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## Abstract

When participating in sport and exercise activities, various – often age-dependent – injuries to any part of the spine are possible. The neck is most commonly injured in sports that involve contact, which place the cervical spine at risk of injury, in some cases with catastrophic consequences. The thoracic spine is less likely to be injured because it is relatively immobile and has extra support, but M. Scheuermann can lead to symptoms. The lower back is subject to a great deal of repetitive strain in many sports, which can result in nonspecific lumbago or more specific lumbar spine conditions, like spondylolysis and spondylolisthesis, disk disease, and lumbar stenosis which need further clinical and radiological investigation. This chapter describes the most common acute and chronic sports-related injuries of the spine.

## 10.1 Introduction

It can be challenging to make a precise diagnosis in athletes with pain in the neck or back, not least because demonstrable pathology is not always present and psychosocial factors often play a role. Low back pain has a lifetime incidence of up to 70 % in the general population (Sarwark et al. 2010). Therefore, it is not surprising that LBP is also a common condition in athletes. In fact, the incidence of LBP in athletes has been suggested to be as high as 30 % (Dreisinger and Nelson 1996).

Cervical pain is also a common complaint in the athletic population. Some injuries are mild in nature; however, more serious injuries, especially those involving the cervical spine, can have devastating consequences (Krabak and Kanarek 2011). Pain originating from the thoracic spine is less common.

Causes of pain in these anatomical regions are rather age specific (Table 10.1). Some sports are associated with a higher than normal percentage of spine injuries.

It is important for physicians dealing with athletes suffering from back or neck pain to understand the differences between serious and mild spinal injuries. In order to make a precise diagnosis, a good knowledge of the basic anatomy of the spine and its related structures, familiarity with mechanisms of injury and common causes of back and neck pain, and a thorough understanding of the clinical presentation of the disorders in these areas is necessary.

**Table 10.1** Etiology of spine-related pain by age

Age	Condition
<18 years	Spondylolysis/spondylolisthesis
	Scheuermann disease
18–50 years	Acute lumbago/acute cervicalgia
	Internal disk disruption
>50 years	Chronic lumbago/facet osteoarthopathy
	Lumbar stenosis
	Osteoporosis and compression fracture

## 10.2 Functional Anatomy

The spine can be divided in five sections: cervical (7 vertebrae), thoracic (12 vertebrae), lumbar (5 vertebrae), sacral, and coccygeal. Special units exist for the “start” (craniocervical junction) and “end-connections” (sacroiliac junction), articulating the spine respectively with the head and with the pelvis.

Normally the cervical and lumbar spine have a lordotic curve, whereas the thoracic spine is kyphotic. The main functions of the spine are to support the head, pelvic girdle, and abdominal organs, attachment of the thorax, protection of the spinal cord, and transfer of weight and bending movements of the head, trunk, and pelvis.

The spine consists of bones, joints, ligaments, and muscles. The vertebrae are joined by joints between the bodies (disks) and the neural arches (facets). The anterior column consists of the vertebral bodies, intervertebral disks, and the anterior and posterior ligaments. Other ligaments are the inter- and supraspinous ligaments and the ligamentum flavum. The posterior column includes the neural arch, facet (zygapophyseal) joints, spinal process, and pars interarticularis (the area between the upper and lower facet joints). Important neural structures (spinal cord, conus medullaris, and cauda equine) lie within the spinal canal that runs through the vertebral foramen.

The intervertebral disks are fibrocartilaginous structures located between the vertebral bodies. It has three components: (1) the annulus fibrosus, the outer circumferential ring with collagen layers arranged in a “criss-cross” type pattern to resist torsional, axial, and tensile loads; (2) the nucleus pulposus, the central core which is composed of 70 % water, determines the disk height and provides resistance to axial compression; and (3) cartilaginous vertebral endplates.

Different muscle groups act on the spine which can be divided into (1) the anterior muscle group (interspinal, intertransverse); (2) the middle muscle group semispinalis, multifidus, and rotators; (3) the posterior muscle group (erector spinae, iliocostal thoracis, longissimus thoracis, and iliocostal lumborum); and (4) the accessory muscle group (latissimus dorsi and trapezius). The anatomy of the neck is also complex; however, it is beyond the scope of this book to give a detailed description.

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## 10.3 Etiology and Injury Mechanism

Acute muscle strains, ligament sprains, and soft tissue contusions are a very common cause of back and neck pain in athletes (Mautner and Huggins 2012). However, most low back injuries are not the result of a single exposure to a high-magnitude load, but instead a cumulative trauma from sub-failure magnitude loads: for instance, repeated small loads (e.g., bending) or a sustained load (e.g., sitting). In particular, low back injury has been shown to result from repetitive motion at end range. Sports that use repetitive impact (e.g., running), a twisting motion (e.g., golf), or weight loading at the end of a range of motion (e.g., weightlifting), commonly cause

damage to the lower back (Alexander 1985). For example, repetitive hyperextension of the low back (gymnastics, figure skating, diving) is a risk factor for the development of spondylolysis.

Contact sports such as football and ice hockey carry an inherent risk of cervical spine injury. The major mechanism of serious cervical injury is an axial load or a large compressive force applied to the top of the head (Chao et al. 2010). This mechanism is more dangerous when the neck is slightly flexed, because the spine is brought out of its normal lordotic alignment, which does not allow for proper distribution of force to the thorax. Flexion puts the cervical spine in a straight line; thus, the musculature cannot assist in absorbing the force. Injury to the cervical spine occurs when it is compressed between the body and the rapidly decelerating head. When a fracture results, if the bone fragments or herniated disk materials encroach on the spinal cord, neurologic damage will occur. This mechanism is the primary cause of cervical fracture, dislocation, and quadriplegia.

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## 10.4 Sports Injuries

### 10.4.1 Sprains, Strains, and Muscle Contusions

The vast majority of back pain in the athlete occurs as a result of soft tissue sprain, strain, or contusion, and these are often a diagnosis of exclusion (Mautner and Huggins 2012). Sprain represents stretching of a ligament beyond its elastic limit. Strain is tearing of a muscle during concentric or eccentric loading. Contusion occurs after blunt trauma to the soft tissue and often leads to formation of a hematoma. These injuries are readily diagnosed based on history and clinical examination. Initially sprains, strains, and contusions can be very debilitating, but most respond to conservative management with rest, NSAIDs, and massage. Activities can be resumed when pain resolves. In case the pain does not disappear or neurological symptoms develop, further examinations should be considered.

### 10.4.2 Cervicalgia and Cervicobrachialgia

Most neck pain is regarded as nonspecific in the absence of radiological evidence of relevant pathoanatomy. Acute cervicalgia is characterized by a sudden onset of sharp neck pain with protective deformity and limitation of movement. It typically occurs either after a sudden, quick movement or on waking. There may have been unusual movements or prolonged abnormal postures prior to the onset of pain (Hutson and Speed 2010).

The “stinger” or “burner” phenomenon is seen frequently in American football and rugby and less often in other contact sports (Standaert and Herring 2009). The player experiences transient upper extremity burning-type pain that may also be accompanied by paresthesia and/or weakness. Traction or compression of the

cervical nerve root and/or plexus brachialis is considered to be the underlying mechanism. Symptoms may be localized to the neck or may radiate to the arm and hand. The symptoms are usually transient, but persistent neurological dysfunction and recurrent stingers may occur.

### **10.4.3 Acute and Chronic Lumbago**

Lumbago can be defined as mild to severe pain or discomfort in the area of the lower back (Patrick et al. 2014). The pain can be acute (sudden and severe) or chronic if it has lasted more than 3 months. Most people will experience lumbago at some point in their life and so do athletes. It can occur at any age but is a particular problem in younger people whose work involves physical effort and much later in life in the elderly. Athletes present with pain across the lower part of the back that sometimes radiates into the buttocks, the back of the thigh, or to the groin. The pain is usually worse on movement. There can be a tense spasm of the muscles surrounding the spine, which causes a stiff back with limitation of flexion and extension of the spine. In some severe cases, the back may tilt to one side causing a change in posture or a limp. If the pain is accompanied by a tingling sensation or numbness in the back or buttocks or leg, which may pass right down into the foot, this is called sciatica, and it indicates irritation of the sciatic nerve, which passes down from each side of the spine to the feet. In most cases it settles in a few days to weeks, but for some it is a persistent problem. In the majority of cases, it is impossible to identify the exact cause of low back pain. Due to a forceful sports-related movement, there may, for example, have been tiny strains or tears of some of the small muscles and ligaments, which can be difficult to pinpoint within the complex structure that is the human back. In most cases of lumbago, no imaging is necessary. However, in about a quarter of cases, a specific problem can be found. Often, these athletes are suffering from conditions like osteoarthritis of the facet joints, a slipped disk (prolapse of an intervertebral disk), a collapse or fracture of one or more vertebrae (especially in the elderly athletes, when they have fallen or there is a deformation of natural spine curvature (scoliosis) or more rarely, skeletal damage due to tumors or infection.

### **10.4.4 Intervertebral Disk Injuries With(out) Radiculopathy**

Discogenic pathology is the primary cause in almost 50 % of young to middle-aged adults that complain of low back pain (LBP), whereas it is the cause of only a minority of cases in young inactive adolescents. Adolescent athletes, however, have a higher risk for internal disk disruption (IDD) than their inactive peers with back pain due to a discogenic cause in 11 % of cases (Haus and Micheli 2012; Mautner and Huggins 2012). The adolescent growth spurt appears to be the most vulnerable time for injuries to the lumbar intervertebral disk. Repetitive hyperflexion and extension loading on the lumbar disk during sports can lead to endplate irregularities, Schmörl

nodes, annular tears, disk protrusions, and endplate fractures. Competitive sports and sports with more frequent trunk rotation, as, for example, gymnastics, soccer, tennis, and golf, are associated with early lumbar disk degeneration. Discogenic pain is often nonspecific. Some findings may suggest a discogenic nature of the pain: midline pain, pain with periods of unsupported sitting, and pain worsening with forward flexion. Posterior annular tears without nerve root compression can cause radicular type buttock, groin, and leg pain. On examination often there is a decreased flexibility. Neurologic deficits are absent.

In case of herniation of the nucleus pulposus with nerve root compression patients typically present with low back, buttock, or hip pain and radicular symptoms including numbness, tingling, and sharp radiating pain in the lower extremity. Pain can be made worse by coughing or sneezing. Besides a full examination of the spine, a careful neurologic examination has to be performed, looking for (subtle) deficits in strength, sensation, or reflexes. Special test like the straight leg raise and slump test can be helpful. One should realize that this classical radicular pattern might be absent in younger patients.

MRI allows excellent evaluation of the intervertebral disk and may show early degenerative changes including disk signal reduction, loss of height, bulging, apophyseal abnormalities, and Modic changes and its interaction with nearby structures like nerve roots (see Chap. 11). However, many asymptomatic patients will have abnormal MRI studies and this should be kept in mind. The natural history of low back pain is often favorable and the mainstay of treatment is nonsurgical. Athletes should be encouraged to remain active (activity modification), and the use of nonsteroidal anti-inflammatory drugs (NSAIDs) as a first-line medication should be considered. Physical therapy to retrain the stabilizing spinal musculature results in less LBP recurrence.

#### 10.4.5 Scheuermann Disease

The prevalence of Scheuermann disease is approximately 1–8 % (Haus and Micheli 2012; Lowe and Line 2007). The typical presentation is in the late juvenile age period (8–12 years). Cosmetic deformity caused by increased thoracic kyphosis is the most common complaint of patients with Scheuermann disease and is typically the primary reason for young patients to seek medical attention. The natural history remains controversial. Scheuermann disease tends to be symptomatic in the acute phase (during the teenage years) with thoracic pain worsening by activity and diminishing later in life. Patients with Scheuermann have more back pain than their healthy peers. This pain is believed not to interfere with daily activities. A recent study, however, reports a lower quality of life and more risk for disability in the activities of the daily living (Ristolainen et al. 2012).

The specific etiology remains unknown but is probably multifactorial. Genetic factors, failure in endplate ossification, chronic trauma (sports, hard labor), and hormonal factors are mentioned. Besides the most frequent “classic” Scheuermann

found at the mid-thoracic spine, there also is a “lumbar” type (type II) localized at the thoracolumbar junction. This type II is typically seen in athletically active adolescent males or those involved in heavy lifting. There is a strong association with repetitive activities involving axial loading of the immature spine. In lumbar Scheuermann typically there is no kyphosis. Endplate irregularities can be more severe and can be confused with tumor, infection, or other conditions.

Imaging plays an important role in defining this condition. Radiological findings, including the typical Schmörl nodes, are discussed in Chaps. 11 and 12. Treatment of classic Scheuermann is controversial. Physical therapy is recommended and patients that are skeletally immature with a kyphosis between 45° and 65° are candidates for bracing. Surgery is generally considered if kyphosis is more than 65° and is associated with pain not alleviated by other methods. Unlike the classic type, the treatment of lumbar Scheuermann is more straightforward as its course is non-progressive. Symptoms generally resolve with rest, activity modification, and time (Afshani and Kuhn 1991; Lowe and Line 2007; Ristolainen et al. 2012).

#### 10.4.6 Spondylolysis and Spondylolisthesis

Spondylolysis is defined as a unilateral or bilateral bony defect in the pars interarticularis (also known as the isthmus) of the vertebral posterior elements. In the general population, the incidence of spondylolysis is around 6–8 % (McTimoney and Micheli 2003). In the athletic population, however, the incidence of spondylolysis is much higher, up to 63 % (Rossi 1978). Spondylolysis is the primary cause of back pain in athletes and responsible for approximately 47 % of low back pain in this population (Micheli and Wood 1995). Spondylolysis is rarely seen in children younger than 5 years, which makes a congenital pathogenesis not very likely. The incidence increases with age until about 20, after which the incidence stabilizes (Brooks et al. 2010). Spondylolysis is more frequent in boys than in girls and more frequent in whites than in blacks (Leone et al. 2011). More recent studies suggest an equal prevalence between boys and girls (Haus and Micheli 2012). This might be due to a general increase in the number of female athletes, especially in sports such as ballet and gymnastics. Spondylolisthesis appears to be more frequent in girls (Loud and Micheli 2001).

The pathogenesis remains controversial. Most likely spondylolysis is a multifactorial condition in which a stress fracture occurs in a congenitally weak or dysplastic pars interarticularis (Leone et al. 2011). The mechanism of injury is often a combination of repetitive forces like flexion, extension, and rotation of the lumbar spine. Sports associated with an increased frequency of spondylolysis are typically sports requiring hyperextension motions such as gymnastics and diving. Contact sports such as football, soccer, hockey, and lacrosse also have an increased risk of spondylolysis (Afshani and Kuhn 1991). The injury may be unilateral or bilateral and occurs most commonly (in 95 % of cases) at the L5 vertebra. When the injury is bilateral, spondylolisthesis may occur. Spondylolisthesis generally refers to the

forward translation of one vertebra relatively to the next more caudal vertebra. It mostly involves the L5–S1 segment. It has different etiologies (cfr. Wiltse classification) with isthmic spondylolisthesis being the most common subtype (Haus and Micheli 2012).

Spondylolysis may be completely asymptomatic. If there are symptoms, the athlete typically complains of a mechanical-type low back pain, typically getting worse with hyperextension and improving with rest. The pain may radiate to the buttocks or posterior thigh. The onset is often insidious, but can be precipitated by an acute injury. Common findings on physical examinations are a hyperlordotic posture and bilateral hamstring tightness. Hyperextension with a one-leg stance exacerbates the pain. Radicular signs are less common, but may occur in the presence of spondylolisthesis (Haus and Micheli 2012; Leone et al. 2011). The role of imaging is discussed in Chaps. 11 and 12.

The treatment of spondylolysis is initially conservative with cessation of sporting activities and spinal bracing for 3–6 months. The aim is to reduce pain and to facilitate healing. Surgical treatment is typically reserved for patients who do not respond to conservative treatment after 6 months. Surgery is necessary in 9–15 % of patients with spondylolysis and/or low-grade spondylolisthesis. Surgery should not be considered lightly as it often concerns young patients (Leone et al. 2011).

#### **10.4.7 Lumbar Stenosis**

Degenerative lumbar spinal stenosis is caused by mechanical factors and/or biochemical alterations within the intervertebral disk that lead to disk space collapse, facet joint hypertrophy, soft tissue infolding, and osteophyte formation, which narrows the space available for the thecal sac and exiting nerve roots (Lee et al. 2013; Issack et al. 2012). The clinical consequence of this compression is neurogenic claudication and varying degrees of leg and back pain. Symptoms include radicular pain, numbness, tingling, and weakness. It is a common diagnosis that is occurring with increased frequency in sports medicine clinics (Borg-Stein et al. 2012). Degenerative lumbar spinal stenosis is a major cause of pain and impaired quality of life in the elderly. The natural history of this condition varies; peripheral vascular disease presents similarly and must be considered in the differential diagnosis.

#### **10.4.8 Sacroiliac Joint Injury/Inflammation**

The sacroiliac (SI) joint may also give rise to low back pain. Symptoms usually develop insidiously and are worsened by sports activities (Brolinson et al. 2003). There is palpation tenderness over the SI-joint. Spine extension is often painful and the FABER test reproduces pain in the affected SI-joint. Straight leg raise testing is negative. Symptoms may be quite similar to those found in patients with spondylolysis. Inflammation of the SI-joint can be associated with several other



conditions like Crohn's disease, psoriasis, and ankylosing spondylitis (seronegative spondyloarthropathies) and Reiter's syndrome. Serological screening and imaging (Chaps. 11 and 12) should be performed in case of doubt with regard to the diagnosis.

### 10.4.9 Fractures and Dislocations

Flexion injuries of the cervical spine can cause compression fractures of the vertebral bodies (McRae and Esser 2008). Flexion fractures occur most frequent at the level C5 and C6 in adolescents. When combined with significant axial loading, flexion injuries can result in burst fractures of the vertebral bodies with retro-pulsion of bony fragments into the spinal canal (Maxfield 2010). The spine is particularly vulnerable for rotational forces; combined rotational forces can result in more severe subluxation due to increased disruption of supporting tissue. Because of the small, flat, almost horizontal configuration of the articular processes of the cervical spine, dislocation can occur relatively easy in case of trauma (Boran et al. 2011).

Acute fractures of the thoracolumbar spine are less frequent than cervical injuries and tend to be less catastrophic. In the thoracolumbar region, compression fractures are the most common type in young athletes. Compression fractures, as the name suggests, occur due to a compression force on the spine. This may happen during a traumatic injury such as a fall from a height, landing on the feet or buttocks (McRae and Esser 2008). More frequently, vertebral compression fractures occur in older people with osteoporosis or other preexisting spinal conditions where the bone is weak. There may not be one particular incident that causes it and pain may develop gradually.

Avulsion fractures of the spinous and transverse processes are also seen in athletes. Avulsion of the spinous process of the C7 and Th1 vertebrae are known as *clay-shoveler* fractures.

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## 10.5 Spinal Injuries Associated with Specific Sports

Some sports are associated with a higher than normal percentage of spine injuries.

Acute spinal trauma can be seen in many sports and is related to an increased risk for trauma. These traumatic injuries do not differ significantly from those seen in non-sports-related trauma, e.g., falls or motor vehicle accidents.

More specific spine injuries are seen in chronic overload and/or strain to the spine occurring in some sports. These will be discussed in detail in this chapter.

The most common sports responsible for spinal injuries are equestrian events (41.8 %), rugby (16.3 %), diving (15.3 %), Gaelic football and hurling (9.6 %), cycling (4.2 %), and miscellaneous (12.7 %) (Boran et al. 2011). In general more males (74 %) than females (26 %) are injured, and the average age is 30.2 years (range 14–72 years).

Injuries are mostly to the cervical spine (60 %) and less to the thoracic (21 %) or lumbar spine (19 %). In 40 % of patients, more than one vertebral level is affected (Boran et al. 2011).

## 10.5.1 Sports Involving High-Velocity Incidents or Falls

### 10.5.1.1 Skiing and Snowboarding

Spinal injuries associated with recreational skiing and snowboarding mostly result from high-energy falls and to a lesser degree from collisions with other skiers, trees, or equipment. In competition snowboarding, spinal injuries are specifically related to the risks associated with jumping and performing moves.

Orthopedic injuries sustained in alpine skiing/snowboarding are numerous, with spinal injuries comprising between 1 and 20 % of all injuries (Floyd 2001; Levy and Smith 2000; Prall et al. 1995; Yamakawa et al. 2001). Snowboarding accidents result in more fractures, especially in the upper limbs, fewer knee injuries, and more severe injuries caused by impacts rather than by torsions (Yamakawa et al. 2001). Spinal injuries are more than two times more frequent in snowboarders compared to skiers.

The incidence of spinal injury in skiing and snowboarding is in general very low (0.001/1,000 skier-days). Although less frequent, spine and spinal cord injuries are the most debilitating and costly of serious injuries sustained by skiers (Prall et al. 1995). The majority (80 %) of spinal lesions are thoracic or lumbar, and multilevel lesions are seen in 20 % of patients. Compression fractures with loss of height of the anterior part of the vertebral body are the most frequent thoracic and lumbar lesions seen in 38–90 % of patients (Floyd 2001; Prall et al. 1995). Severe and/or unstable thoracic or lumbar fractures are seen in less than 5 % of patients. Snowboarders in general have the same pattern of lesions except for transverse process fractures that are significantly more frequent.

Cervical lesions on the other hand, although more rare, are usually more severe. In one major study, spinal cord injuries were seen in 17 % of ski accidents with spinal fractures, usually in association with cervical lesions (Prall et al. 1995).

There is a significantly higher incidence of spinal injury among beginner snowboarders than among beginner skiers. Furthermore, intermediate or expert snowboarders were more likely to be injured because of jumping than beginners, whereas about 70 % of spinal injuries caused by skiing results from a simple fall (Yamakawa et al. 2001).

As a final note in skiers and snowboarders under 13 years of age, helmet use does not increase the incidence of cervical spine injury but does reduce the incidence of head injury (Macnab et al. 2002).

### 10.5.1.2 Cycling

Although the vast majority of injuries suffered while cycling are minor, acute spinal injuries have been reported. Profound neurological deficits are reported in patients that are thrown over the handlebars while traveling downhill at speed

(McGoldrick et al. 2012). Spinal injuries are more frequently seen in mountain bikers, due not only to the characteristics of the terrain but also to the readiness to assume a higher risk compared to cycle racing (Schueller 2010).

Neck and back pain is extremely common in cyclists, occurring in up to 60 % of riders. To avoid or lessen spinal pain, proper fit of the bicycle is critical. Proper frame selection and adjustment can be made by following existing guidelines for frame size, seat height, fore and aft saddle position, saddle angle, and reach and handlebar height (Mellion 1991). Especially an appropriate pedal unit position may reduce low back pain. Positioning the pedals behind the saddle axis permits more physiological spine angles in comparison with the classic one having the pedals in front of the saddle axis (Fanucci et al. 2002). Lower back pain is the most prevalent overuse injury seen in cyclists, with an incidence up to 45 %, and low back pain causes the highest rates of functional impairment and medical attention in cycling (Clarsen et al. 2010). This high incidence might be caused by the creep induced in the viscoelastic tissues of the spine as a result of cyclic loading that subsequently desensitizes the mechanoreceptors within, allowing full exposure to instability and injury (Solomonow et al. 1999).

### 10.5.1.3 Horseback Riding

Horseback riding is the most common sport responsible for a spinal injury. Spinal injuries are an inevitable risk of horse riding with the rider high from the ground, relatively unprotected, and the horse that travels at speeds of up to 65 km/h. Moreover, the spines of the riders are relatively unprotected since effective gear to protect the spine still does not exist. Compared to other sports, horse riding accounts for the largest number of hospital admittance days by far and between 7 and 10 % of all riders requiring hospital admission suffer from spinal injuries (Hessler et al. 2014). In the United States, the rate of serious injuries from horseback riding has been reported to range from 1 per 350 to 1,000 h of riding. In British Columbia, Canada, the rate of hospital admissions for horseback riding injuries is 0.49 per 1,000 h of riding. In the Netherlands, every year, one out of seven riders will sustain an injury (Siebenga et al. 2006). Several studies have suggested that horseback riding is riskier than motorcycle riding, skiing, football, and hockey (Lin et al. 2011; Siebenga et al. 2006). In some countries, 70 % of all spine fractures caused by sports activities are sustained by equestrian activities (Hipp et al. 1977). Although numerically few, spine and spinal cord lesions from horse riding accidents are frequently catastrophic giving rise to paralysis or death (Silver 2002). The injury of actor Christopher Reeve (“Superman”) in 1995, resulting in a complete C2-level SCI, heightened public awareness of the risks associated with horseback riding.

Up to 80–90 % of horseback riding accident victims are female (Hessler et al. 2014; Siebenga et al. 2006). Most spinal injuries are caused by falling of the horse (65–80 %), followed by being kicked by a horse. Around 80 % of the injuries occur at the thoracolumbar junction, either at Th12, L1, or L2 (Siebenga et al. 2006). Lumbar injuries being the most frequent (70 %), thoracic injuries second most frequent (30 %), while cervical injuries are more rare (Hessler et al. 2014). Other

studies found relatively more thoracic injuries (Roe et al. 2003). The majority of fractures (85 %) are vertebral compression lesions (Hessler et al. 2014). Spinal cord injury from horseback riding affects an equal proportion of women and men, has a wide age range, and most commonly results in incomplete tetraplegia followed by complete paraplegia (Lin et al. 2011). Overall figures from the USA show that between 1973 and 1985, a total of 9,647 new admissions with spinal cord injury, 14.2 % were due to sport, of which 2 % represented horseback riding injuries (Stover and Fine 1987). A fall from a horse would appear to be most likely to cause a spinal cord injury. A kick, while it may cause a fracture of a transverse process, usually does not cause spinal cord injury (Silver 2002).

Consequences of injury caused by horse riding can be profound and the long-term effects should not be underestimated (Siebenga et al. 2006). Even years after a major trauma, 43 % of the patients have complaints and 11–20 % will remain permanently unfit for work (Dekker et al. 2003).

As far as stress or overload spine injuries in horse riding go, there is no conclusive MRI evidence to suggest that the cause lies in undue disk degeneration, spondylolysis, spondylolisthesis, or pathologic changes of the paraspinal muscles of the lumbar spine (Kraft et al. 2009). Still, compared to the general population, a high incidence of back pain is found among riders, but a significant correlation between the intensity of riding or the riding discipline and frequency or severity of back pain could not be found. For riders with preexistent back pain, the pace “walk” seems to have a positive influence on pain intensity (Kraft et al. 2009). Saddle types might play a role in the incidence of low back pain and is less often seen in riders that use a deep seated/Western style saddle than in those that use a traditional style/general purpose saddle (Quinn and Bird 1996).

#### 10.5.1.4 Diving

Diving is the second or third most common cause of sports-related spinal injuries. In diving accidents the cervical spine is most often (>90 %) affected, with a highest number of fractures at C5 and C6, followed by C7. Most of these injuries are compression-flexion type injuries. Jefferson fractures, compression fractures of the ring of C1, are also frequently seen in diving accidents and occur by axial compression to the vertex such as diving in shallow water and hitting the bottom with the head first. Overall injury rates for diving are estimated as 4.00 injuries per 1,000 exposures for men and 3.78 injuries per 1,000 exposures for women (Amorim et al. 2011). Many spinal diving injuries result in tetraplegia, in some studies up to 45 % (Amorim et al. 2011). These injuries are associated with a very specific patient profile of a young, healthy, athletic male (>95 %) who suffered an injury to the cervical spine after diving into shallow water almost occurring exclusively during spring and summer time (Korres et al. 2006). Dangerous diving into swimming pools can result in spinal injuries with drastic consequences, including permanent physical disability and a profound impact on socio-professional status. Moreover, there are significant financial costs to society (Borius et al. 2010).

## 10.5.2 Contact Sports

In contact sports, also called “collision sports,” players directly or indirectly have physical contact with an opponent. The pattern of spinal injuries in American football, rugby, lacrosse, soccer, and ice hockey resembles closely. These injuries are induced by relatively high-velocity body contacts between athletes, usually of opposing teams. In ice hockey, impact of the head with the boards after being checked or pushed from behind is the most common mechanism of spinal cord injury (Tator et al. 2004).

The cervical spine is at greatest risk for injury in these sports, followed by thoracic and lumbar injuries in that order (Mall et al. 2012). Cervical spinal cord injuries have been the most common catastrophic football injury and the second leading direct cause of death attributable in American football (Cantu and Mueller 2003). The relatively common “stinger” is a neuropraxia of a cervical nerve root(s) or brachial plexus and represents a reversible peripheral nerve injury. Less common and more serious an injury, cervical cord neuropraxia is the clinical manifestation of neuropraxia of the cervical spinal cord due to hyperextension, hyperflexion, or axial loading (Rihn et al. 2009). Up to 2 out of 100,000 American football players are diagnosed with cervical cord neuropraxia. Characterized by temporary pain, paresthesias, and/or motor weakness in more than one extremity, there is a rapid and complete resolution of symptoms and a normal physical examination within 10 min to 48 h after the initial injury. Stenosis of the spinal canal, whether congenital or acquired, is thought to predispose the athlete to cervical cord neuropraxia (Rihn et al. 2009). Permanent neurological deficits or even death after catastrophic cervical spine injuries are seen in 3–15 per 1,000,000 football players (Kim et al. 2003). These lesions mostly occur after cervical hyperflexion and are usually accompanied by facet joint fracture dislocations and/or anterior wedge compression fractures. Facet dislocations, in particular bilateral facet dislocations, are identified as the most common types of cervical spine injury in rugby. Trauma occurs most often at lower cervical spinal levels, notably the C4/5 and C5/6 motion segments (Kuster et al. 2012). Hyperextension lesions in contact sports are less common but might also have catastrophic results (Silva et al. 2006).

The complex biomechanics of heading in soccer are not completely defined, especially with regard to long-term effects on the neck and cervical spine. Existing studies of long-term effects suggest a predisposition to degenerative changes of the cervical spine, though they are somewhat limited, even when coupled with data regarding athletes in other sports (Mehnert et al. 2005).

## 10.5.3 Chronic Overload Sports

### 10.5.3.1 Gymnastics, Figure Skating, and Dance

Spinal injuries in gymnastics, figure skaters, and dancers are not uncommon. Because of the unique demands of these sports, which repetitively place significant forces across the spine, potential causes of back pain include spondylolysis,

Scheuermann disease, intervertebral disk pathology, and mechanical sources of pain (Kruse and Lemmen 2009). The spine is a frequently injured area of the body in dancers, and many issues stem from poor technique and muscle imbalance (Gottschlich and Young 2011). In male dancers and figure skaters, there is a higher incidence of low back injuries allegedly due to their lifting requirements. However, imaging studies have failed to demonstrate higher rates of degenerative disk disease in gymnasts or female dancers than in control groups of the same age (Capel et al. 2009). Spondylolysis on the other hand is more frequent in elite-level gymnasts than in the general population (Bennett et al. 2006). Specific segmental muscle control exercises of the lumbar spine may be of value in preventing and reducing low back pain in young gymnasts (Harringe et al. 2007). Some studies even suggest lower levels of low back pain in dancers due to greater leanness, not smoking, displaying less anxious/depressive behavior, and developing increased muscle strength and flexibility (Cupisti et al. 2004).

### 10.5.3.2 Weightlifting

The lower back is one of the most commonly injured body regions in powerlifting, but the injury rate is low compared to other sports (Siewe et al. 2011). Other studies report a high frequency of lower back injuries in weightlifting (Alexander 1985). In a study of 12 discordant pairs of monozygotic twins, there were no effects of power sports (2,300 vs. 200 h of weightlifting) on disk degeneration seen on MRI (Videman et al. 1997). The effect of wearing a back belt on spinal injuries is also controversial, reducing spine loading according to some (Kingma et al. 2006), but increasing injury rate of the lumbar spine according to others (Siewe et al. 2011).

### 10.5.3.3 Golf, Tennis, and Cricket Fast Bowling

Injuries related to participation in golf and tennis become more common given the increased popularity of these sports. Golf is considered to be an activity associated with a moderate risk for sports injuries (Sutcliffe et al. 2008). Spinal injuries in golf, tennis, and bowling are usually attributable to overuse of the lumbar spine. More specifically these sports demand a combination of trunk and shoulder rotation while swinging a club or racket or moving a ball at high speeds and loads (so-called rotational sports). In tennis the spine is one of the most frequently injured body parts (Hjelm et al. 2010; Kondric et al. 2011). In golf, the mean peak compressive load at the lower lumbar spine is over six times the body weight during the downswing and the mean peak anterior and medial shear loads approach 1.6 and 0.6 times the body weight during the follow-through phases (Lim et al. 2012). These loads predispose the golfing population to muscle strains, lumbar disk disease, spondylolysis, and facet joint arthropathy (Hosea and Gatt 1996). In cricket fast bowlers, the pars interarticularis of each vertebra is vulnerable to injury due to repetitive flexion, rotation, and hyperextension (Elliott 2000). Fast bowling is directly associated with the development of symptomatic pars lesions of the lumbar spine, particularly unilateral L4 stress lesions, in a significant proportion of the adolescent bowlers (Engstrom and Walker 2007). Within cricketers, unilateral

spondylolyses tend to arise on the contralateral side to the bowling arm (Gregory et al. 2004). Modic type I changes, especially asymmetrically and at the side of the golfers handedness, might be responsible for some of the low back pain complaints (Mefford et al. 2011).

Modification of sports kinematics reduces loads and spinal injuries in all of these sports. Adaptation of the swing in golfers and specifically more hip rotation, more trunk flexion, and less lumbar flexion is correlated with a lower incidence of low back pain (Lindsay and Horton 2002; Vad et al. 2004). In tennis one-handed strokes lay considerably less stress on the lower lumbar spine than double-handed strokes (Kawasaki et al. 2005). In cricket fast bowlers reducing the level of shoulder alignment counter-rotation significantly reduce the incidence and progression of lumbar disk degeneration (B. Elliott and Khangure 2002).

In severe cases, overloads might lead to acute lesions. Stress fractures and avulsion fractures of the cervical and/or upper thoracic spinous processes are documented in golfers (Kang and Lee 2009; Kim et al. 2012). Intradiscal hematoma is described in an elite tennis player (Baranto et al. 2010).

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