence of spinoglenoid cysts or labral pathology has been associated with suprascapular neuropathy.\textsuperscript{[51]}

While basketball injuries are relatively common, only the minority of these injuries are neurological in nature. A single report of a suprascapular nerve lesion without any history of shoulder girdle trauma has been reported in a basketball player, perhaps due to repeated nerve traction over the coracoid notch during dunking of the basketball.\textsuperscript{[52]} Recovery in this player was nearly complete after 3 weeks of inactivity.\textsuperscript{[52]}

Upper extremity peripheral nerve lesions are rarely reported in dancers. There is an isolated report
of painless, isolated weakness of external rotation of the right arm of a professional dancer with clinical and electrophysiological evidence of suprascapular neuropathy. The injury was possibly secondary to repetitive, forceful movements of the arm with external rotation and abduction, with postulated entrapment of the nerve at the spinoglenoid notch. Near complete recovery of muscle function occurred after 4 months of rest from dance.\[53\]

Bodybuilders are at risk for suprascapular neuropathy likely because of repetitive activity of the shoulder.\[4,54\] Bodybuilders may demonstrate both clinical and electrophysiological findings of entrapment of the terminal branch of the suprascapular nerve.\[55\] Resting of the affected shoulder region may be associated with recovery of strength and muscle bulk.

The physical action of blocking or tackling by football players can lead to direct trauma to the shoulder and scapular region, which has been associated with suprascapular neuropathy.\[4\] In wrestlers, excessive shoulder and scapular manipulation, such as with the hammerlock manoeuvre, can lead to suprascapular neuropathy.\[4\]

Lastly, rucksack paralysis in hikers has been associated with an isolated suprascapular neuropathy,\[15-17\] likely due to excessive shoulder traction and improper waist support for the backpack.\[16\]

### 10. Medial Pectoral Neuropathy

Another unique weightlifting-associated neuropathy is a progressive bilateral medial pectoral neuropathy secondary to postulated pectoralis minor hypertrophy and subsequent intramuscular entrapment of the medial pectoral nerves.\[4,56\]

### 11. Axillary Nerve (at the Shoulder)

Peripheral nerve injuries in football may occur secondary to blocking or tackling techniques. In one study, football was the most common sport to cause injury in patients referred for electrodiagnostic testing.\[4\] Mononeuropathies reported in upper limbs of football players have included axillary neuropathy,\[4,57\] which can be associated with shoulder dislocation\[4,58\] or can be isolated secondary to direct trauma to the anterolateral deltoid region (figure 2).\[57\] Although many athletes with axillary neuropathy fail to regain full axillary nerve function, 91% of such athletes return to pre-injury levels of professional sports activities.\[57\] Axillary neuropathy due to direct contact without shoulder dislocation has also been reported in two hockey players.\[57,59\] Peripheral nerve injury is unusual in the martial arts, but direct blows leading to a presumed nerve contusion have been reported to lead to an axillary neuropathy.\[6\]

Rodeo injury incidences vary amongst the different events, but are the highest in bull riding, bareback riding, and saddle bronc events.\[60\] Concussions rather than peripheral nerve injuries account for the great majority of neurological injuries due to rodeo.\[60\] Little has been reported about peripheral nerve injury although it may occur. The authors have seen an axillary neuropathy secondary to...
Rugby and Australian rules football are both highly subject to cerebral concussion, the most common neurological concern within both of these sports. However, peripheral nerve lesions have been reported. Direct trauma to the anterolateral deltoid without shoulder dislocation has been reported as a cause of axillary neuropathy in rugby players. Peripheral nerve injury in wrestlers can also occur due to excessive shoulder manipulation or local nerve trauma causing presumed nerve conduction, as may occur with axillary neuropathy.

An isolated mononeuropathy of the axillary nerve has been reported in younger volleyball players, perhaps related to a quadrilateral space syndrome. Quadrilateral space syndrome has also been reported within the pitching arm of a baseball pitcher due to compression of the distal axillary nerve and partial compression of the posterior humeral circumflex artery.

Lastly, rucksack paralysis in hikers has occasionally presented as an isolated axillary neuropathy due to presumed excessive shoulder traction and a backpack without proper waist support.

### 12. Median Nerve

#### 12.1 Entrapment at Pronator Teres

Median nerve entrapment is most common at the wrist within the carpal tunnel; however, compression as it passes through the pronator teres is another possible site of entrapment with sports injuries. The use of a bow in archery has been associated with compression of the median nerve at the pronator teres intersection, suspected to be due to repeated drawing of the bow and possible hypertrophy of forearm muscles such as pronator teres (figure 3). Measures that may improve archery safety include the use of a lightweight bow, conditioning of forearm flexor muscles, and modifications in the mechanism of drawing the bowstring. Pronator syndrome in the proximal forearm of the pitching arm may occur in baseball pitchers due to entrapment of the median nerve by fibrous bands of the pronator teres, likely related to repetitive throwing actions or relative hypertrophy of the forearm muscles including the pronator teres.

#### 12.2 Entrapment Within the Carpal Tunnel at the Wrist

The carpal tunnel is, by far, the most common site of median nerve entrapment with or without sports-related injury. It is often difficult to discriminate those lesions with direct relationship to sporting activities and those without direct relationship. Although forms of neuropathy are reported very rarely in traditional basketball players, compression neuropathies of the arms are common injuries in wheelchair basketball players. In one study, 30% of world-class wheelchair basketball players were found to have symptoms consistent with carpal tunnel syndrome, with 70% of these having elec-
trodiagnostic confirmation.\textsuperscript{[65]} Similar incidences were found in another case-control study of upper extremity electrophysiology in other forms of wheelchair athletes.\textsuperscript{[66]}

Although the ulnar nerve is more likely to be compressed at the wrist in cyclists, the median nerve may also be abnormal in many cyclists. In one study of professional cyclists, symptoms of carpal tunnel syndrome occurred in 25\% of hands, with 62\% of symptomatic hands tested demonstrating abnormal electrophysiological findings on stimulation of the median nerve.\textsuperscript{[67]} Bilateral median nerve compression may also occur in the cyclist.\textsuperscript{[68]}

Golf is usually regarded as a relaxing recreational sport with an expected low injury rate. Much of the literature regarding golf-related injuries to the nervous system is based upon single case reports. Reports of golf-induced carpal tunnel syndrome are not entirely clear, but repetitive gripping and sustained hyperflexion and hyperextension may contribute to the few noted cases.\textsuperscript{[69]}

Although not commonly reported in football players, median neuropathy at the carpal tunnel with clinical and electrophysiological evidence has been reported and associated with blocking techniques.\textsuperscript{[4]} Peripheral nerve injury in wrestlers can occur due to excessive arm and wrist manipulation, which may lead to entrapment of the median nerve at the carpal tunnel.\textsuperscript{[4]} Repetitive flexion-extension of the wrist in bodybuilders may possibly lead to carpal tunnel syndrome.\textsuperscript{[4]} Lastly, the use of an archery bow has led to compression of the median nerve at the wrist,\textsuperscript{[29]} possibly related to repeated drawing of the bow.

12.3 Entrapment Within the Palm of the Palmar Branch

Golfers may be subject to an atypical location for median nerve entrapment. A neophyte golfer presented with an unusual location for median neuropathy, with segmental demyelination found 2–3 cm distal to the wrist crease, after presentation with sensory deficit within the distal median nerve distribution.\textsuperscript{[70]} This unusual location may relate to pressure upon the palm by the handle of the golf club.

13. Ulnar Nerve

13.1 At the Elbow in the Cubital Tunnel

Ulnar neuropathy is another common entrapment neuropathy where it is difficult to discriminate those cases with certain sports-related aetiologies from those without association. Ulnar neuropathy at the elbow is common amongst baseball pitchers,\textsuperscript{[64,71–75]} although it is uncertain if ulnar neuropathy occurs more commonly than within a control population (figure 4). In one study of 72 professional baseball players undergoing arthroscopic or open elbow surgery, ulnar neuropathy was diagnosed in 15\% of players.\textsuperscript{[71]} Of adult baseball players with ulnar nerve entrapment who underwent surgical correction with anterior transfer of the nerve and place-
ment deep to the flexor muscles, about 50% returned to playing.[72]

Repetitive flexion-extension of the elbow in bodybuilders may predispose to ulnar neuropathy at the elbow.[4] The ulnar nerve may also be at risk for direct trauma and nerve contusion. The action of blocking or tackling can lead to local trauma in the arms of football players, which has been associated with development of ulnar neuropathy.[9] Direct blows to the elbow in the martial arts presumably leading to a nerve contusion have led to ulnar neuropathy.[6] Peripheral nerve injury in wrestlers can occur due to local nerve trauma causing presumed nerve contusion, as may occur with ulnar neuropathy.[4] Lastly, ulnar neuropathy has been reported in a single cross-country skier in whom it was attributed to forceful poling.[76]

One mimic of ulnar neuropathy is a musculoskeletal condition that occurs in a European sport, handball. This sport combines skills of basketball and soccer. Epidemiological studies of injuries within the sport are few. Some goalkeepers have a condition termed ‘handball goalie’s elbow’ presenting as radiating pain or numbness in the ulnar territory of the forearm in addition to local pain in the elbow region pain. Although this may mimic an ulnar neuropathy, electrophysiological assessment is negative, and the condition likely represents a musculoskeletal source of pain due to repetitive forced hyperextensions of the elbow.[77]

13.2 In the Forearm at Flexor Carpi Ulnaris

Ulnar neuropathy has also been reported in a 39-year-old competitive male weightlifter due to suspected compression between the heads of flexor carpi ulnaris with electrophysiological evidence.[78] A professional golf instructor was reported to have ulnar neuropathy localised as a focal conduction block in the distal forearm approximately 7cm proximal to the ulnar styloid, perhaps due to enlargement of the flexor carpi ulnaris and subsequent compression of the adjacent ulnar nerve found at surgery.[79]

13.3 At the Wrist in Guyon’s Canal

Recreational and competitive cycling, including BMX biking and both road and off-road cycling, is associated with a wide range of neurological injuries affecting the peripheral and central nervous system. Probably the most common form of nerve entrapment is that of the ulnar nerve at the wrist, seen among cyclists resulting in weakness of grip and numbness of the fourth and fifth digits.[64] In cyclists, the most common location of ulnar nerve entrapment is within Guyon’s canal.[80] Within a large cross sectional study of 160 male professional cyclists, 30% reported paraesthesia or numbness in the fingers, mostly from the ulnar innervated region.[81] Recovery in cyclists with ulnar neuropathy may occur spontaneously or with avoidance of activity, rather than with an operative procedure.[82] Modification of hand grips on the bicycle handlebars may result in recovery in cyclists with Guyon canal ulnar nerve compression.[83]

The use of a wheelchair in wheelchair basketball players places the ulnar nerve at risk for compression at the wrist – 12% of symptomatic wheelchair basketball players had abnormal electrophysiology of the ulnar nerve at the wrist.[65] Similar incidences have been demonstrated in another case-control study of upper extremity electrophysiology in other forms of wheelchair athletes.[66]

Ulnar neuropathy secondary to forceful poling in a cross-country skier has been reported with entrapment of the ulnar nerve at the wrist.[77] We have seen one patient with bilateral ulnar neuropathies at Guyon’s canal after a full day of snowmobiling with his hands secured to the handlebars with duct tape.

13.4 In the Palm at the Deep Motor Branch

Repeated bench presses over 2 weeks in a young male was associated with weakness of interossei, 4th and 5th lumbricals, adductor pollicis and abductor digiti minimi secondary to injury to the deep motor branch of the ulnar nerve with severe conduction block identified on sequential nerve conduction studies.[84] A compressive lesion of the deep palmar branch of the ulnar nerve was reported in a patient.
who entered an intensive programme of push-ups on a hard floor.\[85\]

**14. Musculocutaneous Nerve**

Upper arm and shoulder muscular hypertrophy as well as repetitive movements at the shoulder may be associated with the presence of musculocutaneous neuropathy in bodybuilders.\[37,65,86\]

**15. Lateral Antebrachial Cutaneous Neuropathy**

Repetitive flexion and extension of the elbow as well as forearm muscular hypertrophy in bodybuilders has led to a lateral antebrachial cutaneous neuropathy.\[4\] Compression of the lateral cutaneous nerve of the forearm has also been seen in a vigorous tennis player,\[87\] perhaps due to muscular hypertrophy of the forearm flexor muscles and excessive elbow flexion.

**16. Radial Nerve**

**16.1 At the Spiral Groove**

Arm wrestling has a relatively common complication of humeral shaft fractures, particularly during times when full force is exerted in an attempt to win the match or to change momentum. In 23% of these cases, a concurrent radial nerve palsy was reported – the sole peripheral nerve injury reported in arm wrestlers (figure 5).\[88\]

Windmill pitching, a technique used by softball pitchers where the pitching arm rotates through extension and abduction, has been associated with radial neuropathy at different anatomical sites including the spiral groove.\[89\] In some cases, the softball pitcher has experienced a humeral shaft fracture associated with the radial nerve palsy.\[90\] Humeral shaft fracture in baseball pitchers have also been associated with radial nerve palsies.\[91\] In adults with humeral fractures associated with throwing a baseball, 16% of patients had concurrent radial nerve palsy.\[91\]

Radial neuropathy in football players has been associated with local trauma to the upper arm during tackling.\[4\] The authors have seen once case of radial neuropathy secondary to humeral fracture in a rodeo performer after a violent dismount.

Finally, tennis players are subject to radial nerve palsy secondary to compression of the nerve by fibrous arches at the lateral head of the triceps.\[92,93\]

**17. Posterior Interosseous Neuropathy**

Tennis, and other related racquet sports, involve repetitive arm swinging. This can lead to a number of musculoskeletal difficulties that may mimic a nerve entrapment syndrome. Specific nerve entrapments do occur within tennis players, and range from rare to common. Electrophysiologically proven posterior interosseous nerve entrapment appears to be common among tennis players and occurs at the Arcade of Frohse, resulting in weakness of the wrist extensors and metacarpophalangeal extensors.\[64,94\]

A professional bodybuilder presenting with proximal forearm pain and supinator tenderness analo-
gous to radial tunnel syndrome secondary to compression of the posterior interosseous nerve was reported. In this case, power squats in which the wrists are in severe extension and elbows in severe flexion were possibly implicated, and conservative treatment led to symptomatic improvement.\(^95\)

A distal posterior interosseous neuropathy has been attributed to repetitive wrist dorsiflexion in a gymnast.\(^96\)

Finally, the lone reported peripheral nerve lesion in active frisbee players is a posterior interosseous nerve syndrome,\(^97\) with probable relationship to recurrent flexion-extension of the wrist.

### 18. Superficial Radial Nerve

The use of a constrictive wrist band or racquetball strap has been associated with a superficial radial neuropathy.\(^98\)

### 19. Digital Nerves (at the Fingers)

A variety of sports may cause neuropathy of the digital nerves. For example, the use of a bow in archery has been associated with compression of the digital nerves,\(^29\) possibly related to repeated drawing of the bow over the length of the fingers. The action of batting in baseball may lead to susceptibility to a traumatic neuroma of the ulnar digital nerve of the thumb.\(^99\)

Ten-pin bowling has only rarely been associated with injury to the nervous system. The repetitive nature of the activity can lead to injuries to the digital nerve of the thumb, which is placed inside the ten-pin bowling ball holes.\(^100\) Perineural fibrosis of the digital nerve of the thumb,\(^100\) as well as a thumb neuroma, have both been reported as a result of chronic trauma due to bowling.\(^101\)

Cheerleading is not an activity that one would expect to be associated with peripheral nerve injury. A sole report of a median palmar digital neuropathy in a 16-year-old girl perhaps related to chronic trauma to the palm during cheerleading activities exists.\(^102\)

Also, digital nerve injuries have been seen in very active tennis players,\(^103\) presumably due to excessive pressure on the palmar surfaces of the fingers by the tennis racquet.

### 20. Lumbar Radiculopathy

Lumbosacral neuropathy is likely underreported in athletes as it relates to sports, as only a single report of a L5-S1 radiculopathy related to football injury has been reported in a single football player (figure 6a).\(^4\)

### 21. Pudendal Nerve

A unique form of neuropathy in the cyclist is the pudendal neuropathy. In fact, ‘bicycle seat neuropathy’ is one of the most common injuries reported by cyclists (figure 6b).\(^104\) One report of male competitive cyclists documented symptoms of recurrent numbness of the penis and scrotum after prolonged cycling, along with an altered sensation of ejaculation and micturition and reduced awareness of defecation. Cyclists may develop pudendal neuropathies secondary to racing-bicycle saddles applying pressure on the perineum. Changes in bike saddle position and riding technique may lead to symptomatic improvement.\(^105\) In a larger cross-sectional study of 160 male professional cyclists, 22% reported symptoms of penile numbness or hypesthesia after a long duration of cycling, and 13% reported transient impotence for weeks. 85% of cyclists reporting genital numbness and impotence also reported hand numbness after cycling, perhaps suggesting predisposing liability to neural injury.\(^81\) In another study of cyclists participating in a 500-mile (805km) bicycle tour, 45% reported mild or transient perineal numbness, 10% reported severe symptomatology, and 2% reported temporary breaks in riding due to symptoms.\(^106\) Not exclusive to male cyclists, 34% of female cyclists also reported perineal numbness.\(^107\) Bicycle seat neuropathy may be due to entrapment of the pudendal nerve passing through the Alcock canal enclosed by ischial bone and obturator internus.\(^108\) Adjustment of the bike seat by tilting the nose of the seat down and lowering the bike seat position to relieve pressure on the perineum may be beneficial.\(^108\)

© 2005 Adis Data Information BV. All rights reserved.
22. Iliohypogastric Nerve

The syndrome of ‘footballer’s hernia’ with lower abdominal bulging may relate to an iliohypogastric neuropathy in some reported cases.\cite{109}

23. Sciatic Nerve

Sciatic nerve lesions may also be underreported in sporting activities, as only scattered case reports detailing sports-related sciatic neuropathy exist. A unique injury dubbed ‘pedal pusher’s palsy’ with bilateral sciatic nerve palsies can occur following prolonged unicycle riding.\cite{110} The small size of the auto racing cockpit places the racecar driver at risk for compressive sciatic neuropathy, presumably near the sciatic notch.\cite{112} Finally, football players are subject to the controversial ‘hamstring syndrome’, which has been mimicked by sciatic neuropathy in some cases.\cite{109}

24. Femoral Nerve

Femoral neuropathy has been reported in dancers who perform repeated simultaneous hip extension and knee flexion (the ‘Horton Hinge’).\cite{64} Gymnastics requires difficult manoeuvres and body postures that place the body at risk for injury, particularly with the involvement of trampolines. Femoral neurolpathy secondary to iliacus haematoma or haemorrhage within the nerve sheath has occurred in gymnasts.\cite{111,112} An anabolic steroid-using bodybuilder developed clinical and electrophysiological evi-
dence of a femoral neuropathy, thought to be associated with hip girdle muscular hypertrophy.[37]

Cross-country skiing has occasionally been associated with mononeuropathies. Cross-country skiing has an injury rate of 0.72 injuries per 1000 skier-days, with more injuries occurring in inexperienced skiers, often when they were on a downhill slope.[112] An isolated femoral neuropathy was reported in a single cross-country skier with vigorous activity.[113]

25. Lateral Femoral Cutaneous Nerve

Lateral femoral cutaneous neuropathy, or the clinical condition known as meralgia paraesthetica, is another relatively common condition that may also be underreported in athletes. A single gymnast has been reported with a lateral femoral cutaneous neuropathy after she entered an intensive programme of jumping rope, with the nerve injury blamed upon repetitive hip flexion and extension.[114] Meralgia paraesthetica secondary to lateral femoral cutaneous neuropathy has been attributed to excessive jogging.[115] A single report of peripheral neuropathy is present for scuba divers with occurrence of lateral femoral cutaneous neuropathy due to compression of the diver’s weight belt upon the nerve.[109]

26. Obturator Nerve

Rugby and Australian rules football players are at risk for obturator neuropathies,[116,117] due to a fascial entrapment of the obturator nerve at the short adductor muscle of the thigh. This condition appears to be very responsive to surgical neurolysis.[116,117]

27. Posterior Cutaneous Nerve of the Thigh

Although not seemingly as common as pudendal neuropathy in the cyclist, another neuropathy due to prolonged bicycle use is posterior cutaneous thigh neuropathy.[108]

28. Peroneal Nerve

28.1 Common Peroneal Nerve

The common peroneal nerve is at risk for entrapment at the fibular head, a relatively common clinical condition. The nerve at this site is at risk for local trauma as well as the possibility of injury with knee injury. Lower limb mononeuropathies in football players have included peroneal neuropathies, particularly in cases where complete knee dislocation and ligamentous injury has occurred. The incidence of peroneal neuropathy when musculoskeletal trauma has occurred at the knee may be as high as 24%.[4,118] Peroneal neuropathy has only rarely been documented in the ice-hockey player due to either laceration of the nerve with a skate blade or due to direct blunt nerve trauma.[119,120] Local blunt nerve trauma occurring in the martial arts has also been associated with contusion of the peroneal nerve.[6]

Running is a highly repetitive activity that has been uncommonly associated with lower extremity neuropathy. In one detailed assessment of 25 long-distance runners, no signs of neuropathy were found, although mild changes in quantitative sensory threshold amplitudes and nerve conduction velocities were reported.[121] Peroneal entrapment neuropathies have been reported in high mileage runners, in one case, bilaterally.[65,115] Peroneal neuropathy in runners has been demonstrated with electrophysiological evidence of entrapment of the peroneal nerve at the fibular neck in several serious runners.[122] One cause of peroneal neuropathy due to running is inversion ankle sprain.[123-125] A differential diagnosis of peroneal neuropathy in runners should include the anterior tibial compartment syndrome, an ischaemic myopathy presenting with post-exertional pain and swelling and possible foot drop.[115]

Many of the injuries experienced by soccer players are musculoskeletal in nature, affecting the lower extremities. Peripheral nerve injury is only very rarely reported in soccer players. There is a single case report of peroneal nerve compression at the fibular neck attributed to excessive play in one soccer player only.[122] Prolonged wave-surfing may lead to repetitive microtrauma and development of a
common peroneal neuropathy in young males.[126,127]

Lastly, auto racing drivers are at risk for common peroneal neuropathy due to compression within a small cockpit and awkward leg placement.[12]

28.2 Superficial Peroneal Nerve

The superficial peroneal nerve is at risk for entrapment with compression along the anterior lower leg. For instance, dancers wearing tight ribbons and elastics in dancing shoes have been reported to be at risk for superficial peroneal neuropathy.[128] Peripheral nerve injury has not been reported due to inline skates, but tight roller skates have been associated with an entrapment of the superficial peroneal nerve.[129]

The lower extremities of runners are subject to a number of forms of neuropathy, including lesions of the superficial peroneal nerve.[130] The superficial peroneal nerve may be susceptible to traction due to perineural fibrosis following inversion ankle sprain injury.[131]

29. Tibial Nerve (at Tarsal Tunnel) and Lateral and Medial Plantar Nerves

Tarsal tunnel syndrome, a compressive lesion of the posterior tibial nerve, can result from repetitive dorsiflexion of the ankle among very active runners.[64] A branch of the tibial nerve, the anterior calcaneal branch, can become entrapped where the nerve passes between edges of the deep fascia of abductor hallucis and os calcis.[132] In runners with heel pain, abnormalities in nerve conduction studies are more commonly found for the medial plantar nerve as opposed to lateral plantar nerve.[133] In addition to runners, tarsal tunnel syndrome may also be caused by repetitive dorsiflexion of the ankle in poor fitting footwear worn by hikers and mountain climbers due to compression of the distal portion of the tibial nerve beneath or distal to the flexor retinaculum.[64,134]

Tarsal tunnel syndrome secondary to inflatable ice hockey skates was reported in a male recreational hockey player with significant clinical and electrophysiological improvement after cessation of wearing the skates.[135]

30. Sural Nerve

Sural neuropathy due to tight ribbons and elastics in dancing shoes has also been reported in professional dancers.[128] Runners can be subject to a number of neuropathies involving the foot, which can include sural neuropathy.[130]

31. Saphenous Nerve

Surfing has only rarely been reported to be associated with peripheral nerve injury. Repetitive microtrauma due to prolonged wave-surfing has been associated with a common peroneal neuropathy and a saphenous neuropathy in young males.[126,127] Runners are also at risk for saphenous neuropathy, possibly due to traction and perineural fibrosis.[130]

32. Dorsal Cutaneous Nerve of Foot

The sole reported lesion of the dorsal cutaneous nerve was reported in professional dancers, who may compress this nerve when they sit on their feet, placing pressure on the dorsum of the foot.[128]

33. Interdigital Nerves of Foot

Another cause of neuropathy of the foot in runners is the repetitive pressure upon the sole, leading to lesions of the interdigital nerves.[130]

34. Morton’s Neuroma of Plantar Nerve

Excessive load upon the heel and midfoot regions may occur in runners with pes planus, which may contribute to forms of focal neuropathy including Morton’s neuroma in the feet.[136] Morton’s neuroma can occur in runners, and must be differentiated from plantar fasciitis and metatarsal bursitis.[35,137] Just as in active runners, serious dancers can occasionally present with a Morton’s neuroma of the plantar nerves.[138] Lastly, a Morton’s neuroma has been reported in one karate participant, presumably due to repeated irritation of the ball of the foot from fighting stances.[6]
35. Calcaneal Neuropathy

Excessive load upon the heel and midfoot regions may occur in runners with pes planus, which may contribute to forms of focal neuropathy in the feet, including calcaneal nerve lesions.\(^{[136]}\)

36. Conclusions

This review has been extremely broad in terms of sporting disciplines and range of injuries. We attempted to provide an overview of sporting-related injuries, but identification of rarely occurring sport-specific injuries has also been attempted. The unique nature of particular injuries, such as atypical mononeuropathies in golfers and weightlifters, provide a contrast to common injuries such as brachial plexopathy and median neuropathy within this review.

We found that nervous system injury can occur with almost any sport. Even apparently benign sporting activities such as cheerleading, golf and dancing have been associated with peripheral nerve injury. Particular sports are associated with alarming incidences of injury. Football, in particular, has very high injury rates and unacceptable morbidity rates of PNS injuries. The literature probably underreports the incidence of injury in many sports. For example, reporting of injuries other than concussion within the National Football League for professional football is meagre, and a sport with high expectation for injury such as rodeo, is largely ignored in the literature.

We limited the review to those reports found by a PubMed search of medical literature and references found in those articles initially found. Abstracts in PubMed go back to the mid-1960s in most cases. Obviously, there have been many injuries missed by this review, either due to lack of reporting, or publication outside of the PubMed scope. In some cases, neurological abnormalities have been reported in the literature in an athlete where the sporting activity may have played no role. Future studies might be strengthened by using a case-control design, a trial of abstention from the offending sporting activity, and longer follow-up periods. The role of electrophysiology in successful diagnosis of sports-related PNS injuries is very important, and should continue to be reported in cases of injury related to sports or recreational activities.

This article is intended to help the healthcare professional in the recognition of sport-specific injuries, as well as to assist in judging their prognosis. It may serve as a reference for physicians who encounter athletes with unique or difficult problems. For physicians not faced with sports-related injuries on a regular basis, and sports medicine physicians not diagnosing neurological lesions on a regular basis, this review may provide a guide for these mutually distinct subspecialties.

Acknowledgements

No sources of funding were used to assist in the preparation of this review. The authors have no conflicts of interest that are directly relevant to the content of this review.

References

82. Wossnichack D, Hussein S, Hollerhage HG. Bicycle rider’s ulnar neuropathy [in German]. Neurochirurgia (Stuttg) 1993 Jan; 36 (1): 11-3
83. Hankey GJ, Gubbay SS. Compressive mononeuropathy of the deep palmar branch of the ulnar nerve in cyclists. J Neurol Neurosurg Psychiatry 1988 Dec; 51 (12): 1588-90
85. Walker FO, Troost BT. Push-up palmar palsy. JAMA 1988; 259: 45-6
120. Shevell MI, Stewart JD. Laceration of the common peroneal nerve by a skate blade. CMAJ 1988 Aug 15; 139 (4): 311-2

Correspondence and offprints: Dr Cory Toth, Department of Clinical Neurosciences, University of Calgary, Room 128, Heritage Medical Research Building, 3330 Hospital Drive NW, Calgary, AB T2N 4N1, Canada.
E-mail: corytoth@shaw.ca